UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 1003

Contribution from the Bureau of Chemistry
W. G. CAMPBELL, Acting Chief

And the University of Idaho, A. H. UPHAM, President

Washington, D. C. ▼ December 5, 1921

THE DISTILLATION OF STUMPWOOD AND LOGGING WASTE OF WESTERN YELLOW PINE

By

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CONTENTS

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By M. G. Donk, *Assistant Chemist, Leather and Paper Laboratory, Bureau of Chemistry*, C. H. Shattuck, *Professor of Forestry*, and W. D. Marshall, *Research Fellow, Forestry Department, University of Idaho.*[1]

CONTENTS.

IMPORTANCE OF WESTERN YELLOW PINE.

Western yellow pine (*Pinus ponderosa*) is the most widely distributed of the western commercial softwoods (4, 10)[2] (fig. 1). The Forest Service estimates the amount of standing timber of this species to be approximately 335,000,000,000 board feet, or more than that of any other species except Douglas fir (6). The reported cut for this species for 1917 was 1,862,914,815 board feet. This represents an area of more than 350,000 acres of land annually cleared and left covered with stumps after logging operations. About one-third of this is within the national forests and is generally of little value for agriculture, because of the roughness of the land. Much of the remaining two-thirds, however, is valuable for crops.

[1] The sections on the importance and distribution of the western yellow pine are by C. H. Shattuck. The report of the investigation is by M. G. Donk.

[2] The numbers in parenthesis throughout this bulletin refer to the bibliography on page 69.

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Removing the stumps is arduous and costly (8), and so far they have been considered to be worthless after removal. Any process which may serve to reduce the cost of clearing the land or lead to the discovery of a profitable use for the stumps is, therefore, worthy of careful consideration. Observations on the methods of utilizing the more resinous portions of the yellow pine of the South in the manufacture of wood-distillation products suggested the possibility that the western species might serve the same purpose, as these trees, especially the stumps, are often quite resinous.

It is well known that western yellow pine was used in California as a profitable source of turpentine during the Civil War (13). In speaking of turpentine obtained from western yellow pine, Schorger (7) says: "There is no reason to suppose that both the California and the Arizona oils will not serve the purposes for which ordinary turpentine is commonly used." According to Betts (2), nearly as much turpentine and rosin was obtained from western yellow pine as from the pines of the Southeast. Wenzell (5) states that the odor, specific gravity, and boiling point of oleoresin from *Pinus ponderosa* correspond with those of the common oil of turpentine. It is therefore reasonable to suppose that turpentine operations in the large tracts of virgin pine timber in the West will be undertaken within a few years, because of the rapid cutting of the yellow pine of the South.

DISTRIBUTION OF WESTERN YELLOW PINE.

For convenience the chief areas of western yellow pine may be grouped as follows:

(1) Arizona and New Mexico.
(2) California.
(3) Oregon and Washington.
(4) Idaho, Montana, and Utah.
(5) Colorado, South Dakota, and Wyoming.

For want of accurate data, no estimates covering the quantities of this species annually cut for fuel and uses other than for lumber are given, although this amount is known to be considerable. Neither is any account taken of the distillation material to be derived from "fat" limbs and "pitchy" butts.

The estimates of stands, and therefore of stumps, in many of the States are low because the results of the cruises of much privately owned timber were not obtainable.

The problem of the better utilization of this species is by no means confined to Idaho. Tables 2 to 12 and the map (fig. 1) furnish conclusive proof of the enormous quantities of yellow-pine stumps to be had in several Western States. It will not be profitable to work up by distillation methods any but the more resinous of the stumps, "fat" limbs, and "pitchy" butts. A complete field survey of each region to determine the stand or number of rich resinous stumps and the practicability of profitable distillation must be left to those in

FIG. 1.—Geographic distribution of *Pinus ponderosa.*

the various regions who plan to enter the field of wood-distillation from a commercial standpoint. Such a survey, however, should always be made before undertaking distillation in any section.

ARIZONA AND NEW MEXICO.

Total area in the national forests	acres	[3] 4, 571, 425
Total stand in the national forests	board feet	17, 002, 000, 000
Total annual cut (1917)	do	154, 297, 815
Total area annually cleared (if clear cutting is employed)	acres	38, 574
Total annual volume of stumpwood	cords	[4] 77, 148

For average stands the number of trees over 18 inches varies from 85 to 12, and the number of those over 24 inches varies from 7 to 9; heavy stands have from 12 to 30 trees 18 inches and over, and from 11.5 to 20 trees 24 inches and over.

Since 500 board feet is a liberal average volume for a yellow-pine tree 22 inches in diameter at breast height, or 24 inches on the stump (3, 13), stands of 5,000 feet an acre would contain 10 trees averaging 24 inches on the stump. The average stand over Arizona and New Mexico being approximately 4,000 board feet for all the area covered with yellow pine, the average number of 24-inch stumps an acre would be 8. Many thousands of acres show stands above 5,000 feet, the actual number of trees 24 inches and over being from 10 to 15 to the acre.

It is evident, therefore, that this region has future possibilities from the standpoint of wood by-products, if it is found that a fair percentage of the stumps are rich in resin. No account has been taken of the material obtainable from "fat" limbs or "pitchy" butts, and only the timber on national forests, where accurate cruises have been made, is here considered. Though no figures are available for the timber on private holdings, Indian lands, and the public domain, it is known that these areas are quite extensive, and many of the stands are average or better.

CALIFORNIA.

Total area	acres	10, 000, 000
Total stand	board feet	85, 000, 000, 000
Total annual cut (1917)	do	154, 297, 815
Total area annually cleared (if clear cutting is employed)	acres	38, 574
Total annual volume of stumpwood	cords	[4] 77, 148

California has about 10,500,000 acres of commercial yellow pine, with from 85,000,000,000 to 90,000,000,000 board feet, or from 8,000 to 12,000 board feet an acre. Trees above 12 inches in diameter, breast high, have an average diameter of 38 inches, or approximately 41 inches on the stump, for which reason the yellow-pine trees of California are the largest known. Since the species usually grows in mixed stands, the number of trees an acre is low. The pitch content, however, is higher than that in any other section. As the yellow pine in California is the heaviest known (Table 1), the amount of "pitchy" wood can safely be taken as average or better.

[3] National forests only. [4] For reducing factors see Table 6.

TABLE 1.—*Stands of western yellow pine in California, Oregon, and Washington, with reduction factors for various volumes and diameters of trees and stumps.*[1]

Diameter.			Average volume—		
Breast high.	Reduction, breast height to stump height.	Stump high.[2]	Of trees.	Of stumps.	Reduction units for different volumes and diameters.
Inches.	*Inches.*	*Inches.*	*Bd. ft.*	*Cords.*	
22	2	24	500	0.25	1
23	2	25	600		
24	2	26	750	.375	1.5
25	2	27	850		
26	2	28	950		
26.5	2	28.5	1,000	.5	2
27	2	29	1,150		
28	2.5	30.5	1,250	.625	2.5
29	2.5	31.5	1,350		
30	2.5	32.5	1,425		
30.5	2.5	33	1,500	.75	3
32	2.5	34.5	1,600		
32.5	2.5	35	1,750		3.5
33	2.5	35.5	1,850	.875	
33.5	2.5	36	1,925		
34	3	37	2,000	1	4
35	3	38	2,150		
36	3	39	2,250	1.125	4.5
37	3	40	2,400		
38	3	41	2,500	1.25	5
39	3.5	42.5	2,600		
40	3.5	43.5	2,750	1.375	5.5
41	3.5	44.5	3,000	1.5	6
41.5	3.5	45	3,250	1.625	6.5
42	3.5	45.5	3,500	1.75	7
43	3.5	46.5	3,750	1.875	7.5
44	3.5	47.5	3,900		
45	4	49	4,000	2	8

[1] This working table must be adapted by the user to meet the variations from the normal stand as they are found to occur. The volumes in board feet represent close approximations of the averages of all obtainable volume tables for the regions named. The volumes in cords are taken from measurements of corded stumpwood in various regions, and are as conservative, when the wood is split for the retort, as those used for volume, B. M.

[2] The height of the stump is here assumed to be 18 inches. For higher stumps the diameter would be duced according to the scale, as given in columns 5 and 6.

TABLE 2.—*Sample cruises of California yellow pine from different parts of the State, with volume and acre equivalent in number of stumps of various diameters required to produce the given yields (area covered, 6,400 acres, average stand, or slightly better).*[1]

Location.	Volume per acre.	Number stumps.			Per cent total stand.
		24-inch.	28.5-inch.	37-inch.	
	Bd. ft.				
Eldorado, T 8 N, R 15 E, sec. 35	10,082	20.00	10.00	5.00	83.6
Lassen, T 25 N, R 14 E, sec. 24	10,501	21.00	10.50	5.25	64.7
Lassen, T 27 N, R 10 E, sec. 5	18,236	36.40	18.20	9.10	46.4
Lassen, T 32 N, R 8 E, sec. —	12,253	24.50	12.25	6.12	68.5
Modoc, T 46 N, R 15 E, sec. 32	12,444	24.88	12.44	6.22	87.6
Plumas, T 23 N, R 9 E, sec. 5	9,503	19.00	9.50	4.80	26.9
Sequoia, T 13 S, R 19 E, sec. 19	5,870	11.74	5.87	3.92	71.6
Sierra, T 5 S, R 21 E, sec. 18	10,518	21.02	10.51	5.25	83.4
Sierra, T 6 S, R 24 E, sec. 27	17,163	34.32	17.16	8.58	72.1
Stanislaus, T 4 N R 18 E, sec. 17	12,276	24.55	12.27	6.11	47.4
Average for 6,400 acres	11,884	23.75	11.88	5.94	64.5

[1] Estimates furnished by T. D. Woodbury, assistant district forester, San Francisco, Calif. If the stump-high diameters were used instead of those breast high, a large number of trees would be included in the 24-inch class, as many trees measuring 22 inches and over, breast high, would come within the 24-inch class if measured on the stump.

TABLE 3.—*Practical application of Table 1.*

Location.	Area.	Volume per acre.	Trees 24 inches and over.	Average diameter stump high.	Stumps per acre equivalent.				
					24-inch.	33-inch.	35-inch.	43-inch.	49-inch.
	Acres.	*Bd. ft.*		*Inches.*					
T 4 N, R 18 E, sec. 19	7	35,490	9.1	48.0	70.9	23.6	20.3	12.8	8.8
T 9 S, R 24 E, sec. 2	16	10,700	6.6	34.5	21.4	7.1	6.1		
T 9 N, R 24 E, sec. 1	16	9,746	5.5	32.0	19.5	6.5			
T 8 N, R 23 E, sec. 15	16	11,000	4.0	43.5	22.0	7.3		4.0	
T 4 N, R 21 E, sec. 32	16	13,112	4.7	43.5	26.2	8.7		4.7	
T 10 and 11 S, R 25 and 36 E	17,495	12,200		33.0	24.4	8.1			
T 4 and 5 S, R 20 and 21 E	6,393	6,710		32.5	13.4	4.5			
T 3 and 4 S, R 19 E	3,820	6,770		33.5	13.5	4.5			
T 7 S, R 22 E	300	8,139		33.0	16.2	5.4			
Volume equivalents:									
Lumber (board feet)		500	1,000	1,500	2,000	2,500	3,000	3,500	4,000
Stumpwood (cord)		.25	.50	.75	1.0	1.25	1.50	1.75	2.00

OREGON AND WASHINGTON.

	Oregon.	Washington.
Total area ... acres	10,000,000	3,400,000
Total stand ... board feet	70,000,000,000	17,000,000,000
Volume per acre ... do	7,000	5,000
Total annual cut (1917) ... do	470,488,000	220,924,000
Total area annually cleared (1917) ... acres	67,212	44,185
Total annual volume of stumpwood ... cords	235,244	110,462

Western yellow pine occurs on about 14,000,000 acres in Oregon, practically a quarter of the State and half of its timbered land. Of this area about 10,000,000 acres may be classed as commercial forest, the estimated stand amounting to 70,000,000,000 board feet, or an average of 7,000 board feet an acre, interforest waste areas included (6).

TABLE 4.—*Representative western yellow-pine stands in Oregon.*

Location.	Area.	Average number of trees.			Per cent of stand.
		12-inch and over.	18-inch and over.	24-inch and over.	
	Acres.				
Near Austin and Whitney	258	25.42	18.97	13.78	83.2
Near Lookingglass Creek	44	34.57	21.34	15.48	87.3
Near Embody	30	32.00	21.23	15.10	99.5
Klamath Lake Section	159	25.37	19.85	15.41	75.2

Table 4 shows average stands of Oregon yellow pine more or less mixed with other timber. Pure stands contain a proportionately greater number of trees. In cruises made by the United States Geological Survey, on pure, heavy stands of yellow pine near Richland, the average number of trees above 12 inches on strip acres ran from 30 to 43, and of those above 22 inches, from 15 to 24. The timber on these strips, running about 10,000 feet an acre, will yield approximately 5 cords of stumpwood an acre.

Munger (6) states that 42 per cent of all butt logs in Oregon are fire scarred, and that 25 per cent of them are "pitched." The average diameter of the "pitchy" area on the basal cross section of the log is 14.7 inches on a tally of 1,184 butt logs. This means that 25 per cent of the stumps would also be "pitched" as the result of fire alone (p. 8).

TABLE 5.—*Cruises on the Whitman National Forest, 1912–1916.*

Location.	Area.	Total volume.	Volume per acre.	Number of stumps per acre.				Volume.	
				24-inch.	28.5-inch.	33.5-inch.	37-inch.	Per acre.	Per area.
	Acres.	*Bd. ft.*	*Bd. ft.*					*Cords.*	*Cords.*
T 10S, R 34E, sec. 19	640	8,511,000	13,299	26.59	13.29	8.86	6.649	6.649	4,255
T 10S, R 34E, sec. 33	640	6,220,000	9,718	19.43	9.72	6.48	4.859	4.859	3,109
T 10S, R 34E, sec. 34	640	7,440,000	11,006	22.00	11.00	7.34	5.503	5.503	3,521
T 11S, R 34E, sec. 1	640	5,128,000	8,012	16.02	8.01	5.34	4.006	4.006	2,564
T 11S, R 34E, sec. 2	640	5,716,000	8,931	17.86	8.93	5.95	4.465	4.465	2,857
T 11S, R 34E, sec. 11	640	6,992,000	10,925	21.85	10.92	7.28	5.462	5.462	3,495
T 11S, R 23E, sec. 23	640	6,260,000	9,781	19.56	9.78	6.52	4.890	4.890	3,130
T 12S, R 34E, sec. 3	640	5,900,000	9,287	18.57	9.28	6.19	4.643	4.643	2,971
T 12S, R 34E, sec. 10	640	4,776,000	7,448	14.89	7.44	4.96	3.724	3.724	2,383
T 12S, R 34E, sec. 21	640	3,153,000	4,926	9.85	4.92	3.28	2.463	2.463	1,576
T 12S, R 34E, sec. 28	640	8,110,000	12,672	25.36	12.68	8.45	6.336	6.336	4,056
Total	7,040	67,701,000							33,916
Average			9,474	18.95	9.47	6.32	4.737	4.737	
Stand on 56 forties	2,240	30,821,000	13,759	27.52	13.76	9.17	6.879	6.879	15,409
Stand on 27 sections	17,280	153,565,000	8,886	17.77	8.88	5.92	4.443	4.443	76,775

The total stand of western yellow pine for Washington is 12,500,000,000 feet in private and State ownership, and 4,500,000,000 feet in Government ownership, or a total of 17,000,000,000 board feet. Allowing a stand of 5,000 feet an acre, which is thought to be low, since Oregon and Washington are similar, the Washington area will be approximately 3,400,000 acres.

The area of the yellow-pine land in the two States is approximately 13,400,000 acres, carrying a commercial stand of from 5,000 to 7,000 feet an acre, or the equivalent of from 10 to 14 trees 24 inches on the stump, which will yield from 2½ to 6¾ cords of yellow-pine stumpwood an acre.

IDAHO, MONTANA, AND UTAH.

	Idaho.	Montana.	Utah.
Total area ... acres	10,000,000	3,500,000	(1)
Total stand ... board feet	58,050,000,000	14,000,000,000	(1)
Volume per acre ... do	5,800	4,000	4,000
Total annual cut (1917) ... do	315,009,000	150,905,000	4,676,000
Total area annually cleared (1917) ... acres	54,311	37,726	1,169
Total annual volume of stumpwood ... cords	157,504	75,452	2,338

[1] No reliable figures obtainable.

Many large areas of yellow-pine timber in Idaho are as good as the best of that in California and Oregon, but as a whole the stand will probably average close to 6,000 feet an acre. Conservative estimates for the area would be 10,000,000 acres, and for the total stand, 50,000,000,000 feet.

There is much wastage in butt logs, due to "pitchiness" resulting from fire scars and natural causes. Fires tend to make the stumps more resinous and to increase the number of those sufficiently "fat" to serve for purposes of distillation. It has been the experience of an Idaho lumber company that some of these "pitchy" butts occur in all the western yellow-pine timber. They state that these pitchy butts are more prevalent in the northern section of Idaho, but that this territory and the Baker, Oregon (Blue Mountain), territory pro-

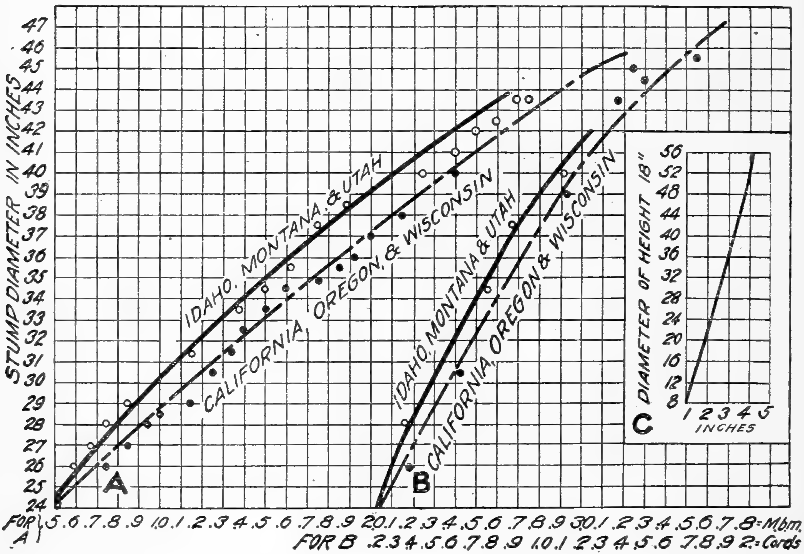

FIG. 2.—Yellow-pine stumpage in 6 western States. A, volume of tree (thousand board feet); B, volume of stumpage (cords); C, difference between diameter breast high and diameter stump high (inches).

duce less "pitchy" lumber than any other yellow-pine section that has come under their observation.

From this it would seem that the question of "pitchy" butts is important, and should not be ignored by those who attempt to determine the amount of resinous wood to be obtained from any locality. Since 25 per cent of the butt logs from the Blue Mountain region bear more or less pitch, and a wastage in "pitchy" butts trimmed off of from 4 to 5 cords a day is reported by one company, this constitutes a very important source of valuable wood for distillation purposes. Samples sent to the University of Idaho compared favorably with the best stumpwood in yield of products. The mill which submitted the samples was compelled to sell more than a million board feet of yellow-pine lumber at a loss, because of the amount of "pitchy" lumber in the butt logs. Inspection by one of the writers showed a large amount of this wood to be suitable for distillation.

TABLE 6.—*Average volume of western yellow pine and reduction factors for various volumes and diameters of trees and stumps (Idaho and Montana).*

Diameter.			Average volume.		Reduction unit for different volumes and diameters.
Breast high.	Reduction, breast height to stump height.	Stump high.[1]	Of tree.	Of stump.	
Inches.	*Inches.*	*Inches.*	*Bd. ft.*	*Cords.*	
22	2.0	24.0	500	0.25	1.0
23	2.0	25.0	550	....	....
24	2.0	26.0	600	....	....
25	2.0	27.0	675	....	....
26	2.0	28.0	750	0.375	1.5
27	2.0	29.0	850	....	....
28	2.0	30.0	1,000	0.50	2.0
29	2.5	31.5	1,150	....	....
30	2.5	32.5	1,250	0.625	2.5
31	2.5	33.5	1,375	....	....
32	2.5	34.5	1,500	0.75	3.0
33	2.5	35.5	1,625	....	....
34	3.0	37.5	1,750	0.875	3.5
35	3.0	38.5	1,875	....	....
36	3.0	39.0	2,000	1.00	4.0
37	3.0	40.0	2,250	1.125	4.5
38	3.0	41.0	2,400	....	....
38.5	3.5	42.0	2,500	1.25	5.0
39	3.5	42.5	2,600	....	....
40	3.5	43.5	2,700	....	....
40.5	3.5	44.0	2,850	....	....
42	3.5	45.5	3,000	1.50	6.0

[1] See also Figure 2.

TABLE 7.—*Cruise of 160 acres of western yellow pine in Boise County, Idaho (all trees calipered).*

Location.	Average stand per acre.	Average diameter.		Number 24-inch stumps per acre equivalent.	Number stumps per acre equivalent, based on average diameter.	Stumpwood.		Equivalent used in reduction.
		Breast high.	Stump high.[1]			Per acre.	Per section.	
	Bd. ft.	*Inches.*	*Inches.*			*Cords.*	*Cords.*	*Bd. ft.*
T 6N, R 5E, sec. 8 NW NW	14,693	25.5	27.5	29.38	20.55	7.34	293.6	715
T 7N, R 4E, sec. 35 SE NE	15,144	27.4	29.4	30.29	16.83	7.57	302.8	900
T 7N, R 4E, sec. 35 NE NE	13,866	25.5	27.5	27.73	19.40	6.93	277.2	715
T 7N, R 4E, sec. 35 NE SE	15,783	26.7	28.7	31.57	18.70	7.89	315.6	800
Average, 4 forties	14,896	26.27	28.27	29.74	19.12	7.681	[2] 189.2	782.5

[1] From Table 6.
[2] Total number of cords of stumpwood for entire area.

TABLE 8.—*Cruises of 478.85 acres of western yellow pine in Latah County, Idaho.*

Location.	Average stand per acre.	Average diameter.		Number 24-inch stumps per acre equivalent.	Number stumps per acre equivalent, based on average diameter.	Stumpwood.		Equivalent used in reduction.
		Breast high.	Stump high.[1]			Per acre.	Per area.	
	Bd. ft.	*Inches.*	*Inches.*			*Cords.*	*Cords.*	*Bd. ft.*
T 39N, R 1W, sec. 2, lot 7	8,750	29	31.5	17.50	7.60	4.18	162.39	1,150
T 39N, R 1W, sec. 9 SE NW	10,625	34	37.5	21.25	6.07	5.12	204.80	1,750
T 39N, R 1W, sec. 23 NE SW	8,750	34	37.5	17.50	5.00	4.19	167.60	1,750
T 40N, R 1W, sec. 23 NE SW	7,500	28	30.0	13.00	7.50	3.75	150.00	1,000
T 40N, R 1W, sec. 24 NE NE	10,500	26	28.0	21.00	14.00	5.25	210.00	750
T 40N, R 1W, sec. 24 NE SE	8,925	26	28.0	17.86	11.89	4.46	178.40	750
T 40N, R 2W, sec. 14 SE NW	11,875	26	28.0	23.75	15.83	5.93	237.20	750
T 42N, R 3W, sec. 36 NE NW	17,500	29	31.5	35.00	15.30	8.75	350.00	1,150
T 41N, R 4W, sec. 29 SE SE	9,625	34	37.5	19.25	5.50	4.81	192.40	1,750
T 41N, R 4W, sec. 31 SE NW	10,000	32	34.5	20.00	6.67	5.00	200.00	1,500
T 42N, R 4W, sec. 33 SE NW	11,500	30	32.5	23.00	9.20	5.57	222.80	1,250
T 42N, R 5W, sec. 36 SW SE	11,000	29.5	32.0	22.00	9.17	5.50	220.00	1,200
Average, per forty	10,545	29.8	32.38	21.09	9.48	5.21	207.97	1,229

[1] From Table 6.

TABLE 9.—*Recapitulation of cruises.*[1]

Location.	Area cruised.	Total stand.	Volume per acre.	Number 24-inch trees per acre equivalent.	Stumpwood.	
					Per acre.	Per area.
	Acres.	*Bd. ft.*	*Bd. ft.*		*Cords.*	*Cords.*
T 39N, R 1W, B M	4,840	24,967,000	5,158	10.32	2.57	12,438
T 40N, R 1W, B M	10,291	52,218,000	5,074	10.15	2.53	26,136
T 40N, R 2W, B M	7,380	69,125,000	9,366	18.73	4.68	34,538
T 42N, R 3W, B M	4,733	36,894,000	7,729	15.46	3.86	18,423
T 41N, R 4W, B M	6,147	37,525,000	6,098	12.21	3.04	18,686
T 42N, R 4W, B M	4,240	25,680,000	6,056	12.06	3.02	12,804
Total	37,671	246,409,000				123,025
Average			6,580	13.15	3.28	

[1] The estimates include only yellow pine, which constituted but 53.34 per cent of the entire stand. A pure stand would be heavier.

In all tables a slight discrepancy will be noticed between the total number of cords of stumpwood, when added and when computed. This is due to the dropping of decimals and the using of even numbers only in cruise tables.

The average stand over large areas of yellow pine in Idaho is from 5,000 to 15,000 board feet an acre, or from 10 to 30 trees, 24 inches in diameter on the stump, the volume of stumpwood running from 2½ to 8 cords an acre. For more open stands the number of stumps will be less, but such stumps are generally larger and consequently more resinous. Therefore the volume of "pitchy" wood will be considerable, but can be determined only by a field survey of each region.

TABLE 10.—*Cruises of 3,200 acres of western yellow pine in Boise County, Idaho.*[1]

Location.	Average per acre for section.	Average diameter.		No. 24-inch stumps per acre equivalent.	No. stumps per acre equivalent, based on average diameter.	Stumpwood.		Diameter equivalent, used in reduction.
		Breast high.	Stump high.			Per acre.	Per section.	
	Bd. ft.	*Inches.*	*Inches.*			*Cords.*	*Cords.*	*Bd. ft.*
T 7 N, R 5 E, sec. 12	9,945	29.2	31.7	19.90	8.50	4.97	3,180.8	1,170
T 7 N, R 4 E, sec. 35	10,960	25.5	27.5	21.92	15.10	5.19	3,321.6	715
T 14 N, R 5 E, sec. 30	15,336	28.5	30.5	30.66	14.60	7.66	4,902.4	1,050
T 14 N, R 3 E, sec. 12	18,814	31.0	35.5	37.63	13.68	9.40	6,016.0	1,375
T 13 N, R 5 E, sec. 7	10,453	22.3	25.3	20.90	18.66	5.22	3,340.8	560
Average	13,101	27.3	29.7	26.20	14.11	6.51	[2]20,761.2	974

[1] Only yellow pine which is practically all over 22 inches diameter, breast high, or 24 inches diameter, stump high, is included.
[2] Total number of cords of stumpwood for the entire area.

TABLE 11.—*Recapitulation of cruises of 509,670 acres of pure western yellow pine.*

Location.	Area.	Diameter, stump high.	No. trees.		Average diameter, stump high.	Average No. bd. ft. per tree.	No. bd. ft. per acre.	Average no. 24-inch stumps per acre equivalent.	No. stumps per acre of average diameter.	Average no. cords stumpwood per acre.
			Total.	Average per acre.						
Kaibab National Forest	*Acres.* 300,000	*Inches.* 13–16	3,258,000	11.76	*Inches.* 15.00	145	1,705			
		18–22	2,400,000	8.00	20.18	330	2,600			
		24+	2,220,000	6.74	28.70	820	5,527	11.05	6.74	4.0
Total			8,148,000	25.50			9,838			
South Payette River, Payette National Forest	52,440	13–16	298,908	5.7	14.8	140	798			
		18–22	167,808	3.2	21.1	410	1,312			
		24+	403,788	7.7	28.2	770	5,929	11.86	7.50	3.62
Total			870,504	16.6			8,039			
Middle Fork, Payette National Forest	58,690	13–16	297,558	5.07	15.38	155	786			
		18–22	190,742	3.25	20.50	355	1,154			
		24+	434,306	7.40	29.50	900	6,660	13.32	7.40	3.9
Total			922,606	15.72			8,600			
Weiser National Forest	98,540	13–16	451,367	4.68	14.29	120	562			
		18–22	274,926	2.79	20.04	325	907			
		24+	675,984	6.86	29.00	850	5,831	11.66	6.86	3.36
Total			1,402,277	14.33			7,300			

All commercial stands of yellow pine in Montana are confined to the western part of the State. Much of the timber is of about the same grade as that found in Idaho, but the stand usually is lighter and the timber a little shorter, and as a rule it contains a slightly smaller percentage of "pitchy" stumps. Many large areas in the

State carry heavy stands of from 5,000 to 7,000 board feet, and in time the resinous wood may be handled to commercial advantage. The working tables for Idaho can readily be applied in efforts to determine the volume of stumpwood on any area. The average stand to the acre for the entire commercial yellow-pine region of the State may be taken to be 4,000 board feet.

The yellow-pine region of Utah is scattered over an extensive area, and until a more detailed survey is made it will be impossible to state the value of the stumpwood for distillation purposes. As a rule, it is far from transportation facilities and markets, so that for the present it may be considered as having but a slight bearing on the distillation problem. It has been assumed that the average stand from which the 1917 lumber cut was obtained carried 3,000 board feet an acre. In all probability it was decidedly higher, as the best stands are generally being cut first. This would reduce the number of acres annually cleared, but would not affect the volume of stumpwood.

COLORADO, SOUTH DAKOTA, AND WYOMING.

	Colorado.	South Dakota.	Wyoming.
Total area [1] ... acres..	916,415	707,000	8,000
Total stand [1] ... board feet..	1,618,614,000	2,873,000,000	23,500,000
Volume per acre ... do...	1,766	4,063	2,937
Total annual cut (1917) ... do...	35,328,000	29,045,000	3,678,000
Total area annually cleared (1917) ... acres..	20,004	7,149	1,252
Total annual volume of stumpwood ... cords..	17,664	14,522	1,839

[1] From Forest Service records.

The commercial stands of yellow pine in Colorado are confined in a large measure to the national forests. They are scattered over nearly a million acres, but the volume to the acre is lower than that in any other State. It is not probable that any value may be derived from this stumpland in the way of distillation products.

The chief yellow-pine area in South Dakota is located in the Black Hills region. The average stand for the 707,000 acres is 4,063 board feet an acre, making the volume of stumpwood about two cords an acre, which is thought to be low for distillation purposes, as the wood is not especially resinous.

The stand in Wyoming is so small as to be entirely negligible for the purposes of distillation.

SUMMARY.

This brief survey shows that the quantity of stumpwood is enormous and that the problem of handling the cut-over areas is of first importance. It is known, however, that not all of these stumps are sufficiently resinous for profitable distillation, under present conditions.

TABLE 12.—*Annual lumber cut of western yellow pine in the United States (9).*

State.	Volume.				
	1914	1915	1916	1917 [1]	Stumpwood [2]
	Bd. ft.	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Cords.*
California	409,953,000	389,991,000	494,973,000	478,565,000	239,282
Oregon	210,438,000	189,203,000	399,102,000	470,488,000	235,244
Washington	175,426,000	148,789,000	188,215,000	220,924,000	110,462
Idaho	159,839,000	201,858,000	240,160,000	315,009,000	157,504
Montana	134,568,000	118,920,000	138,206,000	150,905,000	75,452
Arizona	78,667,000	75,843,000	92,133,000	78,147,022	39,074
New Mexico	54,728,000	61,466,000	72,004,000	76,149,793	38,074
Colorado	65,117,000	37,241,000	27,848,000	35,328,000	17,664
South Dakota	18,744,000	22,457,000	25,466,000	29,045,000	14,522
All other	19,885,000	6,476,000	6,880,000	8,354,000	4,177
Total	1,327,366,000	1,252,244,000	1,684,987,000	1,862,914,815	931,455

[1] From records of the district foresters.
[2] For 1917 only.

SUMMARY OF TABLE 12.

Total volume, 1914–1917, inclusive (board feet)	6,127,511,815
Total area equivalent cleared, 1914–1917, inclusive, assuming 5,000 feet as average per acre (acres)	1,225,502
Total stumpwood, 1914–1917, inclusive (cords)	3,063,755

If the areas are not agricultural in character, they should be allowed to reforest. In this case the land-clearing problem is not so important, although the stumps should be utilized, if it is economically possible to do so. Table 12 shows that for the entire area of western yellow-pine land the average volume of stumpwood is 2.5 cords an acre, or 100 cords for every 40-acre tract. Probably half of this land carries double this amount of stumpwood. Be that as it may, it is certain that many thousands of cords of stumpwood must be removed before those who desire to make homes on the splendid yellow-pine lands, some of which are known to be among the best remaining lands obtainable for agriculture, can bring them into the proper state of cultivation and production.

PURPOSE OF INVESTIGATION.

In January, 1914, the Bureau of Chemistry, United States Department of Agriculture, in cooperation with the Department of Forestry of the University of Idaho, at Moscow, Idaho, began a study of the destructive distillation of logging and land-clearing waste in the State of Idaho, particularly of the yellow-pine stumps of that region. These investigations were instituted with the twofold purpose of ascertaining the feasibility of more effectively utilizing the timber resources of the Northwest and of reducing the net cost of clearing cut-over lands for agricultural purposes by the recovery of commercially valuable products from the stumps. The work resolved itself into determining (*a*) the nature, amount, and probable value of certain by-products obtained in clearing the land of stumps by burning and the practicability of recovering these products by this method, and (*b*) the yield and value of products obtainable from yellow-pine stumpwood throughout the State when subjected to retort distillation.

The chief aim of the cooperative work was to determine the value for distillation purposes of western yellow-pine stumps and such other logging or land-clearing waste in the State of Idaho as might lend itself to the treatment. The abundance of yellow-pine waste is readily inferred from the volume of such lumber sent to market from mills throughout the State, and the relative abundance of yellow-pine stumps in any section can be ascertained from timber-cruise records, supplemented by the proper volume tables. The quality of the stumps with respect to their resin content, on which depends their value for distillation purposes, however, can not be determined from such field or timber-cruise data. The results of careful field inspections have led to the conclusion that much of the western yellow pine is of the relatively nonresinous or "bull pine" variety. Even the more resinous yellow-pine stumps varied so widely in their resin content that it soon became apparent that field investigations were indispensable to a proper knowledge of the proportion in which the various grades of stumps occur in the regions from which samples were collected. A knowledge of the conditions in the yellow-pine belt of the Atlantic and Gulf States made this all the more imperative, for the reason that the apparent preponderance of the lower grade of stumps clearly indicated that the profitable utilization by distillation of all yellow-pine stumps would be found impracticable, and that success in utilizing any of them would depend on a proper selection of material to be treated.

From an agricultural standpoint the object of the work was to determine the practicability of reducing cut-over land clearing costs through recovery of by-products from the stumps. The extent to which distillation products from the stumps can be made to defray the cost of clearing such land obviously depends, among other things, on the total number of stumps to the acre, the number of these stumps suited to distillation purposes, the yield and value of the by-products, and, finally, the cost of recovering these by-products from the stumps to be treated. The first of these probably can be fairly well established from timber-cruise records for regions in which such data are available; the second is a combined field and laboratory problem; the third a laboratory and trade inquiry problem; and the fourth a field and chemical engineering problem. The work accordingly resolved itself into an investigation involving each of these closely related problems.

TAKING SAMPLES.

In the spring of 1914, samples, with the attendant field data, were obtained from four acres in different parts of the State typical of the regions they were selected to represent, namely: (*a*) Cut-over land of a lumber company in Latah County, hereafter referred to as the Potlatch-Deary region; (*b*) the Coeur d'Alene and Hayden Lake region; (*c*) the South Idaho or Boise-Payette region; and (*d*) the Craig Mountain or Winchester region.

In these field-sampling operations a rapid reconnaissance trip was made to get a general idea as to the abundance and apparent quality of the stumps in a region. On the basis of such knowledge an area considered representative of the district was selected, from which samples representing the different qualities of stumps, together with data for an estimate of their relative abundance and number per acre, were taken.

In the beginning the stumps were arbitrarily classed as "rich" when the top showed a marked resinous exudation, or, if burned over, revealed decidedly resinous wood when cut into with an axe, as "medium" when it showed but little of such exudation, and as "poor" when, although apparently sound, it was devoid of any resinous exudation. All stumps containing little if any resinous wood are classed as "bull pine," despite the fact that this term is usually limited to the western yellow pine less than 24 inches across the stump.

Selected stumps of each class were removed by blasting, and only enough of their heartwood was taken to make, with wood from other stumps of the same quality, a cord sample of that class. This cord, or a smaller sample selected from this measured cord, was then shipped to Moscow for the experimental work.

In all cases the sapwood was split off and rejected; hence the results obtained in this investigation do not show what can be obtained from the whole stump of each quality, but only from the resinous heartwood. Because the western yellow-pine stumps ordinarily contained so little heartwood (on an average about 50 per cent), stumps under 24 inches were considered only when they contained larger proportions of the resinous heartwood. Such stumps, in later years, should the sapwood rot off while the heartwood remained sound and resinous, would then be practically 100 per cent resinous, but, of course, would yield a much smaller quantity of total wood.

Distinction between "yellow pine" and "bull pine."—The term "yellow pine" is here used to designate such members of the *Pinus ponderosa* group as contain an appreciable portion of relatively resinous, dark-colored heartwood, compared to the sapwood layer. "Bull pine," although often large, has relatively no such high proportion of the richer resinous heartwood. Botanically, the "bull pine" is considered to belong also to the *Pinus ponderosa*, or western yellow-pine group, appearing to differ from the "yellow pine" only in being a less mature or more rapidly developed tree. Whatever may be the cause, the important fact remains that "bull-pine" stumps, aside from their content of what appears to be sapwood, are all but devoid of resinous matter and are utterly worthless for the recovery of turpentine or other distillation products (Table 14). "Bull-pine" stumps, irrespective of their size, therefore, are not included in the number of yellow-pine stumps to the acre in a given area or section, which makes it highly important to remember that no such distinction between these classes of stumpage is made by timber cruisers.

POTLATCH-DEARY REGION.

The southwest quarter of the southeast quarter of section 15, township 40 north, range 2 west, readily accessible and fairly representative of the number, size, and quality of stumps to the acre of yellow-pine land in the Potlatch-Deary section of the State, had had a yellow-pine stand of 395,000 board feet a "forty," averaging 500 feet a tree. The average yellow-pine stand for the township was 234,000 board feet to 40 acres.

The stumps were taken from a south slope, a ridge, and its adjacent lowland. The trees had been felled six or seven years before, and the stumps were generally found with all the bark. A few burnt-over stumps, of which the bark and sapwood had been destroyed, from trees said to have been dead when cut and in some cases felled for fuel wood 13 years earlier, were included. Ten stumps of each class were blown out and enough of the heartwood from each stump taken to make up a cord sample of each class. The stumps were removed by blasting with both 40 per cent and 20 per cent dynamite. Few of the stumps were removed entirely by the blast, most of them being either split through the middle, with only part of the stump thrown out, or left standing in a shattered condition. It was necessary, therefore, to employ a team of horses to remove enough of such shattered stumps to obtain a sufficient portion of each for the samples.

All of the heartwood of the first few stumps shot out was removed and split to approximately cordwood size, and a sample taken from each stump thus entirely reduced. The labor cost, estimated at from $4 to $5 a cord, made it so expensive, however, that only a portion of each stump sufficient to obtain enough for a sample was reduced. The diameters of the ten "rich" stumps varied from 24 to 40 inches, with an average of 32 inches; those of "medium" quality, from 26 to 36 inches, with an average of 30 inches; and the "poor" stumps, from 24 to 36 inches with an average of 28 inches. The cost of shooting the 30 stumps was as follows (spring, 1914):

Two men, 2½ days, at $2.50 a day of 10 hours	$12.50
50 pounds of 20 per cent dynamite	7.50
165 pounds of 40 per cent dynamite	28.05
Fuses and caps	2.75
Total	50.80

Splitting the 30 stumps so as to obtain from each a sufficient portion for the sample required the work of 3 men for 3 days, which, at $2.50 a 10-hour day, amounted to $22.50. The cost of gathering and hauling the 3 cords of wood, requiring the services of 2 men and a 2-horse team for three-fourths of a day at $7.50 a day, was $5.62. If special stumping powder, selling for $12.50 a 100 pounds at that time, had been used, the powder cost could perhaps have been reduced by 20 per cent, or to $30 for the 30 stumps. The labor cost of placing the shot holes and shooting the stumps could probably be reduced on a steady job. Against this it should be said that to have removed all the stumps completely would have required the time of a man and a team of horses for an additional day, as well as extra powder, fuses, and caps. The labor cost of shooting the 30 stumps should accordingly be left at $12.50. To have split the stumps completely so as to recover all the heartwood and permit the handling of the pieces by 2 men would have taken the 3 men 3 days more, making the cost of splitting the 30 stumps $45. On a steady job with men accustomed to the work, provided with tools or equipment that experience would suggest, this item possibly could be reduced by at least 50 per cent, or, in this case, to $22.50. On the basis of an average of 50 per cent heartwood in the stumps, it is estimated that at least 3 stumps are required to make a cord of wood, or about 10 cords from the 30 stumps. To gather up, haul, and load this on the car would cost 10/3 times $5.62, or $18.73. Summing up on this basis, the cost of these 10 cords of wood loaded on the car after a 1-mile haul is:

Powder, fuse, and caps	$30.00
Shooting	12.50
Splitting	22.50
Gathering and hauling	18.73
Total	83.73
Cost a cord	8.37

Liberal allowances have been made in the items on which the cost of this yellow-pine stumpwood depends, and the cost a cord is confidently believed to be a minimum one. A material reduction of this figure need be expected only from the use of hitherto undeveloped land-clearing methods, from a failure on the part of the farmer to charge the value of his time and equipment in shooting, reducing, and hauling the stumps against the cost of the wood so delivered, or from a decided reduction in the selling price of explosives or in labor.

The conclusions based on this method of sampling were subsequently checked by removing all the yellow-pine stumps on a typical acre, taken to represent a good stand of large yellow pine in the Potlatch-Deary yellow-pine region, in the southwest quarter of the southeast quarter of section 36, township 42 north, range 5 west. The yellow-pine stand on this "forty" was 540,000 board feet, of which 240,000 board feet were from trees averaging 700 feet a tree, and 300,000 board feet from trees averaging 2,500 feet a tree. This figures out to a stand of 9 of the smaller trees containing a total of 6,000 feet and 3 large trees containing a total of 7,500 feet, or a total of 13,500 feet an acre. Of the 12 yellow-pine stumps on this chosen acre, 9 averaged 30 inches and 3 averaged 45 inches in diameter. The proportion and quality of the heartwood were so markedly different in the large stumps, as compared with that in the small stumps, that the woods from the large and small stumps were collected separately as two samples, and are hereafter referred to as "large" and "small" yellow-pine stumps, Potlatch, Idaho.

A sample taken from so-called "rich butts," "tops," etc., was collected throughout the area from which the stumps at Deary were obtained, where a large amount of this material is available in the form of dead standing trees and windfalls. Judged by its appearance, little, if any, of it is rich in resinous matter. Hence one sample only, designated in the tables as "dead, down wood," was selected from the richer material of this class.

COEUR D'ALENE AND HAYDEN LAKE REGION.

The Coeur d'Alene and Hayden Lake region, taken as being representative of cut-over yellow-pine lands in northern Idaho, proved to be an unwise selection, as a larger proportion of "bull pine" or nonresinous material was found there than in the Pend d'Oreille River country farther to the north. It should be considered typical rather of the yellow pine in the territory within a 50-mile radius of Spokane. Two yellow-pine samples were taken, one on a ranch some 2 miles northwest of Hayden Lake towards Garwood, the other from the Mica Bay section of Coeur d'Alene Lake. The first was representative of the average quality of yellow-pine stumps proper in the Hayden Lake region, few, if any, of which showed resinous exudation, and approximated 20 to 35 an acre in the closest yellow-pine stand of this region, which had been cut over a few years before.

The sample collected at Coeur d'Alene Lake was from "rich" stumps on a 20 to 30 acre tract near Mica Bay, not yet brought under cultivation. Stumps of the quality represented by the sample do not occur in commercial quantities in the Coeur d'Alene Lake region.

SOUTH IDAHO REGION.

The wooded country throughout the South Idaho region is practically undeveloped and without railroads. The forests remain untouched, except in a few places where small-scale logging operations have been carried on to supply local mills. The timber resources are now being opened up for extensive logging operations to supply a mill of about 200,000 feet daily capacity at Barber, some 6 miles out from Boise.

Working out from this company's logging camp, about 35 miles northeast of Boise, a hasty survey was made of an area which had been cut over in places 7 or 8 years before the company had taken over the land or timber rights. Although the timber throughout this region is largely yellow pine, few of the stumps appeared pitchy enough to be considered "rich." Fully 50 per cent were unsound and therefore worthless for distillation purposes. The stand of yellow-pine trees or stumps 24 inches or more in diameter is estimated as not exceeding an average of 10 an acre. The actual count for several 1-acre plots, taken to represent a close stand, was 20, 22, and 18 trees, respectively. Three 1-acre plots taken to represent a stand of medium density ran 10, 6, and 9 trees an acre. Toward the other extreme the stand diminished to where, on the higher ridges, no yellow pine was encountered.

According to one of the company's cruisers, the whole of the Boise-Payette pine belt is very much like the land traversed, and an estimate of 10 yellow-pine trees, over 24 inches in diameter, an acre is liberal.

Of the total number of yellow-pine stumps on a given area in the old cuttings perhaps 1 out of 25, or not to exceed 5 per cent, may be considered as belonging to the "rich" or "pitchy" class, probably 40 to 50 per cent are of "medium" quality, and the remainder of a quality from which it was not considered worth while to take a sample. Four samples were taken: (*a*) One from old cuttings to represent the "rich," or "pitchy," stumps; (*b*) one of "medium" quality, from the old cuttings; (*c*) one from green stumps from which the tree had been felled within a month of the time the stumps were shot; and (*d*) one of green "bull-pine" stumps. Samples *c* and *d*, included because they were the stumps and logs from freshly fallen trees, though containing no well-defined heartwood, had an abundant exudation of what appeared to be gum on the freshly cut surface. There was a little dead, down wood, and, as the tops of freshly fallen trees did not appear to be essentially different from those seen elsewhere and were obtainable nearer Moscow, a sample of this wood was not taken. It was difficult to judge the relative quality of the green stumps other than by the proportion of heartwood to sapwood, the apparent resin content of the heartwood being quite uniform. The proportion of truly resinous heartwood to sapwood varies greatly, however, a matter of importance in considering the value of the stumps, owing to the dearth of resin in the sapwood. Probably 50 per cent of the green yellow-pine stumps are of the quality represented by sample, and the remainder of inferior quality, in so far as the proportion of heartwood to sapwood is concerned.

It would be very difficult to remove these stumps unless they were taken out with the logging operations, because of the fact that the mountainous topography and limited rainfall preclude an extensive agricultural development in the wake of the logging operations. The surface of the land presents an irregular series of steep ridges between which wind deep, narrow valleys, where spur tracks are laid for the logs which are skidded down the hillsides to be loaded on tracks, moved as fast as the logs are taken away. The stumps, therefore, become inaccessible as soon as the tracks are taken up.

CRAIG MOUNTAIN REGION.

The yellow pine of the Craig Mountain region is a practically pure stand over an area some 10 miles long by 5 miles wide on an elevated, fairly level plateau. Receding from this central area the timber opens abruptly on Mission Canyon and the prairie country toward the north and west, and less abruptly toward the east, while toward the south it soon becomes mixed with fir and tamarack in the Salmon River country. A lumber mill with a daily capacity of about 125,000 feet operates in Winchester, which is centrally located in this yellow-pine belt. Comparatively little of the timber had been cut.

In the central pine area the stand of yellow pine varied from 400,000 to 800,000 board feet a "forty," with an average of approximately 20 stumps over 30 inches in diameter an acre where the stand was closest. The mill men and cruisers consulted agreed that probably 25 per cent of the total stand throughout this region is "bull pine."

Seven samples were taken from this region, as follows: (*a*) Green yellow-pine stumpwood from several stumps blown out of the roadbed in extending spur tracks for logging purposes; (*b*) medium to rich stumpwood from stumps blown out in highway construction; (*c*) medium to poor stumpwood from the same locality in which the medium to rich samples were obtained; (*d*) medium to rich stumpwood shot on land that had been cut over 4 or 5 years before; (*e*) dead, down yellow-pine wood collected from the better quality of knots, limbs, and trunks of trees lying throughout the woods; (*f*) rich, dead tops from trees felled in logging operations, the tops of which were dead from advanced maturity, and dead standing trees that had died from the same cause; (*g*) the better quality of tops and limbs from freshly felled trees. In addition, certain other samples were included in the investigation. The sample designated "rich stumpwood, Viola" was from western yellow-pine stumpwood, from a ranch located near Viola. These stumps, the last of those remaining scattered through the field, had been shot out with dynamite, and the best snaked to the house for fuel. It was from this lot, the weight a cord of which was estimated to be 3,500 pounds, that a sample was taken. Trees cut from these stumps were said to have been felled 35 or more years before. The wood was very resinous, and to all appearances the same as the better grades of pitch pine of North Carolina or other southern States.

The sample 30-inch stump from Priest River, obtained from a single large yellow-pine stump sent in from Priest River, Idaho, was selected as representing the best of the rich, or pitchy, stumps in that region. It had been blown out with dynamite, and the whole stump, roots and body, split into several pieces by the blast, was weighed, split, and reduced to stove-wood size. It was then mixed by being thrown together in a heap and repiled five or six times, after which it was neatly stacked under a shed. Dimensions of the pile of wood thus stacked were 8x7x1.5 feet, equal to a volume of 84 cubic feet. The stump weighed 2,190 pounds, so that as piled this wood weighed $\frac{2,190 \times 128}{84}$, or 3,330 pounds a cord, in round numbers. The tree cut from this stump had been felled about seven years, not long enough for the sapwood to have rotted away or become detached from the lightwood within. This sapwood contained absolutely no turpentine and impoverished the wood to that extent. It is estimated to have constituted 20 per cent of the total volume of wood in the stump.

The samples identified in Table 14 as "dead, down limbs" and "fire-scarred butts, Viola" were from yellow pine taken near Viola. Both samples were very resinous for these classes of wood. There was not a sufficient quantity of either to determine closely the weight of a measured cord. Nevertheless, if these facts are borne in mind and these samples are considered with other samples of the same classes of wood, they furnish an indication of the products to be recovered from these materials, which are quite plentiful in some sections. In some regions as much as 20 per cent of the butt logs are fire scarred. The values on these samples given in Table 14 are, therefore, only estimates.

SUMMARY.

Northern Idaho:
- Rich stumpwood, Priest River.

Potlatch-Deary Region:
- Rich stumpwood, Viola.
- Dead, down limbs, Viola.
- Fire-scarred butt, Viola.
- Poor stumpwood, Deary.
- Rich stumpwood, Deary.
- Medium stumpwood, Deary.
- Dead, down limbs, Deary.
- Rich stumpwood, Potlatch (three large stumps).
- Medium to rich stumpwood, Potlatch (from stumps other than the three large, rich stumps).

Coeur d'Alene Region:
- Rich stumpwood, Coeur d'Alene Lake.
- Medium stumpwood, Hayden Lake.

South Idaho, Boise Region:
- Bull-pine stumpwood, Boise.
- Medium stumpwood, Boise.
- Rich stumpwood, Boise.
- Green selected stumpwood, Boise.

Craig Mountain Region:
- Selected green stumpwood, Craig Mountain.
- Rich roadside stumpwood, Craig Mountain.
- Medium stumpwood, Craig Mountain.
- Rich, cut-over stumpwood, Craig Mountain.
- Dead, down limbs, etc., Craig Mountain.
- Dead tops, limbs, etc., Craig Mountain.
- Green tops, limbs, etc., Craig Mountain.

Moscow:
- Tamarack stumpwood.

DISTILLATION OF SAMPLES.

PREPARATION.

The wood as delivered was sawed in lengths that would fit into a pile of cord dimensions and split into pieces approximately 2 to 4 inches in diameter. It was then thrown into a heap, repiled a sufficient number of times to render it uniform in quality, corded, taking care to pack closely, and left standing, protected from the weather, until run. The entire sample thus prepared was weighed on a portable platform scale immediately before the distillation, and the weight calculated from its measured dimensions. In making these weighings 3 separate portions, usually of 175 pounds each, were taken from throughout the entire pile in such manner as to make sure that each sample was truly representative of the original field sample.

When a cord of wood is split into smaller pieces and again corded its volume is increased because of the greater proportion of voids or air spaces, the weight decreasing as the cubical content increases. An increase of about 10 per cent is said to result from reducing average cordwood to the size in which the wood making up the samples used in this work was piled and measured, from which it would appear that the weights per cord on which the yields are computed should be increased by 10 per cent. Owing, however, to the irregular shape of the pieces of stump cordwood and the care observed in piling the reduced wood closely, it is believed that the observed weights are not essentially lower than the average weight of a commercial cord of western yellow-pine stumpwood of corresponding quality. In support of this it was found that of the 3 cords of stumpwood from near Deary, Idaho, piled and measured in the field, when corded again after having been reduced to the size in which they were used in the retort, one measured an even cord, one 19 per cent less than a cord, and the third 10 per cent more than a cord. It seems unnecessary, therefore, to use other than the observed weights in calculating results.

The retort distillations were made on charges of known weights, varying from 150 to 200 pounds, depending on the nature of the wood. The distillation products were measured in liters per charge and the yields reported in gallons per cord. This basis of statement was selected in preference to the more exact unit-of-weight basis, the ton, for example, because of the difficulty of estimating the quantity of the several classes of wood on a given acre and applying the results to the problems in hand on other than the cord basis. The yields can be quickly figured to the ton basis from the data given in Table 14.

APPARATUS.

In principle, the apparatus (figs. 3 and 4) is essentially an oil-jacketed retort (*a*) in which high-flash cylinder oil, heated to the desired temperature, is circulated through closely spaced heating coils (*b*, *c*, and *d*) within the retort. The coil system of jacketing is preferable to a double shell in that it insures a positive flow of the heated oil, and, by dividing the coils into sections, prevents an excessive drop in temperature between the incoming and outgoing oil. A 3-inch layer of asbestos lagging and pipe covering of the same material protects the retort and exterior piping against excessive radiation. A coarse wire-gauze screen placed on the jacket coils facilitates removal of the charcoal.

The motor-driven oil pump (*f*) takes oil from the overflow tank (*g*) and discharges it through the gas-fired oil heater (*e*) into the jacket coils (*b* and *c*), from the other end of which it flows back into the tank (*g*). This circulation is maintained with the jacket oil as it comes from the heater and is held at 260° C. as registered on thermometer 1 until the turpentine has been recovered. The temperature is then raised to 343° C., and the bottom coil (*d*) made to join in the circulation of the oil by opening valve *o* until destructive distillation of the charge has been effected. Valves *m*, *n*, and *o* are adjusted (ordinarily unnecessary) so that thermometers 2, 3, and 4, registering the temperature of the return oil from coils *b*, *c*, and *d*, respectively, read essentially alike, indicating thereby that the oil flows equally through the three coils.

PROCEDURE.

Turpentine is present in resinous wood, along with rosin, as an oleoresin. Subjected to the designated retort temperature this oleoresin is partially sweated out and escapes from the pores of the wood, losing the turpentine by vaporization, while the resin accumulates with certain decomposition products, as pitch, in the bottom of the retort. The distillation is therefore conducted in two stages.

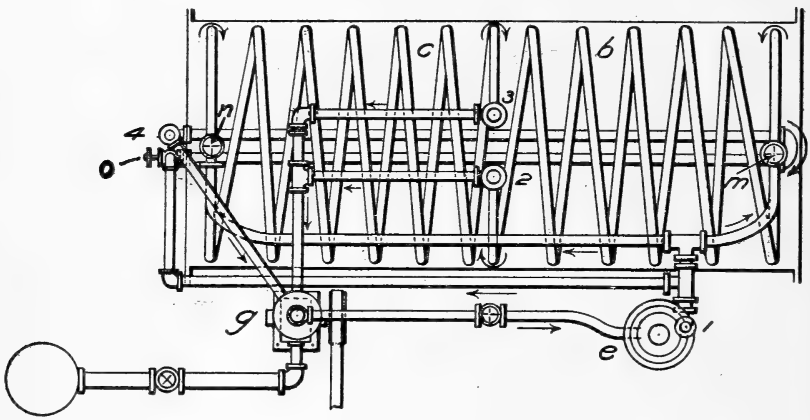

FIG. 3.—Plan of retort used for distillation of samples.

During the first stage the turpentine is recovered, and the resulting rosin liberated from the wood is collected in the bottom of the retort. The oil-bath temperatures during this stage are between approximately 220° and 265° C. The valve to the bottom coil (*d*) that lies embedded in the molten rosin is then opened, and the temperature of the circulating oil raised to 343° C. This brings about destructive distillation of the wood and the rosin, with the production of pyroligneous acid and the formation of rosin oils containing also creosote and other constituents derived from the wood, which distil from the retort in two stages as light oil and heavy oil.

The light and heavy oils come over with the aqueous distillate (pyroligneous acid) resulting from the chemical transformation of the wood and rosin during the destructive stage of the distillation, the light oil between 260° and 330° C., and the heavy oil above 330° C. A strong evolution of wood gas, which burns with a bright luminous flame, takes place while the heavy oil comes over. Charcoal and pitch are the end products of the distillation. The pitch is drawn off through a plug cock in the bottom of the retort at the end of a run. There is no sharp line of demarcation between the stages in which the distillation is conducted, because decomposition of the wood takes place long before all the turpentine has distilled over, and to effect a maximum recovery of it this stage of the distillation

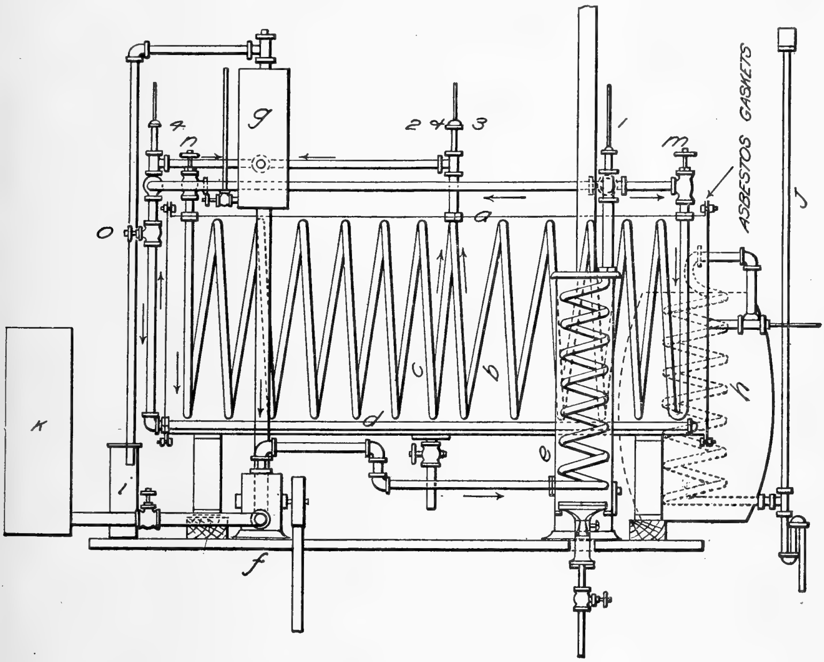

FIG. 4.—Elevation of retort.

a, Retort shell.
b and *c*, Main heating coils.
d, Bottom heating coil.
e, Oil heater.
f, Oil circulating pump.
g, Overflow tank.
h, Worm condenser.
j, Trapped vent pipe.
k, Oil tank.
l, Overflow catch.
m, *n*, *o*, Valves.
1, 2, 3, 4, Thermometers.

must be continued to the point at which the wood is converted into a brown friable substance approaching charcoal in its nature. This decomposition sets in when most of the hygroscopically held moisture has been expelled from the wood (about 260° C.), and is made apparent by the sharp odor of the distillate and development of a reddish color in the hitherto colorless aqueous layer. This incipient decomposition is soon attended by a perceptibly acid taste of the distillate, turbidity of the turpentine layer, and the escape of noncondensable gases (mostly carbon dioxid) from the vent pipe (*j*). This point in the distillation can be distinguished by an experienced person within fairly close limits by means of the changes indicated.

Contamination with decomposition products and the proportion of heavier oils, that subsequently must be removed, increase rapidly beyond this point. This comparatively pure fraction, therefore, is not allowed to mingle with that coming over beyond this point, but is collected separately as "first crude turpentine," while the remainder constitutes "second crude turpentine." The aqueous distillate coming over with the first crude turpentine, being practically free from alcohol and acid, is discarded, but that from the second turpentine is collected and saved with the pyroligneous acid obtained throughout the remainder of the run. The temperature being held fairly constant, the second turpentine fraction is continued to the point where the flow of distillate from the condenser drops below a practical limit, equivalent to about a gallon a half hour in these experiments, and the oil passing over no longer contains turpentine, as shown when it is dry distilled.

Along with the drop in speed of condenser discharge, the distillate suddenly takes on a true consistency and undergoes such a characteristic change of odor that there is no mistaking the point at which all turpentine has passed over. By the time combustible gases that burn with a pale blue flame begin to escape from the vent pipe. The bottom coil is then opened and the temperature of the jacket oil run up to approximately 345° C., where it is maintained until the end of the distillation. The oil becomes heavier as the temperature rises, until presently it separates from the aqueous portion of the distillate only after standing for some time. This marks the end of the "light-oil" period. The greater viscosity of the heavy oil and its characteristic odor are further relied on in cutting the light and heavy oil fractions. The discharge of noncondensable gases now reaches a maximum, and these suddenly burn with a bright luminous flame in place of the one hitherto blue.

RESULT OF DISTILLATION.

The products obtained by this method of destructive distillation are, therefore, seven in number: Crude first turpentine, crude second turpentine, light oil, heavy oil, pyroligneous acid, pitch, and charcoal. The temperatures and the volumes of oil and acid distillate collected were entered every half hour in a log kept of each charge (Table 13). The distillates were collected in large graduated cylinders and the oil removed from the aqueous layer in separatory funnels. The sum of the half-hour oil readings tends to be a little high because of the imperfect separation of the water and the volume of the oil accumulated by the end of the period a little low because of unavoidable transfer losses. The mean of the two, therefore, is used in calculating gallons a cord.

TABLE 13.—*Specimen log of a run of 150 pounds of Boise medium yellow-pine stumpwood.*

Time.	Temperature of oil bath.	Products obtained.		Combined oil and water.	Remarks.
		Oil.	Water.		
A. M.	*° C.*	*Cc.*	*Cc.*	*Cc.*	
8.25	....	....	....	....	Lighted gas, started pump, closed bottom coil.
10.00	223	....	....	....	Distillate started.
10.30	238	410	790	....	
11.00	250	540	1,100	....	
11.30	260	500	940	....	
12.00	261	495	800	....	Took sample acid liquor for analysis.
12.30	256	430	640	....	Noncondensable white vapors first appeared; last of first turpentine.
P. M.					
1.00	261	360	485	....	First of second turpentine; began saving acid liquor.
1.30	261	385	530	....	
2.00	261	370	570	....	
2.30	260	300	590	....	Gas from vent-pipe burns.
3.00	260	235	590	....	
3.30	263	180	570	....	
4.00	258	160	560	....	Last of second turpentine; ran up temperature; opened bottom coil.
4.30	281	135	490	....	First of light oil.
5.00	298	165	560	....	
5.30	310	170	830	....	
6.00	319	380	1,550	....	
6.10	322	230	740	....	Last light oil.
6.30	327	....	....	3,050	Heavy oil started.
7.00	336	....	....	4,050	
7.30	340	....	....	2,050	
8.00	344	....	....	1,550	
8.30	346	....	....	1,100	
9.00	342	....	....	600	
9.30	342	....	....	240	
10.00	342	....	....	90	Shut down, drew pitch; drip 150 cc. heavy oil by next morning.

CHARACTER OF CHANGES OCCURRING DURING DISTILLATION.

Wood tissue is made up primarily of cellulose, which, built up into cells and tissue, constitutes the structural element of plants, and lignin, which occurs as an incrusting matter or coating on the cell walls. In resinous wood there is a further deposit in the wood tissue of oleoresin from which the turpentine and pine oils are obtained when the wood is subjected to distillation at a relatively low temperature.

As previously explained, the nonvolatile substance remaining when the volatile oils are distilled from the oleoresin is rosin, a substance largely composed of abietic acid. Toward the end of the turpentine stage of the distillation the contents of the retort may be considered as made up principally of abietic acid, cellulose, and ligninlike substances, all of which are composed of the elements carbon, oxygen, and hydrogen. The molecules of these substances being comparatively large and complex, are readily broken down by the application of heat into a series of simpler compounds, some of which, reacting the one on the other, may form still other compounds. Of them all, water is the compound formed in the greatest quantity, because of the fact that oxygen and hydrogen constitute 55 per cent of cellulose, the principal wood constituent. This water, holding in solution numerous other compounds, produced simultaneously with its formation, is referred to in this bulletin as the "acid liquor," an exceedingly complex liquid of a wine-red color, having a sharp, tarry odor and strong acid reaction. In addition to water, it is largely made up of acetic acid, methyl or wood alcohol, tar acids, oils, esters and acetone aldehyde bodies, together with small proportions of numerous other compounds of an unknown nature.

It is not meant to convey the idea that these changes occur in clear-cut stages. Neither is it strictly true that the charge in the retort is in reality made up of cellulose, lignin, and abietic acid or rosin at any time during the distillation, for these compounds, owing to their instability toward heat when dry, undergo progressive changes as the moisture is more and more completely driven out of the wood, before the recovery of turpentine is complete. Though the period during which the distillation products do not result from decomposition of the wood substances and the destructive stages of the distillation merge into each other or overlap, the nature of the changes taking place is essentially as set forth.

Distillation of Wood (Exothermal) and of Rosin (Endothermal).

The chemical reactions brought about during the destructive distillation of cellulose are exothermal, that is, heat is given off during the changes taking place once the action, for which a temperature of 270° C. is necessary, has been started. The amount of heat thus liberated was found by Klason, Heidenstam, and Norlin[5] to be equivalent to 4.6 per cent of the calorific or fuel value of the wood (pine). The reactions involved in the decomposition of rosin by destructive distillation, in the course of which rosin oils are formed, however, cease unless an adequate supply of heat is maintained throughout the distillation. This is due to the fact that the changes taking place, instead of liberating, take up heat, being "endothermic" reactions.

These facts are of significance in view of the difference in behavior observed when the more highly resinous wood and that containing but little resinous matter, such as "bull pines," are distilled. In the case of the more highly resinous wood a decided exothermic effect was observed while the destructive stage of the distillation was in progress, continuance of the high temperature (343° C.) being necessary to carry the distillation to completion. In the distillation of "bull pine" in the same state of dryness, however, the reaction be-

[5] Arkiv. Kemi. Min. Geol., Band 3, No. 10, Heft 2. Published by the Royal Academy of Sciences at Stockholm.

came so violent when a temperature of about 300° C. was reached that the distillation could practically be completed without further heating, and in less time than the richer wood with continued heating.

It was necessary, therefore, in distilling the "bull pine" to watch the oil-bath thermometer carefully in running up the temperature for destructive distillation and turn off the heater flame when this period was reached. The reaction progresses so rapidly that the discharge of gas and vapors may exceed the otherwise ample condenser capacity, and loss of distillate result from imperfect condensation. The difference in behavior is due to the fact that the richer wood contains a much greater ratio of rosin to cellulose. The heat set free during decomposition of the wood substance is more than offset by that required to effect decomposition of the rosin in such wood, and additional heat must be supplied to insure the decomposition of rosin and the distillation of the products.

The fact that in the destructive distillation of nonresinous woods enough heat above a certain temperature is developed to complete the distillation without the application of heat from outside sources, necessitates the installation of larger condensers in the distillation of nonresinous woods than are needed in the distillation of resinous woods. When the exothermal reaction begins, it proceeds so rapidly that the condensers, which in the earlier stages were large enough to condense all condensable material, can no longer do so, and a loss of valuable products occurs if the condensers are too small to meet all the requirements that may be placed upon them during the exothermal period.

Yields.

The yields of crude products obtained in the retort distillation, and of the refined turpentine and pine oil for each sample, are given in Table 14. A summary of these tabulations, giving the average recovery from the various grades of wood distilled, is given in Table 19.

TABLE 14.—*Results of destructive distillation of Idaho western yellow pine.*

(Expressed in units per cord.)

Grade.	Kind and source of wood.	Weight per cord.	Crude products. Turpentines. First.	Crude products. Turpentines. Second.	Crude products. Light oil.	Crude products. Heavy oil.	Crude products. Acid liquor.	Crude products. Pitch.	Crude products. Charcoal.	Steam-refined: First turpentine from— First crude.	First turpentine from— Second crude.	First turpentine from— Total.	Second turpentine from— First crude.	Second turpentine from— Second crude.	Second turpentine from— Total.	Pine oil fraction from— First crude.	Pine oil fraction from— Second crude.	Pine oil fraction from— Total.	Final merchantable products. Turpentine.	Final merchantable products. Pine oil.
		Lbs.	*Galls.*	*Galls.*	*Galls.*	*Galls.*	*Galls.*	*Lbs.*	*Lbs.*	*Galls.*	*Galls.*	*Galls.*	*Galls.*	*Galls.*	*Galls.*	*Galls.*	*Galls.*	*Galls.*	*Galls.*	*Galls.*
Rich	Stumpwood, Viola	3,500	17.1	17.8	8.3	70.5	72.6	164	966	13.3	7.9	21.2	0.7	2.3	3.0	1.7	2.6	4.3	25.7	3.1
Do	Stumpwood, Priest River	3,300	14.8	11.4	4.0	48.0	74.4	110	988	11.8	5.2	17.0	.6	1.3	1.9	1.1	1.2	2.3	19.5	1.7
Dead, down [1]	Rich, dead, down limbs, Viola	3,000	17.8	13.5	4.9	47.0	61.9	104	850	13.6	2.9	16.5	1.3	1.9	3.2	1.6	2.8	4.4	21.0	3.1
Medium [1]	Fire-scarred butt, Viola	2,400	7.1	6.4	....	....	....	....	....	5.1	1.5	6.6	.8	1.0	1.8	1.1	1.0	2.1	8.9	1.6
Poor	Poor stumpwood, Deary	2,100	6.9	6.8	2.9	23.6	59.4	83	714	5.7	2.8	8.5	.4	.7	1.1	.3	.6	.9	9.7	.8
Rich	Rich stumpwood, Deary	2,600	14.9	13.0	4.9	44.6	55.9	232	670	12.9	6.5	19.4	.6	1.8	2.4	.9	1.6	2.5	22.4	1.9
Medium	Medium stumps, Deary	2,200	9.3	8.9	2.8	31.7	54.3	140	651	7.5	3.6	11.1	.4	1.5	1.9	.6	1.2	1.8	13.4	1.4
Dead, down [1]	Dead, down, Deary	2,200	6.3	5.2	3.3	25.7	53.4	92	863	4.7	2.1	6.8	.4	.7	1.1	.5	.8	1.3	8.2	1.0
Rich	Rich stumps, Coeur d'Alene	2,800	16.5	12.7	3.7	51.5	60.9	237	736	13.2	5.6	18.8	.9	1.7	2.6	1.2	2.0	3.2	22.3	2.3
Medium	Medium stumps, Hayden Lake	2,200	6.8	6.9	2.8	25.8	61.4	104	722	5.4	3.0	8.4	.4	.9	1.3	.5	1.0	1.5	10.1	1.1
Do	Bull-pine stump, Boise	1,900	1.6	....	1.0	12.2	64.3	....	688	.6	....	.6	.2	....	.2	.3	....	.3	.9	.2
Do	Medium stumps, Boise	2,400	9.0	8.8	4.9	24.8	63.9	188	800	7.7	4.4	12.1	.5	.9	1.4	.3	.9	1.2	13.7	1.0
Rich	Rich stumps, Boise	2,500	14.5	10.7	4.1	44.9	59.5	230	693	12.2	5.3	17.5	.6	1.5	2.1	.9	1.3	2.2	20.1	1.7
Green	Selected green stumps, Boise	2,400	9.9	5.0	3.2	32.1	63.6	144	768	8.1	2.5	10.6	.7	.5	1.2	.3	.5	.8	11.8	.8
Do	Selected green stumps, Craig Mountain.	2,500	8.7	7.4	2.5	30.1	69.2	143	823	7.2	3.8	11.0	.4	1.0	1.4	.5	.4	.9	12.5	.8
Rich	Roadside rich stumps, Craig Mountain.	2,600	13.4	7.6	2.7	42.3	63.6	160	770	10.0	3.4	13.4	1.0	1.3	2.3	1.1	1.1	2.2	16.2	1.7
Medium	Roadside medium stumps, Craig Mountain.	2,300	9.9	7.2	2.8	25.9	66.6	119	673	7.3	2.9	10.2	.6	1.0	1.6	1.1	1.0	2.1	12.3	1.6
Rich	Cut-over rich stumps, Craig Mountain.	2,500	13.3	8.0	3.7	36.6	62.4	214	752	10.7	3.2	13.9	.6	1.1	1.7	1.1	1.1	2.2	16.2	1.6
Dead, down	Selected dead, down, Craig Mountain.	2,400	4.5	2.8	2.8	22.2	75.8	42	778	2.6	.8	3.4	.6	.4	1.0	.6	.4	1.0	4.6	.8
Do	Selected dead tops, Craig Mountain.	2,000	5.9	3.7	3.3	19.5	63.2	98	671	4.8	1.6	6.4	.3	.3	.6	.3	.3	.6	7.2	.4
Green	Selected green tops and limbs, Craig Mountain.	2,400	3.1	2.8	3.3	16.1	80.8	22	764	2.0	1.1	3.1	.3	.3	.6	.2	.3	.5	3.8	.4
Do	Tamarack stump, Moscow	2,500	.2	....	....	6.5	74.1	....	803	....	....	....	....	....	....	....	....	....	....	....
Rich	Large rich stumps, Potlatch	2,700	14.5	7.6	5.1	29.5	65.7	155	736	10.3	3.1	13.4	1.3	.9	2.2	1.6	1.1	2.7	16.3	2.0
Medium	Heartwood, small stumps, Potlatch.	3,000	12.1	10.5	4.8	24.4	74.4	102	....	9.7	6.1	15.8	.7	1.2	1.9	.7	.9	1.6	18.0	1.3

[1] Exceedingly scarce; can not be considered as a source of wood for distillation purposes in itself.

CRUDE PRODUCTS OF RETORT DISTILLATION.

CRUDE WOOD TURPENTINE.

The crude wood turpentine is distilled from the wood during the first stage of the destructive distillation. During this first stage of distillation the turpentine passes over for the most part unchanged, as it probably exists in the wood tissue. The crude first turpentine, therefore, is nearly free from pyroligneous bodies. It is often light in color, and usually possesses an agreeable odor. It has a specific gravity of about 0.875 at 20° C., a refractive index of about 1.4768 at the same temperature, and an initial boiling point of about 164° C.

The crude second turpentine necessarily contains more of the pyroligneous or heat-decomposition products and of the heavier pine oils, since the retort operator cuts the distillate at the first signs of decomposition of the wood, indicated by the appearance of noncondensable gases, and collects the remainder of the turpentine as "seconds." The heat-decomposition products of the rosin and wood constituents consist of acids, alcohols, ketones, phenols, aldehydes, etc., the nature and quantity of which depend on the temperature and rate at which the turpentine stage of the distillation is conducted. This crude second turpentine is darker than the crude first, and its color is sharper and more suggestive of wood decomposition. It has a specific gravity of about 0.910 at 20° C., a refractive index of about 1.4850 at the same temperature, and an initial boiling point of about 130° C. (due to the presence of decomposition products).

The difference between these two crude turpentines is well set forth in Table 15.

TABLE 15.—*Products of dry distillation of crude turpentine at 760 mm. pressure.*

Temperature of distillation (° C.).	First turpentine.	Second turpentine.
	Per cent.	*Per cent.*
Below 170	9.3	7.5
Between 170 and 175	52.8	9.06
Between 175 and 180	16.0	18.05
Between 180 and 185	....	18.02
Residue	21.9	47.37

The details of refining the crude turpentine are discussed on page 56.

LIGHT OIL.

The crude light oil is brownish black, has a sharp, penetrating, empyreumatic odor, an average specific gravity of about 0.995, a refractive index of 1.514, each at 20° C., and an acid value of about 29. Its average viscosity at 25° C. is 2.58° Engler. The yield is about 4½ gallons a cord of rich wood. Distilled in the ordinary manner at atmospheric pressure, using a fractionating column, it has an uncertain initial boiling point, around 70° C., due to the presence of water and other low-boiling constituents, which rises rapidly to 160° C. The complex nature of this material is indicated by its wide temperature range when subjected to distillation. Typical results are shown in Table 16.

TABLE 16.—*Distillation data of composite crude light oil.*

Material distilling between—	Amount.	Material distilling between—	Amount.
	Per cent.		*Per cent.*
55° and 120° C.	3.5	230° and 350° C.	54.3
120° and 180° C.	13.6	Watery layer	1.8
180° and 230° C.	21.1	Residue soft pitch	5.7

On subjecting the various samples of crude light oil to dry distillation at atmospheric pressure, using a fractionating column, an average of 34.5 per cent was found to distil below 225° C. Of the total distillate an average of 1.8 per cent was aqueous. This aqueous portion, as well as the lighter portions of the oily distillate, contains quantities of acetic acid, methyl alcohol, and acetone. The difficulty of their recovery in a state pure enough for quantitative estimation is such, however, that it is as yet possible only to estimate the quantities of these bodies present.

On treating the distillate obtained below 225° C. with an excess of 20 per cent alkali solution, a marked contraction in volume of the oil and decided heating were observed. When the oil thus treated was steam distilled to exhaustion, 87 per cent (1.3 gallons a cord) of total distillate was recovered as a rather sharp-smelling, light-yellow oil having an uncertain initial boiling point of about 125° C. On dry distilling this steam-distilled oil, 60 per cent passed over below 175° C., and the remainder distilled up to 250° C. In its behavior on distillation it shows a close resemblance to rosin spirits.

By treating the crude light oil with alkali and distilling with steam as in the refining of the crude turpentine, 10 per cent (0.4 gallon a cord) of the oil is recovered as refined rosin spirits distilling at from 130° to 200° C. and 20 per cent as a pine-oil fraction distilling at from 175° to 275° C. The pine-oil fraction distilling at from 175° to 275° C. has a lemon-yellow color like refined pine oil, but an unpleasant, altogether different odor, and can not be considered as pine oil, except perhaps in certain of its constituents. Fifty per cent of it distils below 200° C.

The residue from this steam distillation of the crude light oil forms a heavy emulsion with the alkali present. On the addition of acid about 10 per cent of the original oil separates out as a heavy tar that settles to the bottom. The remaining oil has about the density of water, slowly floating to the top, is dark, and has a mild odor.

Distilled in a vacuum of from 10 to 20 mm., 80 to 85 per cent (3.2 to 3.4 gallons a cord) of the crude light oil is recovered as a clear, brownish-red oil that darkens on standing and has a creosote odor. The residuum from this distillation is a hard pitch. Repeated rectification of this light oil has given a series of fractions ranging from 166° to 176°. The fraction from 174° to 176° gives an oily bromin addition product. Apparently it adds hydrochloric acid gas to form needlelike crystals after standing a number of days, but all attempts to make a nitrosyl chlorid were fruitless.

The yield of crude light oil, compared to that of heavy oil, is small. Since the light oil differs but little from the heavy oil, it probably will be found expedient to collect and market or work it up along with the heavy oil in the operation of a commercial plant. One application to which this crude oil may be put is as a vehicle for cheap paints and shingle stains, and other such purposes for which certain of the creosote oils are now used.

HEAVY OIL.

The properties of the heavy oil which results chiefly from the destructive distillation of rosin resemble strongly those of rosin oil. The crude oil also contains decomposition products of the wood tissue, to which extent it is like wood creosote and rosin oil. The crude heavy oil is slightly heavier than water (average density of 1.048 at 20° C.), is brownish black, and has a penetrating, creosote-like odor. The average viscosity at 25° C. is 11.9° Engler. Like the light oil, it is comparatively unknown and untried, and therefore lacks a well-established market value.

Heavy oil is one of the important products obtained in the distillation of resinous woods. The yield is exceedingly variable, running from about 75 gallons a measured cord of very rich stumpwood to as little as 16 gallons from dead, down wood. Making up a large proportion of the total volume of oil recovered, its disposal to the best advantage possible is essential to the profitable operation of a commercial plant where the process is similar to that employed in this investigation. Consequently, certain experiments, looking to the most probable means by which an enhancement in the value of the crude oil may be expected, were conducted.

From the results of laboratory work it was found that in separating its low-boiling fraction by distilling at atmospheric pressure from a flask fitted with a Hempel column, distillation begins at an uncertain initial temperature of about 85° or 90° C., with an average recovery of 25 per cent (8.7 gallons a cord) below 225° C. This fraction is quite similar to the corresponding fraction obtained from the crude light oil.

The crude heavy oil can be used with some success for flotation purposes. In other fields of industry it must be sold largely in competition with products commonly obtained from coal tars such as are used in the manufacture of roofing cement and shingle stains, and as a softener and binder in treating heavy cotton cloths with metallic resinates, for water and mildew proofing purposes. In Russia a similar pine product is used extensively as a leather dressing for harnesses, boots, etc. Either by itself or mixed with tar it might be successfully employed in the preparation of cordage, tar soap, moth-proof paper bags, leather dressings, etc. Bacteriological tests have shown it to possess a phenol coefficient equal to one-half that of carbolic acid.

Both the light and heavy crude oils, as well as some of the other products of this investigation, were examined to determine their adaptability to flotation purposes by the United States Bureau of Mines at Salt Lake City, Utah (page 54), and also by several mining companies operating in the western States. One company reported that while all the pine oils were generally satisfactory for zinc ores, the crude light oil and a partially refined pine oil were particularly good. Another stated that the results differed only slightly from those obtained with oil from the southeastern pines, this being one of the most effective oils for flotation purposes. Probably all would be good for copper ores if used in conjunction with kerosene sludge acid.

PITCH.

The average yields of pitch from all classes of wood are not widely different except those from dead, down wood, which are much smaller than those from richer woods. No tests, either physical or chemical, have been developed with which to compare the qualities of the different samples of resinous-wood pitch found in commerce, other than the presence or absence of foreign matter, and no specifications on the basis of which to make such comparisons have been established. For this reason, and because its most important application is for impregnating fibers in the manufacture of oakum and cordage, and for closing seams in the decks of vessels, when it is combined in various proportions with tar and turpentine to secure the consistency desired, a systematic examination of individual samples of this material has not been made. These differ so little, the only apparent distinction that could be drawn between samples being a slight variation in their relative hardness, that a general description will suffice.

The pitch is a black, brittle to slightly pliant solid, having a specific gravity of 1.144 to 1.148 and in hardness varying from that of common rosin, in the more brittle, to that holding a finger print and possessing slight tackiness in the softer samples at ordinary temperatures. So susceptible is it to temperature changes that samples which were found to be tough or pliant through the day became quite brittle during the night. Its melting point is consequently very indefinite. It behaves like a viscous fluid at 75° to 100° C., is sirupy at 100° to 125° C., and free flowing at about 125° to 150° C. It is practically devoid of taste or odor, and dissolves readily in turpentine, but only very sparingly in either cold or hot alcohol, differing in this respect from common or black rosin. Its acid value was found to be 2, extracted with alcohol, against 150 to 180 for black rosin.

It differs from what is purchased under Government contracts for "North Carolina pitch" in being, on the whole, blacker, and somewhat softer, and in having, therefore, a generally lower melting point. It is believed, however, that this will not detract from its value in the uses previously enumerated, but rather that its somewhat greater pliability may be found to be advantageous.

CHARCOAL.

The charcoal obtained in these experiments from western yellow pine, especially that from the richer or more resinous samples of wood, is very soft and friable It retains an appreciable amount of bituminous matter, due undoubtedly to incomplete distillation, which causes it to burn with a long, smoky flame. Its possible application is suggested in industries where powdered fuel is used, or in metallurgical operations in which the crushing strength is not a prime requisite.

The charcoal from "bull" pine was in every respect superior to that obtained from yellow pine proper, and, in general, the quality of the charcoal fell off as the rosin content of the wood increased. Compared to that from hardwood, the western yellow-pine charcoal must be considered of inferior quality, especially as to hardness.

Tamarack charcoal has a much denser structure and is not so friable as that obtained from yellow pine. Moreover, it is clean or free from bituminous matter, and appears to be quite similar to hardwood charcoal.

ACID LIQUOR (PYROLIGNEOUS ACID).

The specimen log of a run (page 27) shows that an aqueous distillate which is nearly pure water comes over with the turpentine at the beginning of a distillation and is rejected. As the heating is continued, the wood tissue begins to decompose and the aqueous liquor takes on a straw color. From this point it contains acids and alcohol in varying quantities, and constitutes a true acid liquor, which in these experiments was retained and examined.

The acid liquor results from chemical transformations of bodies making up the wood tissue and rosin contained in the wood, brought about by heating the wood to a sufficiently high temperature. This reaction is a true chemical process, none of the compounds found in the liquor occurring in the untreated wood. The action is altogether different, therefore, from the recovery of turpentine and pine oils, the separation of which is effected by a physical change of state. In other words, the heat serves only to convert these oils into vapors, which, after being cooled in the condenser, are collected essentially as originally present in the wood.

The three important constituents of acid liquor are acetic acid, methyl (wood) alcohol, and acetone. Up to the present time these products have been obtained almost exclusively from hardwood. Owing to the greater amount of tarry substances present, softwood acid liquor is extremely difficult to free from this constituent, and the calcium acetate made therefrom is inferior in quality to that from hardwood acid liquor. The yield, consisting of methyl alcohol and acetone, is also substantially lower than that from hardwoods.

The proportions of acid, alcohol, and acetone as found in these western yellow-pine acid liquors (Table 17) were obtained by analyzing a composite sample of acid liquor from each set of charges run on the various kinds of wood.[6]

TABLE 17.—*Composition of acid liquors.*

Grade and source.	Acid liquor, per cord.	Acetic acid.		80 per cent acetate of lime (calc. from acetic acid), per cord.	Methyl alcohol.		Acetone.		Dissolved oils and tars.	
		Per liter.	Per cord.		Per liter.	Per cord.	Per liter.	Per cord.	Per liter.	Per cord.
	Galls.	*Gms.*	*Lbs.*	*Lbs.*	*Galls.*	*Galls.*	*Gms.*	*Galls.*	*Gms.*	*Lbs.*
Poor stumpwood, Deary	59.4	67.76	33.6	55.3	27.82	2.10	2.24	0.20	....	....
Rich stumpwood, Deary	55.9	64.67	30.2	49.7	25.45	1.80	2.77	.16	120.08	56.0
Medium stumpwood, Deary	54.3	67.82	30.7	50.5	26.11	1.79	2.44	.16	134.58	60.9
Dead, down wood, Deary	53.4	64.49	28.7	47.2	25.98	1.76	2.33	.15	156.86	69.9
Rich stumpwood, Coeur d'Alene	60.9	64.37	32.7	53.8	23.19	1.79	2.00	.15	122.34	62.2
Medium stumpwood, Hayden Lake	61.4	65.44	33.5	55.1	27.35	2.13	1.92	.15	136.11	69.7
Bull-pine stumpwood, Boise	64.3	77.55	41.6	68.5	29.37	2.40	2.21	.18	172.12	92.3
Medium stumpwood, Boise	63.9	64.67	34.5	56.8	25.21	2.04	2.12	.17	133.90	71.4
Rich stumpwood, Boise	59.5	68.12	33.8	55.6	25.34	1.91	2.16	.16	128.54	63.8
Green selected stumpwood, Boise	63.6	71.05	37.7	62.0	27.64	2.23	2.42	.19	161.16	85.5
Green selected stumpwood, Craig Mountain	69.2	70.40	40.7	67.0	26.18	2.29	2.26	.19	159.29	92.0
Rich cut-over stumpwood, Craig Mountain	62.4	73.41	38.2	62.9	30.17	2.38	1.81	.14	152.37	79.3
Rich cut-over stumpwood, roadside, Craig Mountain	63.6	65.12	34.6	56.9	29.27	2.36	2.07	.16	143.31	76.0
Tamarack stumpwood, Moscow Mountain	74.0	41.95	25.9	42.6	13.88	1.30	1.49	.14	66.15	40.8
Selected dead, down wood, Craig Mountain	75.8	48.35	30.6	50.4	24.32	2.34	1.75	.17	119.71	75.7
Selected dead tops, Craig Mountain	63.2	57.90	30.5	50.2	27.71	2.22	2.09	.16	117.81	62.1
Selected green tops and limbs, Craig Mountain	80.8	49.67	33.5	55.1	28.09	2.87	1.73	.17	78.98	53.2
Medium stumpwood, roadside, Craig Mountain	66.6	58.21	32.4	53.3	28.21	2.38	2.10	.17	114.49	63.6
Rich stumpwood, near Potlatch	65.7	59.72	32.7	53.8	18.26	1.54	1.69	.14	120.83	66.1

[6] The analyses of the acid liquors were made by V. E. Grotlisch and G. C. Spencer, Bureau of Chemistry, United States Department of Agriculture.

The yield of calcium acetate is approximately but one-fourth of that generally obtained in distilling the best hardwoods. Probably on a commercial scale the yields would be somewhat less than those shown by the analyses. The yield of wood alcohol also is but one-fourth of that generally obtained in hardwood distillation.

PRODUCTS OBTAINED IN REFINING CRUDE TURPENTINE.

REFINED TURPENTINE.

In order to separate the valuable turpentine constituents of the crude turpentines from the pyroligneous and resinous heat-decomposition products of the wood, the crude turpentines are first treated with caustic soda, which combines with acids and resinifies the aldehydes and phenols, forming nonvolatile compounds. By a subsequent steam distillation the turpentine and pine oil are recovered. Just as in the case of the original retort distillation of the wood, the oily products of the steam distillation are separated into several fractions. The first product is called "first grade" or "first-quality refined turpentine." The receivers are changed at a certain point (page 58), and the distillate which then comes over is called "refined second-quality turpentine." This has distilling temperature limits somewhat higher than those accepted for true commercial wood turpentine. Finally, the receivers are changed again, the last of the distillate being called "pine-oil fraction."

On refining crude first turpentine a yield of approximately 80 per cent of refined first-grade turpentine is obtained, most of which distils between 170° and 175° C. From crude second turpentine the yield of refined first-quality turpentine lies in the neighborhood of 43 per cent. The other distillates from the crude turpentines are as follows: From crude first turpentine, 5½ per cent refined second-quality turpentine fraction and 7½ per cent pine-oil fraction; from crude second turpentine, 13 per cent refined second turpentine and 12 per cent pine-oil fraction.

TABLE 18.—*Properties of refined turpentine.*

Kind and source of wood.	Source.	Specific gravity, 20° C.	Refractive index, 20° C.	Color.	Odor.	Initial boiling point.	Amount distilling— Below 170° C.	Between 170° and 175° C.	Between 175° and 180° C.	Between 180° and 185° C.	Total below 175° C.	Total below 185° C.
	Crude.					° *C.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Rich stump, Viola	First	0.862	1.4728	Water white	Sweet	168.5	8.25	76.50	8.35	2.15	84.75	95.25
Do	Second	.864	1.4733	do	Good	167.3	7.95	63.20	19.35	4.35	71.15	94.85
Rich stump, Priest River	First	.861	1.4728	do	Sweet	169.0	2.50	81.95	8.60	1.95	84.45	95.00
Do	Second	.865	1.4730	do	Sweet; slightly disagreeable.	166.0	8.55	66.10	17.15	3.70	74.65	95.50
Dead, down limbs, Viola	First	.864	1.4726	do	Sweet	168.5			6.25	2.00	88.15	96.40
Do	Second	.866	1.4725	Nearly white	Peculiar; sweet	166.0	32.00	41.50	13.75	4.75	73.50	92.00
Fire-scarred butt, Viola	First	.864	1.4727	White	Sweet	168.0			7.75	2.50	85.75	96.00
Do	Second		1.4730	Pale green	Sharp; destructive.							
Poor stumpwood, Deary	First	.860	1.4729	White	Sweet	169.0			9.50	2.50	80.75	92.75
Do	Second	.867	1.4732	Faint yellow	do	166.0	14.65	58.00	15.35	4.65	72.65	92.65
Rich stumpwood, Deary	First	.860	1.4722	White	do	168.5			7.00	2.00	86.75	95.75
Do	Second	.863	1.4728	Faint yellow	do	168.0	8.33	63.66	18.33	4.33	72.00	94.65
Medium stumpwood, Deary	First	.861	1.4729	White	do	168.0	19.50	67.00	7.25	1.75	86.50	95.50
Do	Second	.864	1.4730	Faint yellow	do	167.0	15.33	53.33	17.00	5.00	68.66	90.66
Dead, down limbs, knots, Deary	First	.860	1.4723	White	do	168.0	13.50	71.50	8.00	2.00	85.00	95.00
Do	Second	.865	1.4725	Faint yellow	do	168.0	9.33	63.33	16.66	4.33	72.66	93.65
Rich stumpwood, Coeur d'Alene	First	.861	1.4722	White	do	168.0	21.00	65.25	6.00	2.25	86.25	94.50
Do	Second	.864	1.4727	Faint yellow	do	167.0	11.00	63.33	16.33	4.00	74.33	94.66
Medium stumpwood, Hayden Lake.	First	.863	1.4727	White	do	169.0	7.00	79.25	8.25	2.25	86.25	96.75
Do	Second	.865	1.4732	Faint yellow	do	168.5	9.33	65.33	17.33	3.66	74.66	95.65
Bull-pine stump, Boise	1st & 2d	.865	1.4708	Faint yellow	Disagreeable	165.0	59.33	30.00		6.00	89.33	95.33
Medium stumpwood, Boise	First	.860	1.4722	White	Sweet	169.5	4.50	81.25	7.25	1.75	85.75	94.75
Do	Second	.865	1.4730	Faint yellow	do	168.0	7.50	68.00	14.75	4.00	75.50	94.25
Rich stumpwood, Boise	First	.860	1.4724	White	do	168.5	19.75	63.25	7.75	2.00	83.00	92.75
Do	Second	.864	1.4725	Faint yellow	do	168.0	10.00	63.75	15.50	4.50	73.75	93.75
Selected green stump, Boise	First	.861	1.4723	White	do	168.0	17.50	68.50	6.00	1.50	86.00	93.50
Do	Second	.865	1.4729	Faint yellow	Peculiar; sweet	167.5	13.25	67.50	11.25	3.00	80.75	95.00
Selected green stump, Craig Mountain.	First	.862	1.4726	White	Ethereal; sweet	169.0	13.00	72.50	7.00	1.50	85.50	94.00
Do	Second	.865	1.4728	Faint yellow	Sweet	168.5	10.00	65.25	14.50	3.50	75.25	93.25
Roadside rich stumpwood, Craig Mountain.	First	.862	1.4726	White	do	168.5	9.50	71.00	10.00	2.75	80.50	93.25
Do	Second	.865	1.4730	Faint yellow	do	165.0	14.00	56.00	14.66	5.33	70.00	89.99
Roadside medium stumps, Craig Mountain.	First	.861	1.4722									
Do	Second	.862	1.4725									

Rich cut-over stumpwood, Craig Mountain.	First	.860	1.4726	White	Sweet	170.0		83.75	8.75	2.00	83.75	94.50
Do	Second	.864	1.4726	Faint yellow	do	168.5	9.00	60.33	19.33	4.66	69.33	93.32
Selected dead, down knots, etc., Craig Mountain.	First	.858	1.4722									
Do	Second	.861	1.4723									
Selected dead tops, Craig Mountain.	First	.859	1.4730									
Do	Second	.861	1.4730									
Selected green tops, limbs, etc., Craig Mountain.	First	.858	1.4725									
Do	Second	.861	1.4728									
Tamarack stump, Moscow (1)												
Large, rich stumps, Potlatch	First	.859	1.4725									
Do	Second	.862	1.4730									
Heartwood, small stumps, Potlatch.	First	.856	1.4722									
Do	Second	.860	1.4728									

[1] None.

PINE OIL.

Pine woods contain oils other than those entering into the composition of commercial spirits of turpentine. These oils, collectively spoken of as pine oil, are liberated more or less completely from the wood in their original form, along with the turpentine constituents proper. This pine oil is a complex substance made up to a large extent of oxygenated derivatives of the terpenes (turpentine constituents), and has a comparatively high boiling point and specific gravity. The characteristic odor of pine wood is due chiefly to the presence of this oil, in conjunction with turpentine. The characteristic odor of wood turpentine is also due to small quantities of pine oil present. The quantity of this oil recovered is always relatively small, varying from a total of 3⅓ gallons from a cord of very rich stumpwood to less than 1 gallon from a cord of dead, down wood and poor stumps. It is necessary to remove or separate this oil as completely as possible from the turpentine, because it does not evaporate readily, and a turpentine containing even a small percentage of it will remain sticky or "tacky" after drying. Its value as a thinner in the paint and varnish industry would be affected accordingly.

The sum of the total refined turpentine and pine oil recovered from the crude first turpentine amounts, on an average, to 92 per cent, and that from the crude second turpentines to 70 per cent. On the basis of the average yields from rich and medium stumpwood, this would amount to 13.5 and 7.8 gallons a cord for the first crude turpentine, and 8.3 and 5.7 gallons for the second crude turpentine. These are the results obtained when the steam distillation is continued to the point where the oil layer makes up 5 per cent of the total distillate coming over at the time. By continuing the distillation to exhaustion, or until no more oil is carried over by the steam, an additional 5 or 8 per cent of pine oil may be recovered. Considerations for economy of operation did not warrant the carrying of the distillation to this state of completion. The composition of the pine oil progressively changes, so that the portion coming over at the close of the distillation is heavier than that passing over at the earlier stages.

ALKALI RESIDUUM.

On prolonged standing the black, alkaline liquid remaining from the distillation separates into an aqueous layer and a thick, oleaginous, soaplike mass which floats on top of the water. This mass will be designated " alkali residuum." Dissolved in the aqueous layer is a small proportion of what appears to be creosote bodies. The alkali residuum, which is essentially an impure rosin soap, dissolves in water to form a colloidal solution of great stability that exhibits an alkaline reaction. This solution possesses germicidal properties, the undiluted material having a phenol coefficient of 0.5. When the alkali residuum is decomposed by the addition of acid in excess, a heavy oil separates, about 75 per cent of which distils over between 180° and 340° C. Most of this distils between 200° and 300° C. The higher-boiling portion has the general appearance and odor of rosin oil. When the alkali residuum is distilled without previous treatment with acid, about 3 per cent of its volume is recovered as pine oil, along with 30 per cent of water, after which the residue remaining in the flask solidifies to a hard, soaplike mass soluble in water, forming a colloidal solution similar to that from the original alkali residuum.

CALCULATION OF YIELDS OF REFINED TURPENTINE AND PINE OIL.

A composite sample of the refined second-grade turpentine when dry distilled through a fractionating column yielded 83 per cent of turpentine distilling between 170° and 185° C., having a density of 0.8622 and a refractive index of 1.4736. The residue from this distillation was a true pine oil, the density of which was 0.9423, with a refractive index of 1.4937. A composite sample of the pine-oil fractions obtained in refining first and second crude turpentines, distilled in a like manner, gave 40 per cent of turpentine distilling between 175° and 185° C., the density and refractive index of which were 0.8655 and 1.4755, respectively. The residuum was also true pine oil similar to that remaining from the distillation of the second-quality turpentine.

The properties of the turpentine fractions thus obtained from the refined second turpentine and the pine-oil fractions do not differ markedly from those of the refined first turpentine. Moreover, the volume being but small compared to that of the refined first turpentine, it is believed that these may be combined without materially lowering the quality of the product. The total merchantable turpentine, therefore, will be figured on the basis of the first refined turpentine plus 83 per cent of the corresponding second refined turpentine and 40 per cent of the pine-oil fraction, respectively. The sum of the three is entered in the "merchantable turpentine" column of Table 14.

On the same basis, the volume of true pine oil will be 17 per cent of the refined second turpentine plus 60 per cent of the pine-oil fractions obtained in refining the crude turpentines. The yield of pine oil given in the "merchantable pine oil" column of Table 14 is thus obtained. The sum of the refined first and second turpentine and pine-oil fraction is not equal to the sum of the first and second crude turpentine. The portion thus unaccounted for is retained during the refining process, partly in the alkali residuum and partly in the aqueous distillate.

A summary of yields a cord of both crude and refined products obtained from each class of wood is given in Table 19.

TABLE 19.—*Yields per cord of crude and refined products from each class of wood distilled.*

Product.	Rich stumpwood (8 samples).			Medium stumpwood (6 samples).			Green stumpwood (2 samples).			Dead, down wood (4 samples).			Poor stumpwood (1 sample).	Green tops and limbs (1 sample).
	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.		
Crude first turpentine (A)..........gallons..	17.1	13.3	14.9	12.1	6.8	9.0	9.9	8.7	9.3	17.8	4.5	8.6	6.9	3.1
Crude second turpentine (B)..........gallons..	17.8	7.6	11.1	10.5	6.4	8.1	7.4	5.0	6.2	13.5	2.8	6.3	6.8	2.8
Total..........do....	34.9	21.0	26.0	22.6	13.5	17.1	16.1	14.9	15.5	31.3	7.3	14.9	13.7	5.9
Crude light oil..........do....	8.3	2.7	4.6	4.9	2.8	3.6	3.2	2.5	2.9	4.9	2.8	3.6	2.9	3.3
Crude heavy oil..........do....	70.5	29.5	46.0	31.7	24.4	26.5	32.1	30.1	31.1	47.0	19.5	28.6	23.6	16.1
Acid liquor..........do....	74.4	55.9	64.4	74.4	54.3	64.1	69.2	63.6	66.4	75.8	53.4	63.6	59.4	80.8
Refined first turpentine from A..........gallons..	13.3	10.0	11.8	9.7	5.1	7.1	8.1	7.2	7.6	13.6	2.6	6.4	5.7	2.0
Refined first turpentine from B..........gallons..	7.9	3.1	5.0	6.1	1.5	3.6	3.8	2.5	3.2	2.9	.8	1.8	2.8	1.1
Total..........do....	21.2	13.4	16.8	15.8	6.6	10.7	11.0	10.6	10.8	16.5	3.4	8.2	8.5	3.1
Refined second turpentine from A..........gallons..	1.3	.6	.8	.8	.4	.6	.7	.4	.5	1.3	.3	.7	.4	.3
Refined second turpentine from B..........gallons..	2.3	.9	1.5	1.5	.9	1.1	1.0	.5	.8	1.9	.3	.8	.7	.3
Total..........do....	3.0	1.7	2.3	1.9	1.3	1.7	1.4	1.2	1.3	3.2	.6	1.5	1.1	.6
Pine oil fraction from A..........gallons..	1.7	.9	1.2	1.1	.3	.7	.5	.3	.4	1.6	.3	.7	.3	.2
Pine oil fraction from B..........gallons..	2.6	1.1	1.5	1.2	.9	1.0	.5	.4	.5	2.8	.3	1.1	.6	.3
Total..........do....	4.3	2.2	2.7	2.1	1.2	1.7	.9	.8	.9	4.4	.6	1.8	.9	.5
Merchantable turpentine..........gallons..	25.7	16.2	19.8	18.0	8.9	12.7	12.5	11.8	12.2	21.0	4.6	10.2	9.7	3.8
Merchantable pine oil..........gallons..	3.1	1.6	2.0	1.6	1.0	1.3	.8	.8	.8	3.1	.4	1.3	.8	.4
Pitch..........pounds..	237	110	188	188	102	131	144	143	143	104	42	84	83	22
Charcoal..........do....	988	670	789	800	651	711	823	768	795	863	671	790	714	764
Cord weights..........do....	3,500	2,500	2,812	3,000	2,200	2,417	2,500	2,400	2,450	3,000	2,000	2,400	2,100	2,400

The average weight a cord of the rich stumpwood is 2,612 pounds, as against 2,450 pounds for selected stumpwood, and 2,412, 2,400, 2,100, and 2,400 pounds for medium stumpwood, dead, down knots and limbs, poor stumpwood, and green tops and limbs, respectively. The corresponding yields of refined first turpentine are 16.8, 10.8, 10.7, 8.2, 8.5, and 3.1 gallons a cord; and the yields of total merchantable turpentine are 19.8, 12.2, 12.7, 10.2, 9.7, and 3.8 gallons a cord, respectively. With the exception of that from the green tops and limbs, the yield of turpentine a cord follows the weight a cord. The yields of pine oil and crude light oil, while not varying greatly, show the same tendency to follow the weight a cord and field classification of the wood. This tendency is shown also by the yield of heavy crude oil and of pitch. The acid liquor and charcoal, however, are not subject to any such general deductions, although the highest yields of acid liquor are generally given by the green woods, followed by the richer stumpwood. In all probability this is due to the fact that acetic acid is one of the decomposition products of rosin.

An experienced person can classify stumps in the field into several grades from which the average yields of valuable products differ to such an extent as to necessitate a proper selection of the material before collection.

COMMERCIAL DISTILLATION PROCESSES.

There are four general processes for the recovery of products from resinous wood. Two of these are destructive distillation processes and two are nondestructive extraction processes. They are: (*a*) The common or ordinary destructive distillation process; (*b*) the controlled temperature destructive process; (*c*) the steam distillation or extraction process; and (*d*) the solvent extraction process. Of these the ordinary destructive distillation process is the only one which seems to be well adapted to the stump-disposal project in the Northwest.

ORDINARY DISTILLATION PROCESS.

The wood-distilling oven now in general use for the destructive distillation of wood is an outgrowth of the old charcoal heap. By-product charcoal kilns, round iron retorts, and rectangular iron or concrete ovens are in use, the rectangular oven being preferred in the best practice. Experience with these different forms has taught that there is a mean temperature which gives the most satisfactory yields. This temperature is necessarily more difficult to maintain in direct-heated retorts, the smaller of which have the further disadvantage that the charcoal must be removed by hand, necessitating a loss in time required for cooling as well as a fuel loss in reheating the retort for the next charge.

The uneconomical working of the round retort has led to the development of the rectangular oven. Such ovens are of steel or concrete construction and are heated either directly by fires under them, in the case of the steel ovens, or by means of internal-heating flues in the concrete ovens. The second method is said to be better adapted to softwood distillation. The height and width of the ovens are uniform, being in general 8 feet 4 inches and 6 feet 3 inches, respectively, and the length ranges from 26 to 54 feet or more, according to the desired capacity. An oven 52 feet long, 6 feet 3 inches wide, and 8 feet 4 inches high holds 10 cords of wood.

The charge of wood, of regular cordwood size, is loaded onto steel tramcars of special construction and hauled into the retort or oven, which is, of course, tightly closed during the distillation. At the end of this operation, the train of cars bearing the still hot charcoal is hauled out into the cooling shed of sheet iron, where the charcoal cools down without loss of fire. Simultaneously, another trainload of wood enters the oven, and the new distillation proceeds with a minimum heat loss.

In addition to the ovens, coolers, cars, and necessary brickwork or the setting of the ovens, condensers, which should be of ample capacity to handle the distillate under the most unfavorable operating conditions, will be required, as well as stills, steel tanks to hold the product, wooden tanks, pumps, generators, steam boilers and engine, yard tracks, piping, etc., and the necessary buildings for housing the plant.

A conservative estimate of the cost of such a plant is between $4,000 and $5,000 a cord capacity. Before the war these plants could be built for from $1,500 to $3,000 a cord capacity, or at a total cost, including working capital, of approximately $20,000 for a 10-cord plant. The cost of construction and of operation and the design and character of the equipment will vary, and quite widely, with the proposed location of the plant and the work it is to do, and with the experience and practice of the designing and constructing engineers. For these reasons, no details of equipment or specifications are given. This information can best be secured from wood-distillation engineers and from builders of the equipment, whose advertisements appear in the various industrial journals. The Bureau of Chemistry can furnish a list of engineers and builders of wood-distilling plants.

CONTROLLED TEMPERATURE PROCESS.

The controlled temperature or circulating oil process and retort have been fully described in the preceding pages. Even on a commercial scale a prerequisite of this process is that the pieces of wood be relatively smaller in diameter than those used in the ordinary destructive process, to insure rapid distillation. When properly carried out, better separation of the several products of distillation is obtained, with the result that the turpentine ordinarily obtained commands a slightly higher price (3 to 5 cents a gallon) for paint or varnish purposes than the turpentine produced by the regular destructive process, in which the temperature is not definitely controlled. While this process yields a better grade of wood turpentine, the equipment and upkeep are more expensive, and greater skill and a larger force are required in operating than for the uncontrolled process. For this reason it is rarely used for distilling resinous wood.

STEAM DISTILLATION PROCESS.

The steam distillation process requires that the wood to be extracted shall be finely divided by chipping or shredding before treatment; the finer the chips, the more rapid and complete the extraction. For this reason the steam process has been installed by several sawmills for the recovery of turpentine from sawdust. The best results are not obtained with all dust, however, as it packs so tightly that the steam is kept from penetrating throughout the entire mass to be extracted. Chips of a size passing an inch and retained by a quarter-inch screen are desirable, and a limited amount of sawdust can be mixed with such chips.

Few plants, other than lumber mills where the production of wood turpentine and pine oil is only a side issue, have continued to operate on the steam process alone, and have invariably closed when turpentine sold at less than 50 cents a gallon. The turpentine produced by this method is of high quality, approaching that made by the regular distillation from gum. The practicability of maintaining a steam distillation plant depends entirely on market conditions; if the price of turpentine is sufficiently high the steam method will be a paying proposition. The steam distillation outfit is now usually installed in conjunction with a solvent plant that can extract the residual wood chips for the recovery of rosin and certain of the heavier pine oils.

SOLVENT EXTRACTION PROCESS.

In the solvent process also the wood must be finely divided. This process is one where the wood is extracted in large, tight digestors at a relatively high temperature by means of suitable volatile solvents, the choice of which is determined mainly by price. Gasoline, coal tar, naphtha, or turpentine can be used, gasoline being the one in common use. When the solvent is added in the beginning of the operation, that is, with no previous steam distillation, all of the soluble pine products are removed altogether, and the resulting mixture is fractionated to recover the naphtha or other solvent and to separate the turpentine and pine oils from the rosin. The rosin obtained in this way is not so free from tackiness as pure gum rosin, and has a rather darker color, but is quite clear when properly made. Furthermore, it is very difficult to remove the solvent completely from the turpentine. It has been found advantageous, therefore, to combine the steam and solvent processes, the only objection to this being that the steam leaves the chips in a moist condition, in which state the extraction does not take place as readily as if they were absolutely dry.

BATH PROCESS.

An advantage of the bath process, another method which has been used to a limited extent, is that the wood does not require previous shredding. The wood is run into the retort on cars, and the retort is flooded with a high-boiling material, such as molten rosin, pitch, or tar, heated to a sufficiently high temperature. Most of the extracted turpentine and pine oils are volatilized at the temperature of the bath, and the rest is blown out of the bath with steam. The remaining wood, which is saturated with the rosin or other material of the bath, may be destructively distilled to recover the light and heavy crude oils, tar, charcoal, and pitch.

FEASIBILITY OF DISTILLING WESTERN YELLOW PINE.

Yellow-pine stumps of a quality such as to yield more than 12½ gallons a cord, the average yield from medium-grade stumpwood, of merchantable wood turpentine, of the properties shown in Table 18, and other products in corresponding proportion, are comparatively scarce. "Fat" or "pitchy" stumps, averaging 20 gallons of merchantable turpentine a cord, are not sufficiently numerous to be considered in a class by themselves as an impediment to land-clearing operations, and would need to be hauled for long distances in supplying wood to distilling plants.

The daily yield from a 10-cord plant and the market value of the products from the rich portion of medium-grade stumps, based on the yields obtained in these experiments and on the prevailing eastern prices June, 1918, using the ordinary ovens in general use, would be approximately as follows:

Merchantable turpentine	127 gallons @ $0.50	$63.50
Pine oil	13 do. @ .40	5.20
Light oil (at tar oil prices)	35 do. @ .20	7.00
Heavy oil (at tar prices)	275 do. (6 barrels) @ $0.15	41.25
Pitch	7 barrels (1,400 pounds) @ $3.50	24.50
Charcoal	350 bushels (7,110 pounds) @ $0.12	42.00
		183.45
Total value of products a cord of selected medium-grade resinous wood or heartwood		$18.36

The average yield and market value of the products recovered from a cord of rich stumpwood on the same basis are estimated to be:

Merchantable turpentine	19.8 gallons @ $0.50	$9.90
Pine oil	2.0 do. @ .40	.80
Light oil	4.5 do. @ .20	.90
Heavy oil	46.0 do. @ .15	6.90
Pitch	138.0 pounds @ 3.50 a barrel	2.41
Charcoal	38.0 bushels (790.0 pounds) @ $0.12	4.56
Total value of products a cord		25.47

These yields and values are comparable to those obtained in distilling longleaf-pine lightwood in the South Atlantic States, as shown by the following figures, taken from Bureau of Chemistry Bulletin 144:

Products from 1 cord (4,000 pounds) of longleaf yellow-pine lightwood (destructive process).

Total crude oil	gallons	36 to 120
Refined wood turpentine	do	5 to 20
Pine oils	do	2 to 5
Rosin oil	do	20 to 65
Light and heavy oils:		
Creosote	gallons	8 to 20
Rosin spirits	do	2 to 10
Charcoal	bushels	30 to 50

Cost of operating per day and per cord (1915 figures).

10 cords of wood, at $8.37 a cord, delivered	$83.70
Fuel wood, in addition to gases and fine charcoal, 10 cords, at $2.50 a cord, delivered	25.00
Labor, 8 men (3 shifts), at $2.50 a day (average wage)	20.00
Technically trained works manager, at $125 a month	4.15
Depreciation, at 15 per cent of investment in plant ($20,000)	8.20
Upkeep, at 8 per cent of investment in plant ($20,000)	4.40
Insurance, at 3 per cent of investment in plant ($20,000) (average)	1.65
Chemicals for still house, etc	1.00
Barrels or other containers for making deliveries	15.00
Interest on total investment ($25,000), at 6 per cent	4.11
	167.21
Total daily production cost, exclusive of sales or marketing expenses, a cord	16.72

Marketing expenses, although an important item, are not included, because they depend largely on the business policy of the management and upon competition.

The cost of operating a plant in the South Atlantic States is but little more than half this estimate, because of the much lower cost of wood and of labor in the South. If the medium-grade wood could be distilled at the usual southern cost, it would yield a fair return. The approximate cost of operating a destructive distillation plant in the South Atlantic States is as follows:

Cost of wood for distilling, a cord	$1.50 to $3.00
Management, labor, fuel, packing, a cord	2.50 to 6.00
Interest and depreciation, a cord	.60 to 1.60
Total	4.60 to 10.60

The values assigned to the several products are representative of those prevailing on the eastern coast shortly after the European war started. To this must be added the cost of transportation to the West and western dealers' profits, which were not included for the reason that they vary greatly, and also because local freight rates to interior points would, in many instances, be nearly as great from western points to consuming points as the through rates from the South to the same consuming points. Since, in any event, such competitive freight charges would vary greatly with the locality, they are not included in the estimation of values here given, but they must receive very careful consideration before the erection of a plant for the recovery of products from wood.

On the basis of the foregoing carefully considered and conservative estimates of cost of production and of the value of products, it must be concluded that stumps of medium quality, giving the average yields stated, can not be profitably utilized generally by the destructive distillation methods. Needless to state, if, because of exceptionally favorable local conditions, the cost of wood at the plant can be materially reduced, wood of medium richness could be profitably distilled. Such localities should be given very thoughtful and systematic consideration by experienced and practical distillation experts before undertaking their exploitation.

Since poor stumps and dead, down wood contain even less resinous matter than the medium stumps, they could not be profitably distilled.

On the other hand, the rich or pitchy stumps contain enough resins to make their distillation profitable in those localities where they are sufficiently numerous. With wood containing enough resinous matter to average the yields given for rich stumpwood, obtainable at even $10 a cord, a wide margin of profit is possible by the process outlined, provided all the products can be marketed at prices not materially lower than those used in the foregoing estimate. To maintain an adequate wood supply of this quality, sufficient for a plant to operate a number of years, it will be necessary to resort to a long-distance railroad haul and long-distance wagon transportation to railroad sidings. For this reason, a cost of something like $10 a cord should be allowed in estimates for such wood, the cost of getting out the stumps alone exceeding $6. The possibility of obtaining at reasonable prices sufficient quantities of rich stumps which are thinly distributed over the land, entailing a high cost of collecting, is the vital point in considering the practicability of wood distillation in the Pacific Northwest.

The impression that more material than that obtained from the rich stumps might be drawn on, because, the margin of profit for this material appearing quite large, an appreciable proportion of wood intermediate in quality between that from rich and that from medium-grade stumps combined with the rich grade would give a material worth working up, would in general be misleading.

When stumps of the different grades (p. 15) were dynamited but little difference was found between the poor and medium-quality stumps. Furthermore, unless the exudation of rosin is exceptionally abundant, it can not be taken as an indication that the stumps are rich or pitchy. So disappointing was this superficial indication of quality, used before its true value was established from dynamiting a number of stumps, that, to avoid shipping a lot of what was plainly worthless material, the poor stumps were taken from those that had been classified as medium, leaving only a few specially selected stumps from which the rich wood proper was obtained.

In view of these facts, poor and medium-quality stumps, as the terms are used in this bulletin, are those in which the sound heartwood approximately equals in resinous appearance that found in the heartwood of an average yellow-pine log, except that it is richer toward the spreading of the roots. The resinous material in such wood comes largely from this portion of the stump. Medium stumps differ from poor stumps only in that there is a somewhat larger proportion of the very resinous wood at the spreading of the roots, the main volume of heartwood in these two classes of stumps appearing to be essentially alike. Rich or pitchy stumps differ from the medium in that the heartwood is more uniformly resinous throughout the whole of the stump and constitutes perhaps from 60 to 80 per cent, or more, of the whole stump, while in the poor and medium stumps the resinous portion constitutes less than half of the entire stump.

To verify the conclusion that the rich or pitchy stumps average not more than a cord an acre of wood suitable for distillation, all the stumps on a typical area were removed, representative samples selected, and an estimate made of the total quantity of such wood on the area from which stumps were taken. This selected representative acre contained 12 stumps, 9 of which were classed as medium to poor, and 3 as resinous or rich. The 9 nonresinous stumps contained between 3 and 4 cords of wood, of which but 1,500 pounds, or one-half cord, was sound heartwood, the remainder being doaty, nonresinous sapwood, which was separated from the heartwood in the field, only the heartwood being taken to the laboratory. At least 80 per cent of worthless nonresinous material was split out of these stumps in obtaining the half cord of heartwood. In the large resinous stumps there were 1½ cords of resinous wood, all of the quality represented by the sample. The nonresinous stumps, though quite large (36 to 40 inches), were smaller than the resinous stumps.

The wood selected from that classed as the less resinous stumps was richer than that from the 3 rich stumps. Weight for weight of material in the selected samples this is true. However, of the wood running 18 gallons of turpentine a 3,000-pound cord, only about 1,500 pounds, or one-half cord, in the entire lot of 9 stumps contained an estimated volume of 3 or 4 cords of wood. To run all of this wood would eliminate the cost of splitting out the resinous wood from the sapwood. It would, however, quadruple the cost of rail and wagon haul and the time and cost of distilling, and, at the same time, would cut down the yield to about 5 gallons a cord of very inferior turpentine, with a proportional reduction in other products.

The half cord of resinous wood from the 9 stumps, combined with that from the 3 more resinous stumps, gave about 2 cords of wood, running 17 gallons of turpentine a cord. Had all the wood on the acre plot been used, there would have been 6 cords, yielding not more than 6 or 7 gallons of turpentine a cord, with the other products in like proportions. Neither the results of these experiments nor the wood-distillation practices in the South warrant the belief that wood of this quality can be profitably distilled. It is better to split out and reject the low-grade wood.

While a large proportion of the yellow-pine stumps in Idaho contain a certain amount of resinous wood which is as rich as the truly pitchy stump, such wood forms so small a proportion of the entire stump that its removal from the nonresinous wood is prohibitively expensive. The case is similar to that of many ore-bearing formations in which the valuable mineral is disseminated through so large a proportion of worthless material as to make its concentration in a form rich enough for treatment commercially impracticable.

At the 1915 prices for raw material and for products, wood from 60 to 80 per cent of which must be split off and rejected, or wood which will yield but 6 gallons of turpentine or a total of 30 gallons of resinous products a cord, could not be profitably distilled. When the nonresinous portion of the stumps has rotted away, leaving only the resinous heart, this material, which then would be similar to the rich stumps, could, of course, be profitably used, provided the ratio of cost to selling value remained essentially the same.

Future careful studies of the uses to which the heavy crude oil may be put probably will result in a revision of the price here assigned to it. That of 15 cents a gallon is based on its probable value for uses to which certain of the creosote oils are being put. Undoubtedly its value can be enhanced by suitable refining methods, or by working it up into special products. These would necessitate additional equipment and labor, thus increasing the manufacturing cost, the probable expediency of which can not be foretold. The same consideration applies to the light-oil fraction. From the prevailing price of articles with which such refined or special products must compete, it is doubtful if the balance between production cost and market value of the output of a plant would be materially affected thereby.

The acetone, wood alcohol, and acetic acid content of the aqueous distillate is, roughly, one-fourth that obtained in the crude distillate from hardwood plants. The value a cord of the alcohol and acetic acid recovered as acetate of lime, based on 1915 prices, is approximately $1 and $1.50, respectively. The crude liquor as obtained from the retorts is so heavily charged with tarry bodies that the acetate if obtained therefrom by the ordinary method is of a low grade and at best usually commands too low a figure to make its recovery profitable. Even by some improved processes, the recovery of these three products, which would increase the gross income by about $2.50 a cord, could be accomplished at best only on a narrow margin of profit, and the earning power of a plant thus equipped would not be materially increased by so doing. A company in the Northwest, operating a wood-distilling plant on selected Douglas fir mill-waste, including the recovery of these products in their margin of profits, found the enterprise, as then carried out, unprofitable.

One other possibility needs to be mentioned. It has been stated that lean and also medium resinous stumps contain small proportions of heartwood nearly if not quite as rich in resin as the resinous portions of rich stumps, but the proportion of such wood is so small that the cost of splitting it out would be prohibitive. Should the nonresinous portion rot off the lean and medium stumps in the course of a few years, as happens in the longleaf yellow-pine cut-over lands, the remainder or heart of the stump would then be practically 100 per cent resinous and suitable for distillation. Unfortunately, few such rotted stumps showing only the sound, rich heart were observed in any of the districts visited. The rotting off of the sapwood would unquestionably proceed more rapidly farther south.

RELATION OF WOOD DISTILLATION TO LAND CLEARING.

One of the purposes of this investigation was to secure information on what part of the cost of clearing land for farm purposes might be paid for by distilling the wood or by selling the wood for distillation.

The cost of clearing land for farming in the Pacific Northwest varies widely, depending on the size, number, and age of the stumps, the lay, nature, and water content of the soil, cost of labor and materials, and other factors. The United States Department of Agriculture, in cooperation with the State agricultural experiment stations of Washington, Wisconsin, and Minnesota (11), and the University of Idaho (8), have done much actual work on land clearing in this section, and have found the cost of clearing for farm purposes to vary from $50 for the lightest clearing ground to $150 an acre for heavily wooded hardwood land.

In the sections from which samples were collected 20 yellow-pine stumps to the acre is a high average on land where the stand is mostly or entirely yellow pine; under more commonly occurring conditions in which there is more of a mixed stand, such as in the Potlatch-Deary district, 10 to 12 yellow-pine stumps to the acre is more nearly correct.

If, as indicated by these investigations, 10 per cent of the yellow-pine stumps are of the rich, resinous type, yielding 20 gallons of turpentine and other products in proportion a cord, or 15.4 gallons a ton, the 12 stumps an acre would yield 1 cord, and 20 stumps about 2 cords of wood an acre.

If the wood could be disposed of for $10 a cord, the return for the extra labor, time, and expense required to split and sort out the resinous wood and haul it to a shipping point would be from $10 to $20. Experiments in clearing 1 acre carrying 12 yellow-pine stumps, varying from 2 to 5 feet in diameter (page 18), have shown that this return will a little more than pay for the powder needed to blast out all the yellow-pine stumps. In other words, provided a market for the wood at $10 a cord is available, the net cost of land may be reduced from 6½ to 40 per cent, less the cost of sorting and hauling to a shipping point.

The chief question is whether a farmer can afford to shoot all the yellow pine clear of the ground, or crack with explosives and pull the pieces with a puller, then sort the wood and haul it to the railroad, or whether he can get his land cleared more cheaply by using some of the methods of burning described in Idaho Agricultural Experiment Station Bulletin 91, or United States Department of Agriculture Farmers' Bulletin 974. If the returns from the fat stumps on a tract are sufficient to justify the more expensive methods of clearing, and it is some advantage to have all the roots out of the ground, blasting is the method which will be most used.

About 100 pounds of explosive would be required to shoot clear of the ground all the yellow-pine stumps on an acre, while 25 pounds would crack them enough so that they could be burned. In the first case, the cost of explosive (1914–15) would be about $15 and in the second case $4. The explosive could be placed with a little less work if the stumps were to be burned. Possibly it would require about the same amount of labor to burn the stumps in the ground as it would to sort over the pieces, burn those unfit for distillation purposes, and haul the rest to the railroad. On the assumption that it would, it will be seen that the farmer would just about break even if he could sell the rich wood for $11 an acre.

A wood-distilling plant of any size can not operate profitably without an ample and steady supply of rich wood extending over a number of years. For this reason a wood-distilling plant should be built and conducted as an independent business rather than primarily as a means of meeting the cost of land clearing. Naturally, it would be located with reference to available material; that is, where there was land ready to be cleared. Such wood as the settlers could supply would be simply an addition to the stock, though in some instances the bulk of the wood might be obtained from this source.

In the Winchester and Craig Mountain country, where the conditions are quite different from those observed in the other sections, there is a close almost pure stand of yellow pine. As there are no heavy underbrush or slashings, clearing such cut-over lands consists practically entirely in burning the tops of the cut trees and removing about 20 large yellow-pine stumps.

The comparative absence of younger growth between the trees, fairly even surface of the country, and uniform stands, of which perhaps 40 per cent of the stumps are quite rich or resinous, make such sections possible localities in which the cost of land clearing may be met, in a large part at least, if not entirely, by distilling the stumps.

SMALL, SEMIPORTABLE WOOD-DISTILLING PLANTS.

Wood-distilling plants as usually constructed where the daily capacity varies from 10 to 100 cords of wood, are permanent, especially when a number of products are made and refined for market. Furthermore, such plants require capital for financing and technical skill and experience for profitable operation. Therefore, wood-distilling plants would be comparatively few, and small plants of about 1-cord capacity that can be set up, torn down, and relocated at will would be useful, particularly in sections removed from railroads and where transportation is difficult. Especially would this be true if the mixed crude oil and tar obtained could be profitably disposed of to refiners or directly to users.

Since the work described in this publication was completed, private companies have built and operated such small plants. Plants of this kind, of 1-cord capacity, can be built for from $3,500 to $4,500. They might be bought and operated by a community, the crude oil being sold direct to the zinc, lead, and copper miners, who use it for the concentration of ores by the flotation process. The cheap, semiportable 1-cord retort is probably better adapted to Northwest conditions than are the large, more permanent, and more expensive plants making and refining a number of products.

USE OF OIL FOR ORE FLOTATION.

Of the many oils that have come into use for ore flotation, oil of eucalyptus, costing about $1.50 a gallon, is prized most highly. Next in the order of merit come the pine oils, selling for from 40 to 60 cents a gallon. In the effort to discover cheaper oils, most of the wood creosotes, as well as many coal-tar creosotes, have been found to be acceptable. They range in price from 15 to 30 cents a gallon. Producers of petroleum have also entered the flotation field, though with but limited success when petroleum alone is used. Better results are obtained by mixing a small amount of pine or creosote oil with the crude petroleum. "Kerosene sludge acid" from California oils, obtained by treating the crude oil with sulphuric acid in the refining process, is also being sold for flotation. The sludge acid from coal tar is said to have a flotation value as good as or better than that from petroleum, and even coal tar itself is extensively used because of its low price.

These different products entering into ore flotation may be divided, in a general way, into two classes, known as "frothing agents," which promote foaming, and "collecting agents," the function of which is to coat with a film of oil the mineral particles only, so that, adhering to the air bubbles in the foam, they are thus separated from the gangue. While all oils possess both frothing and oiling or collecting properties in some degree, eucalyptus oil, the pine oils, pine-tar oils (the "light" and "heavy" oils of this publication), and crude turpentine are primarily used as frothing agents. Coal tar, pine tar, together with hardwood tar, and "sludge acid" are used as collecting agents. Success in ore flotation demands a proper adjustment of these two physical properties to the particular requirements of the ore to be treated. While all of the products mentioned can be used in proper combination, with some measure of success, the pine oils occupy a commanding position in the field of ore flotation.

Samples of pine oil and of the crude distillates obtained in the retort work were submitted for flotation tests to the Bureau of Mines Metallurgical Experiment Station, Salt Lake City, Utah, to ore mills in the Coeur d'Alene district, and to the testing department of a large copper mining company. The results from their tests showed that the crude turpentine was virtually as effective a flotation agent as the pine oil, and even the light and heavy oils were applicable, though requiring a greater proportion a ton of slime, especially in the case of the heavy oil. Even the acid liquor was found useful on certain pyrite ores.

Where, therefore, the efforts of the producers were formerly directed toward refining the crude distillate to recover a maximum quantity of turpentine, the change in market conditions makes it desirable to throw as much of it into the pine-oil fraction as is possible, or to go a step farther and market the entire crude distillate as flotation oil. If this were done it would, of course, reduce decidedly the cost of running the plant, and simplify operation. The consequent reduction in cost of production would probably amount to $2 or $3 a cord.

As to future flotation-oil values it is difficult to conjecture. The Bureau of Mines, which experimented with the various oils obtained in the course of this work, commenting on the conditions that will probably have to be met in the flotation-oils market during the coming years, points out that:

Pine oil at 50 to 60 cents per gallon has cost too much. Crude petroleum and coal tar containing small additions of pine oil can be made to do almost the same grade of work and are hence cheapening the cost of flotation oils. Pine cresote, pine tar oils, and various hardwood fractions, together with hardwood tar, are finding acceptance in place of the more expensive products. There will always be a market for pine products, however, as long as they do not cost too much; 30 to 40 cents per gallon, f. o. b. the West, will probably be the price paid for such material and when the price goes much above that, the material will merely be eliminated from consideration.

Some idea of the quantities of these pine products used in the flotation of ores may be obtained from Table 20.

TABLE 20.—*Monthly consumption of flotation oils in the United States (1916).*

[Compiled from a report of the Bureau of Mines.]

Type of ore.	Monthly tonnage of ore.		Wood products.				
	Beginning of 1916.	End of 1916 (estimated).	Pine oil.[1]	Pine-tar oil.[2]	Oil of eucalyptus.	Wood creosote.[3]	Crude turpentine.
	Tons.	*Tons.*	*Galls.*	*Galls.*	*Galls.*	*Galls.*	*Galls.*
Copper	1,248,000	1,942,000	7,800	95		47,600	205
Zinc and complex	248,000	350,000	8,000	85		30,000	450
Lead	115,000	136,000	515		28	13,800	
Gold and silver	45,700	123,000	1,300	95		4,600	
Total	1,656,700	2,551,000	17,615	275	28	96,000	655

[1] Probably includes a considerable amount of the lighter fractions of pine-tar oil.
[2] The crude light oil would probably come in this class.
[3] The crude heavy oil would probably come in this class.

It has been pointed out that combinations of different oils are used by mixing the more expensive pine-wood distillates with crude petroleum, coal tar, etc., in suitable proportions to obtain the desired foaming and collecting effect for the kind of ore to be treated. While this is to a large extent done at concentration plants, some producers in the East market blended oils on this same principle. This should, of course, be given careful consideration by those who may engage in the production of flotation oils from resinous wood wastes in the Northwest. A list of uncompounded pine oils and other distilled wood products used, either alone or for producing blended oils for flotation, is given herewith. Some idea of the required properties may be derived from the specific gravities:

Crude pine oil.
Crude wood turpentine.
Pine oil, steam distilled (sp. gr., 0.925 to 0.940).
Pine oil, destructively distilled.
Pine-wood oil (light) (sp. gr., 0.950).
Pine-wood oil (heavy) (sp. gr., 1.025).
Pine-tar oil (sp. gr., 1.025 to 1.035).
Pine-tar oil, double refined (sp. gr., 0.965 to 0.990).
Pine tar, thin (sp. gr., 0.980 to 1,000).
Wood (pine) creosote, refined.
Hardwood oil (Michigan) (sp. gr., 0.960 to 0.990).
Hardwood oil (Michigan) (sp. gr., 1.06 to 1.08).

REFINING CRUDE WOOD TURPENTINE.

The crude wood turpentine is a complex mixture of oils, both lighter and heavier than pinene, certain of which impart to the turpentine an objectionable, penetrating odor and dark color, from which wood turpentine having the accepted commercial requirements, and of uniform quality, is to be obtained. To compare favorably with gum spirits the refined product should, in addition to its odor and color, have a correspondingly narrow boiling-point range or distillation-temperature limits.

In refining crude wood turpentine it is customary to subject it to steam distillation, after thorough mixing with caustic alkali to remove or hold back certain constituents, whereby it is separated into a fraction lighter than turpentine, having a yellow color and penetrating odor, a turpentine fraction, and a pine-oil fraction. The details of operation and the proportion and quality of the products thus obtained vary greatly with the quality of the crude oil, as well as with the care observed in dividing or cutting the fractions. In doing this the still operator is commonly guided by the density, odor, color, etc., of the oil in changing over from one fraction to another, which is not conducive to uniformity of results. This insufficient standardization of the product has contributed materially to the unfavorable attitude of consumers toward wood turpentine, as well as to the lower price commanded by and greater difficulty in marketing this product as compared with gum spirits.

The necessity of separating a light fraction that must be marketed as an inferior turpentine or special product because of its objectionable odor and color, moreover, is a wasteful practice, in that this product is made up largely of pinene which properly belongs in the turpentine fraction. Owing further to imperfect fractionation, or the tendency of the heavier oils to pass over with the turpentine, only in part overcome by the use of column stills, a considerable proportion of the turpentine fraction is retained in the residual pine oil.

Because of these defects in refining processes, efforts were directed in the beginning of this work to devise a laboratory method for recovering a maximum of high-grade spirits from the crude oil that would be applicable to the operation of a commercial plant, on the basis of which yields of commercial turpentine from different woods could be compared. It soon became apparent that sufficient importance is not attached to the amount of alkali required and to the manner of its application. Instructions merely to distil with alkali or to treat with alkali until action ceases are entirely inadequate, because the amount of alkali used materially affects the proportion of the light fraction, the sharpness of the fractionation, and the quality of the turpentine as indicated by its odor, color, and boiling point limits. The intimacy and period of contact of the alkali has equal or greater influence.

The alkali appears to serve a double purpose, aside from that of neutralizing the free acid present in the crude oil. First, it brings an apparent polymerization of the aldehydes whereby these are converted into resinous, nonvolatile compounds, in which form their elimination from the turpentine is effected on distillation. Second, the action of the alkali, if used in sufficient quantity, results in the formation of a soap with the tar and resin acids. This, in a manner not understood, although it may be through formation therewith of a so-called water-soluble oil, restrains the escape of the pine-oil constituents, while the turpentine distils over, thus effecting a materially sharper separation of the two. The alkali solution being immiscible with the turpentine and the polymerization process partaking in its nature of a catalytic or surface reaction, the effectiveness of the alkali depends on extremely intimate contact with the turpentine for a sufficient length of time to permit the carrying of the reaction to completion before beginning the distillation. It is in this respect that refining methods as ordinarily carried out are wrong in principle, for the reason that, with the alkali added in the still, distillation begins before completion of the reactions that "fix" the aldehyde bodies. These in part pass over with the turpentine and are removed from the sphere of action of the caustic solution before the reactions that render them nonvolatile have been completed. Agitation of the turpentine in a separate vessel and removing and distilling the oil thus separated from the alkali are also wrong in principle, because advantage is not taken of the deterring action of the soap solution on the distillation of pine oils.

To combine the action of the two principles here set forth the crude oil is agitated with caustic soda solution at boiling temperature in a return-flow condensing apparatus before distilling. Mechanical agitation with a paddle-wheel stirring device was the first resort. It was subsequently found, however, that heating over a flame in a distilling flask fitted with return-flow condenser is equally effective and much simpler in execution. This method of treatment thoroughly emulsifies the oil and caustic solution, giving the intimacy of contact desired, while the inverted condenser continually returns the aldehyde bodies to the action of the alkali until they have been changed to the nonvolatile products previously discussed. The inverted condenser is then replaced by a Hempel column and the contents of the flask distilled with steam, yielding from the start a turpentine of standard requirements.

Steam distillation is admirably adapted to the production of turpentine of uniform quality, because it affords a simple means of control, in that the ratio of oil to water in the distillate is an index of the composition of the turpentine (12). This is a gradually diminishing ratio in proportion as the oil contains less pinene and correspondingly more of the higher-boiling pine oils. For any observed oil-to-water ratio, however, the turpentine has a definite composition, as indicated by its density, refractive index, distillation-temperature limit, etc. This, of course, follows from the law of relative vapor pressure of immiscible liquids. Its application as a simple and remarkably accurate means by which to judge the composition of the turpentine at any time during the distillation, however, has not been given the consideration it merits (12) as a means of standardizing the output of commercial plants. Properly used, the oil-to-water ratio makes possible the production of turpentine having a constant, predetermined composition, any consignment of which will be practically the same as a preceding or subsequent shipment.

Following up preliminary observations, based on the considerations set forth, a series of experiments was conducted to determine: (*a*) The relative efficiency of caustic soda, carbonate of soda, and milk of lime as refining agents; (*b*) the proportion of alkali to crude oil and concentration of the alkali solution giving the best results; (*c*) the time necessary for the reactions set up by the alkali treatment to produce its full effect; (*d*) the effect of drawing off the alkali after treatment and washing the oil with water before distilling; (*e*) the effect of passing a current of air through the oil during treatment with alkali.

In carrying out these experiments 500 cc., taken from a large composite sample of crude western yellow-pine turpentine, were used in each test. The turpentine fraction proper was continued to where the ratio of oil to water was 4 to 6, beyond which the proportion changes rapidly, and a second turpentine fraction collected between the 4 to 6 and 3 to 7 ratios. The distillation was continued for the recovery of pine oil to the point where the oil constitutes but 5 per cent of the distillate coming over. The odor, color, refractive index, density, where possible, and volume of each fraction thus obtained by the different methods of treatment were noted in order to determine by the comparison of these constants which process gives the closest separation and best yield of high-grade product.

As was to be expected the best results were obtained by the use of caustic soda. With carbonate of soda, used in such proportion that its hydroxyl strength was equivalent to that of the hydrate, the quantity of the turpentine recovered from the crude oil was the same as that obtained with caustic soda, but of inferior quality with respect to odor. For commercial use, moreover, the fact of its being cheaper than the hydrate is offset by its greater equivalent weight and the correspondingly larger quantity required to produce the effect of an equivalent amount of sodium hydrate. Milk of lime has only low cost to recommend it. The calcium resinate or lime soap formed, being insoluble, does not form the pine-oil emulsion that helps materially to effect a sharp separation of the turpentine. The yield of the turpentine is lower by 10 per cent than when sodium hydrate is used, and the product is inferior in odor. Moreover, the lime soap seriously fouls the apparatus with an incrustation difficult to remove.

It was found that the quality improved and the percentage of turpentine recovered increased with increasing amounts of alkali up to 75 cc. of 20 per cent caustic-soda solution per 500 cc. of crude oil, or, in industrial terms, 75 gallons of 20 per cent caustic-soda solution (containing 20 parts per hundred of actual sodium hydroxid) to 500 gallons of crude turpentine. This proportion was found to be satisfactory for refining the crude second turpentine. For the crude first turpentine the amount of alkali probably could be diminished. The concentration of the alkali solution is not so important, since the use of half this quantity of 40 per cent alkali solution does not materially affect the results. The duration of the chemical treatment before beginning the distillation is of great importance, and at least 30 minutes after the mixture reaches the boiling point should be allowed for the completion of the reactions involved. Separation of the alkali solution from the turpentine before distilling has a profound effect. Not only is the quality of the turpentine much inferior to that of the turpentine obtained when the distillation is made in the presence of the alkali solution, but the yield is lower by 20 per cent, with a corresponding increase in the second turpentine and pine-oil fractions, showing that, however brought about, the soap solution exerts a restraining influence over the pine oil, the complete separation of which from the turpentine is most essential to the production of an article possessing the properties demanded by the trade. Passing air through the oil during the alkali treatment yields a turpentine having a sweeter odor than that obtained without aeration. The other properties and the yield of turpentine recovered, however, are not materially influenced thereby. In refining a crude oil which is heavily charged with the decomposition products of destructive distillation, aeration to improve the odor may be found advantageous.

This procedure was followed in refining the various crude turpentine samples obtained:

Transfer a 500 cc. portion to a round-bottomed liter flask, add 75 cc. of 20 per cent NaOH solution, and some finely broken pumice. Attach a large reflux condenser and heat the contents to and maintain at the boiling temperature, over a gas flame, for one-half hour. When sufficiently cooled, to avoid loss, remove the reflux condenser, attach a Hempel column of fairly good size filled three-fourths full with short pieces of glass tubing, and a condenser in the ordinary position, and distil the contents of the flask with steam in the usual manner. The oil coming over to where the ratio of oil to water is 4 to 6 is first-quality commercial turpentine, ready to enter the trade as such. That coming over between the 4 to 6 and 3 to 7 ratio contains a small proportion of lighter pine-oil constituents, and needs to be distilled a second time for their complete removal. The distillation is continued for the recovery of pine oil to the point where the pine oil forms 5 per cent of the distillate coming over at the time, below which ratio it was not deemed economical to go.

To determine quickly the proportion of oil to water in the distillate it was found convenient to use a coordinate paper diagram (fig. 5), in which abscissæ are the water readings and ordinates the total distillate readings collected during a short interval. Right lines are drawn from the origin of coordinates to intersect, at 100 on the ordinate axis, the points 60, 70, and 95 on the axis of abscissæ, respectively, these corresponding to the percentage of water in the distillate at the transition points. To use the diagram for determining the end of, say, the turpentine fraction, the volumes of water and total distillate are read. The volumes of water are transferred to the horizontal and those of the distillate to the vertical axis. If the intersection falls above the 60 per cent water line, the proportion of oil exceeds 40 per cent, and similar readings are taken at suitable intervals until it falls on the line. Similarly, the 70 and 95 per cent lines determine the end of the other fractions.

The odor and color of the refined turpentine samples thus obtained were noted, the specific gravity and refractive index determined, and a distillation made from which to judge their quality (Table 18).

The distillation temperature limits of turpentine are so susceptible to pressure variation that it is essential, in making such comparisons, to conduct the distillation under normal pressure. The laboratory at Moscow, Idaho, being at an elevation of about 2,800 feet above sea level, it was necessary to increase the pressure in the distilling apparatus accordingly. This is accomplished by means of the apparatus devised in the Bureau of Chemistry and described in detail in Bureau of Chemistry Bulletin 135, "Commercial Turpentines."

The distillation data, along with the other data thus obtained, bring out a striking uniformity in the physical properties of corresponding samples from various sources, differing, however, from the better quality of wood turpentine from the South Atlantic and Gulf States in their higher, though equally narrow, boiling points.

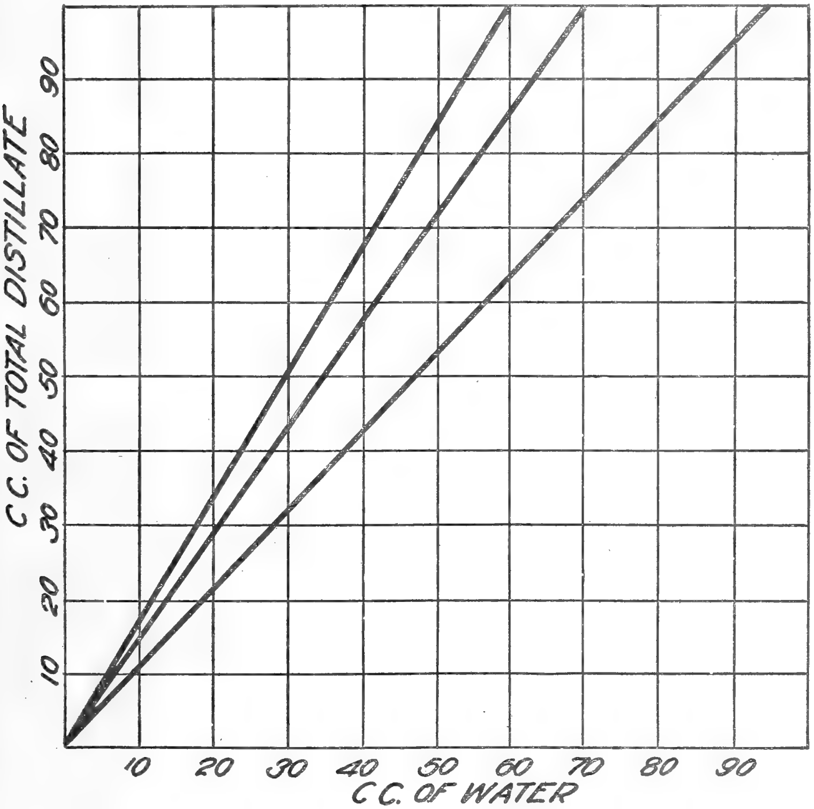

FIG. 5.—Proportion of oil to water in distillate.

The major portion of turpentine from western yellow pine distilling between 170° and 175° C. instead of 160° and 165° C., as is the case with gum turpentine obtained from southern yellow pine, indicates that in place of alpha-pinene this turpentine from western yellow pine is largely made up of beta-pinene (7).

To obtain a closer separation of its constituents, and thereby gain a better insight into the proportion and nature of the bodies probably entering into its composition, a composite sample of refined first-grade turpentine, from first and second crude turpentine combined in proportions as recovered from the crude turpentine, was carefully distilled from a Hempel fractionating apparatus, and the boiling point, specific gravity, and refractive index curves plotted from these data.

The boiling point, refractive index, and specific gravity curves (figs. 6, 7, 8) point to the presence, to the extent of about 2 per cent,

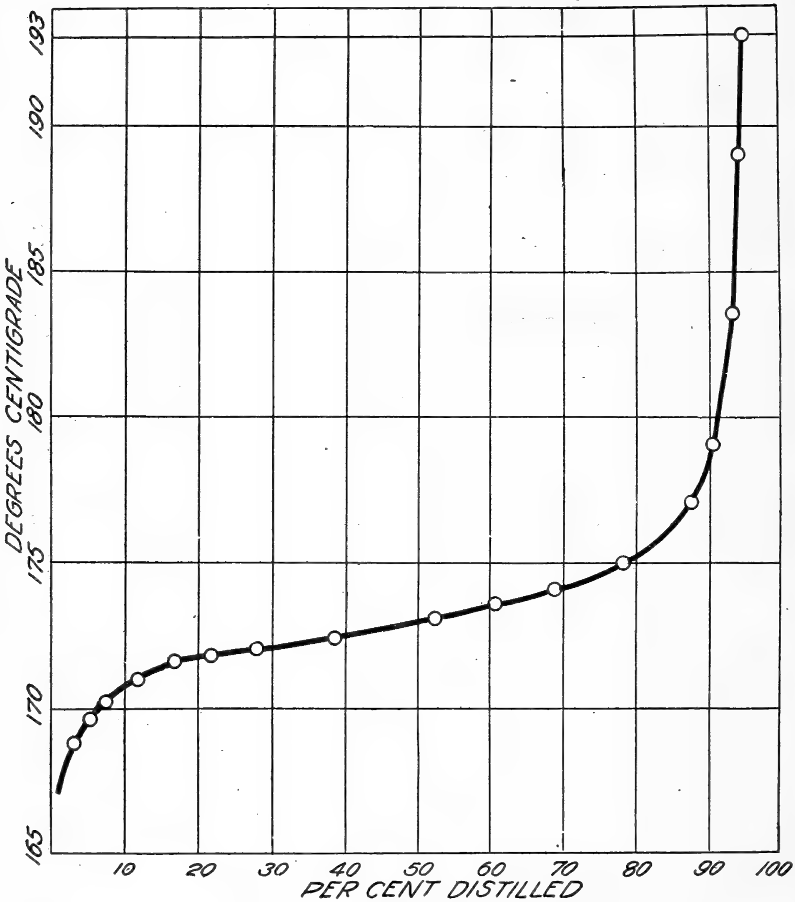

FIG. 6.—Boiling point of distillate.

of a body distilling at a relatively low temperature, having also a much lower refractive index than the major portion of the distillate. This is probably alpha-pinene, which in a pure state has a boiling point of 155° C., a specific gravity of 0.858, and refractive index of 1.4660 at 20° C., whereas the corresponding values of beta-pinene are 162° C., 0.868, and 1.4734. Polarimetric readings on the first two fractions, up to 6 per cent total distillate, showed laevo-rotations, indicating that the pinene present is laevo-alpha-pinene. Subsequent fractions showed dextro-rotations, in a continually advancing degree.

The extra high density of the first distillate to come over is to be attributed to the presence of traces of water, held in solution by small quantities of methyl alcohol, known to occur in this portion of refined turpentine recovered from crude second turpentine, and also partly to the presence of the alpha-pinene. As the distillation pro-

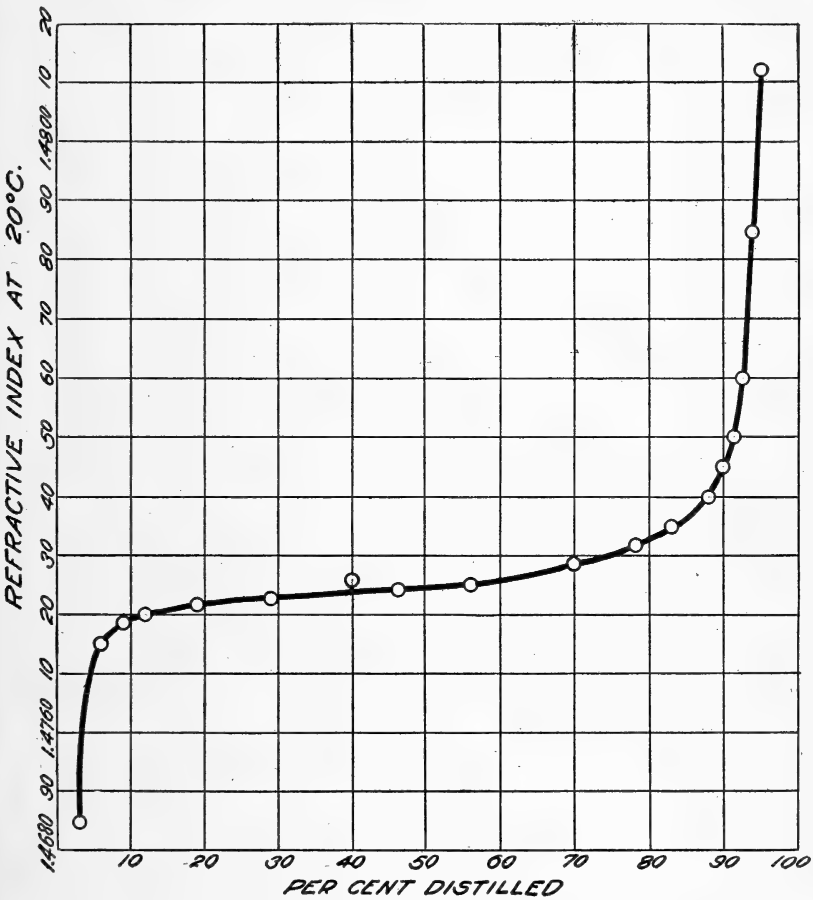

FIG. 7.—Refractive index of distillate.

gresses the specific gravity of the distillate slowly rises with the boiling point to where, at about 20 per cent of total distillate, the presence of a body having a specific gravity lower than that of the distillate immediately preceding it again asserts itself by a bending backward of the specific-gravity curve at this point. This may be due to the presence of one or more of several bodies, the most probable of which is limonene or dipentene (specific gravity 0.845, refractive index 1.4730, each at 20° C., boiling point 178° C.), dipentene being known to be a constitutent of wood turpentine. A materially higher temperature than the boiling point of betapinene at which, even from the beginning, the turpentine distils, points further to the presence of appreciable amounts of dipentene, the greater portion of the turpentine distilling at a temperature intermediate between that of beta-pinene and dipentene. Above 80 per cent of total distillate the

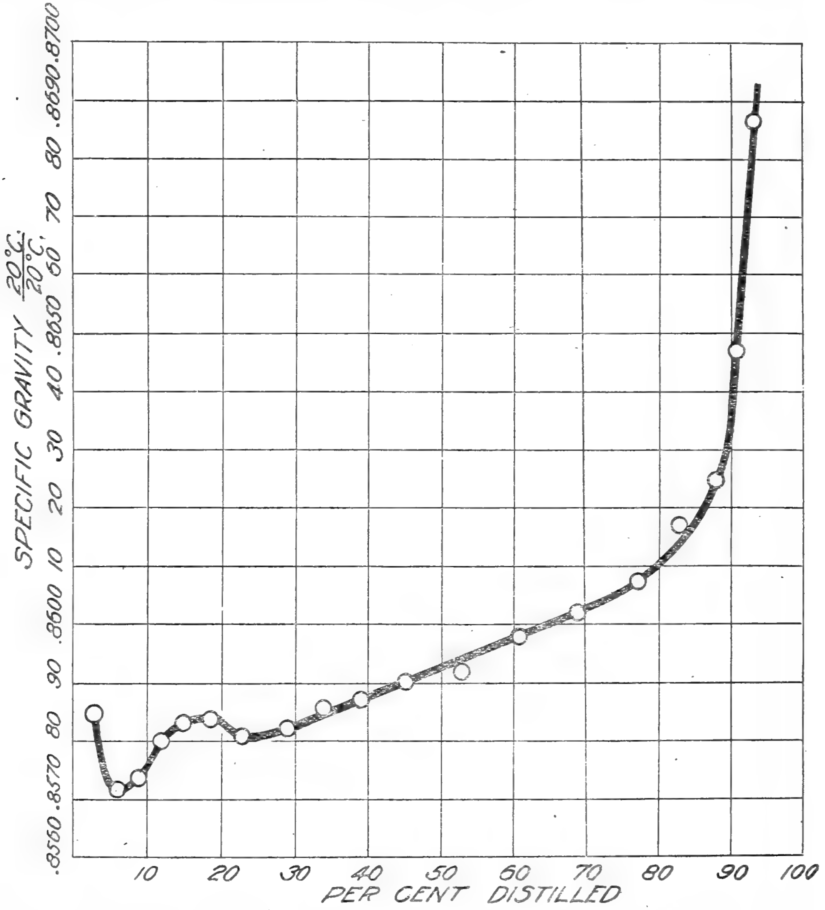

FIG. 8.—Specific gravity of distillate.

boiling point, specific gravity, and refractive index rise rapidly, showing that the composition of the distillate is undergoing a further marked change.

The principal constituents of turpentine, collectively spoken of as terpenes, are a closely-related series of organic compounds possessing such a close similarity in chemical and physical properties that precise knowledge concerning their quantitative estimation has not as yet been placed on a satisfactory basis. The problem is rendered more difficult because of the tendency exhibited by the terpenes as a class to pass readily from one form to another, and, in addition, to combine with oxygen and the elements of water, under conditions not well understood, to form a series of altogether more complex, oxygenated bodies possessing properties entirely different from those of the parent substance.

Hesitation is felt, therefore, in assigning numerical relations to or making an apportionment of the constituents that appear to enter into the composition of this turpentine further than to say that it seems to be largely made up of beta-pinene and dipentene, or its optically active modification, d-limonene, a small proportion, 5 per cent or less, of alpha-pinene containing perhaps some camphene, and about 15 or 20 per cent of relatively high-boiling terpene derivatives of unknown composition. The boiling-point and specific-gravity curves indicate that the proportion of dipentene, or limonene, probably exceeds that of beta-pinene.

To what extent ordinary turpentine possesses "drying" power, in the sense of being an oxygen carrier, is an open question in the chemistry of paints and varnishes, and the relative oxygen-transferring power of beta-pinene compared to that of alpha-pinene has not been determined. Kremers (5) found that limonene absorbs oxygen quite as rapidly as does pinene, from which it may be inferred that dipentene possesses this property to a like degree.

To what extent the relatively high distilling temperature of turpentine from western yellow pine will influence its value for use in paints, varnishes, etc., can be definitely determined only from actual use. The results obtained in comparative evaporation tests, at room temperature, of gum spirits and wood turpentine from the South, and wood turpentine from western yellow pine, secured in the course of this work, however, show that the product from the western yellow pine is materially slower in evaporating than either the gum or wood spirits from the South. Moreover, the film remaining from the evaporation of the western yellow-pine wood turpentine after drying twice as long as that from either of the others could not, properly speaking, be said to have become dry or resinified, compared with the films from the other samples. This fact is undoubtedly due to the high-boiling constituents, the approximately 20 per cent which distils above 175° C. If this material were not mixed with the turpentine where it does not belong, but were added to the pine oil which it actually is, the turpentine would dry much more rapidly and be more acceptable as a paint and varnish thinner. For some purposes, however, a slow-drying solvent is desired, in which case the presence of the high-boiling constituent is beneficial. The solvent power of this turpentine appears to be equal to that of turpentine from ordinary sources, and it is quite as light in color. Its odor, while different from that of gum spirits, is in no way objectionable, the main point of distinction in this respect being the pine wood odor so characteristic of the better quality of wood turpentine generally.

While not suitable perhaps for all the technical uses to which ordinary turpentine is adapted, this turpentine will answer for most such purposes and it should find a ready market if properly introduced to the trade.

APPLICATION OF METHOD TO THE COMMERCIAL PLANT.

The method of refining crude turpentine just described is readily adaptable to the commercial plant. Two procedures may be followed, according to the size of the plant and the available capital for investment. The simplest and cheapest equipment for refining the crude wood turpentine is a single copper refining still, so fitted with a water-cooled return-flow condenser and a short fractionating column and condenser, of any efficient type, that either one may be used singly. After suspended and undissolved tarry matter has had an opportunity to settle out, the crude turpentine is drawn into the still, where it is mixed with the proper quantity of caustic soda solution and boiled for the prescribed length of time, with the return-flow condenser open and the fractionating column shut off from the system. The heat for bringing the contents of the still to a boil can be obtained either directly from a furnace under the still or from closed steam coils inside the still at the bottom. The steam coils are the safer arrangement. An open steam coil, with a number of small openings along the length of the coil, is also placed inside the still with the closed coil. This open coil may be connected by a proper arrangement of piping and valves to both the boiler and a small air compressor, and used during the preliminary boiling to aerate the turpentine and alkali mixture.

At the end of the preliminary boiling period the fractionating column is opened, the return-flow condenser closed, and steam turned on in the open-coil system. The turpentine and pine oil are distilled off with the steam and collected in three fractions, as already outlined (p. 58). Toward the end of the distillation additional heat may be supplied by again turning high-pressure steam into the closed coil, to help drive over the last portions of pine oil. At the end of the distillation the alkali residuum is drawn off from the still. The same still may be used for the subsequent refractionation of the various fractions from the first distillation.

A more expensive arrangement, that probably is better adapted to a larger plant, consists of two separate stills, the first of which, for the preliminary boiling with alkali, is fitted with the return-flow condenser. At the end of the period of boiling the contents are drawn off into a second steam still with a short fractionating column. With this arrangement the operation can be conducted almost continuously. As soon as the charge, after preliminary boiling, is drawn into the steam-refining still, a new charge of crude turpentine can be drawn from the settling tanks into the first still.

In a large plant the final refractionation of the first steam-distilled fractions can very well be carried out in a small continuous fractionating still fitted with a short column.

The alkali residuum, which consists partly of pine and tar oil, with the sodium soaps of tar and resin acids, and an excess of alkali, has been shown by test to have germicidal properties approximately half as great as those of phenol. Its probable use as a local disinfectant, after partial neutralization of the free alkali with the waste acid liquor, is thereby suggested. Probably it can be used, after the addition of a small amount of coal-tar creosote, as the basis of a dip for hogs to rid them of lice. No actual experiments to determine the real value of this material have been made. It is impossible, therefore, to give concise directions for its use.

SUMMARY.

(1) In general, the stumps of western yellow pine are not as uniformly rich in resin as those of the longleaf yellow pine in the South Atlantic and Gulf States.

(2) The only wastes from western yellow-pine logging suitable for profitable distillation on a commercial scale are those resinous stumps which contain at least 50 per cent or more of resinous heartwood, and the resinous heartwood of stumps, dead, down wood, and limbs from which the sapwood has rotted away.

(3) It is impossible to classify western stumps into such grades as "rich" or "pitchy," "medium," and "poor" merely by a superficial examination of the quantity of resinous exudation on the face of the stump.

(4) "Rich" stumps, containing not less than 60 per cent of very resinous heartwood, probably can be profitably distilled in a commercial plant where the stand of such stumps is dense enough to keep a plant supplied for a number of years.

(5) Owing to the fact that there is a well-developed market in the West for crude pine-wood oils for use in the flotation concentration of ores, and also to the small volume of "rich" wood obtainable within hauling distance, it is probable that single retort plants, which can be dismantled and moved when necessary, are the most suitable for wood distillation in that section of the country, espe-

cially in regions remote from the railroad. Such plants might be owned and operated jointly by a number of settlers.

(6) "Medium" grade stumps, though much more plentiful than "rich" stumps, could be used in a commercial plant only at a cost, delivered, materially less than the calculated cost per cord of such wood, $8.37, and at prices for products not materially less than those given in this bulletin.

(7) The refined turpentine from western yellow-pine stumpwood, consisting mostly of beta-pinene and limonene, has higher boiling-point limits than similar turpentine from southern yellow pine, and dries much more slowly. For this reason paints and varnishes thinned with the turpentine take longer to dry than the same paints and varnishes thinned with turpentine made from the longleaf yellow pine of the South.

(8) The solvent power of this turpentine is not less than that of wood turpentine from longleaf yellow pine made and refined by the same process. It is suitable for many if not all of the purposes for which wood turpentine can be employed.

(9) The refined pine oil and the crude oils obtained by distilling western yellow pine are valuable for ore recovery by the flotation process. This is probably the most profitable use to which these products can be put.

(10) The crude light and heavy oils have germicidal properties approximately half as great as those of phenol, for which reason they are useful for shingle stains, wood preservatives, vermin killers, and disinfectants.

(11) The pyroligneous acid or "acid liquor" contains approximately one-fourth the amount of acetic acid, methyl alcohol, and acetone ordinarily recovered from hardwood acid liquor, and is heavily charged with dissolved tarry matter, resembling in all respects the pyroligneous acid obtained in distilling southern yellow-pine wood. At the usual prices, the recovery of these materials at a profit is hardly possible by present methods.

(12) A simple method for the commercial refining of crude wood turpentine, which yields a superior product, has been devised.

The figures given in this bulletin are based on those which prevailed in 1914 and 1915. Prices have increased materially since that time and estimated profits may be more or less. Material changes in the ratio of total cost of production to selling value of products will increase the calculated profits from wood distillation if the value of products has risen faster than cost of materials and of production. Calculated profits will be decreased if the materials and cost of production have increased more than the value of the products of distillation. In order to estimate at any given time the probable profits from distilling western yellow-pine wood, costs and values must be calculated on the basis of the cost of labor, wood, equipment, overhead, etc., and on the basis of the value of the products, at the time the estimate is made.

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