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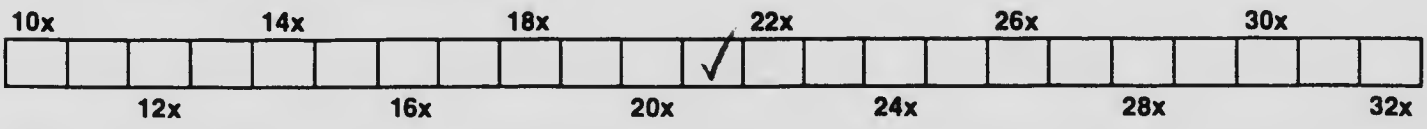

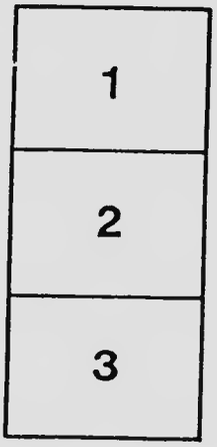

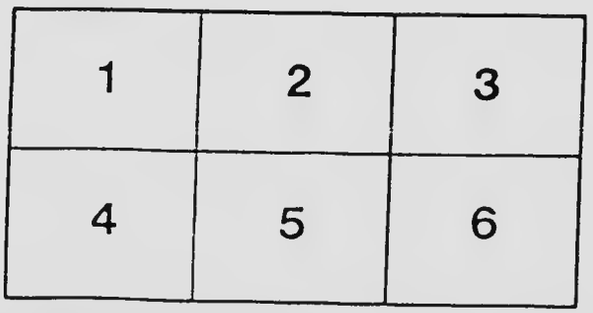

CANADIAN WOOD OILS FOR ORE FLOTATION

BY

R. E. GILMORE

Forest Products Laboratories of Canada,
Forestry Branch, Montreal

AND

C. S. PARSONS

Division of Ore Dressing and Metallurgy,
Mines Branch, Ottawa

A paper presented to the Canadian Mining Institute, October, 1917, and published with the permission of the Director of Forestry and the Director, Mines Branch.

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CANADIAN WOOD OILS FOR ORE FLOTATION[1]

By R. E. Gilmore and C. S. Parsons[2]

In August, 1916 the Canadian Government at the request of the Cobalt mining interests began active work on an investigation of Canadian wood oils for ore flotation.

The success of the process for the concentration of the low grade silver ores had already been demonstrated. On account of the difficulty which the flotation plants, (the number of which was rapidly growing) experienced in obtaining an adequate supply of imported pine oil, it was decided to investigate the possibilities of either finding a substitute for pine oil, which was found necessary as a selective frothing oil, or of producing a satisfactory grade of pine oil in sufficient quantities from Canadian resinous wood waste.

The collecting of the wood oils was carefully planned and speedily carried out by the Forest Products Laboratories, Montreal, where physical and chemical examinations were made. The flotation tests were made by the Division of Ore Dressing and Metallurgy, Mines Branch, Ottawa.

Part 1.

The Collection and Examination of the Wood Oils.

Experience has shown that the flotation value of an oil or oil mixture for a given ore, and especially the silver ores of the Cobalt area, cannot as yet be forecasted. Hence it was necessary to collect all available wood oils, both resinous and hardwood, of which the price seemed to be reasonable; and in the collecting

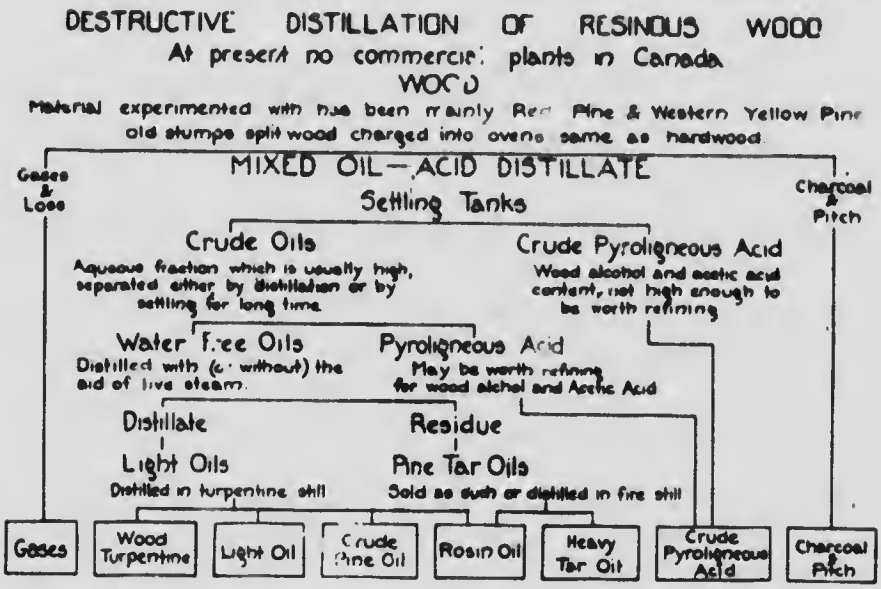
[1] A paper entitled "Flotation Experiments with Canadian Wood Oils" was presented at the March meeting of the Canadian Mining Institute in Montreal. This paper, which was given primarily as an introduction of the results to date to the mining companies interested and which dealt mainly with the flotation experiments from the Mines Branch viewpoint, will be published in Vol. XX of the Transactions of the Canadian Mining Institute.

[2] R. E. Gilmore, Forest Products Laboratories of Canada, Forestry Branch Montreal.
C. S. Parsons, Ore Dressing Division, Mines Branch, Ottawa.

of these oils special care was taken to learn their origin and to make sure, as far as possible, that these oils could be duplicated commercially.

With the permission of the Standard Chemical Iron and Lumber Company of Canada, Limited, the accompanying flow-

Flow Sheet No. 1.—Hardwood Destructive Distillation Process.



Flow Sheet No. 2.—Resinous Wood Destructive Distillation Process.

sheet (No. 1) outlines the origin of the hardwood oil samples collected from their Longford, (Ontario) plant.

As yet there is no commercial source of resinous wood oils in Canada. The purest grade of pine oil is derived by the steam and solvent process, and a less pure grade by destructive distillation, from the longleaf southern pine of the Southern States. As it is very doubtful that any process other than destructive distillation will prove successful for Canadian resinous wood waste a flow sheet (No. 2) of the destructive distillation process only is given here. Resinous wood oil samples collected and tested for flotation value include crude oil distillate and its fractions, from experimental runs made on red pine stumps at the Buffalo Mines, Cobalt, Ontario, and crude oil distillate including crude turps, crude light oil and pine tar oil from experimental distillation runs, by the Pritchard heat control process, on British Columbia western yellow pine stumps at Wilmington, North Carolina.

In addition to a knowledge of the origin of an individual oil, a fractional distillation and determination of physical properties of the fractions in detail were considered ample in order to describe the oil and to be able to obtain a duplicate sample when desired. In the following standard method adopted for the exam-

ination of the oils by fractional distillation the description of an oil by curves was employed. A few of the more successful oils are illustrated in Figures 1, 2, 3 and 4.

Details of this standard fractional distillation method are as follows:

Distillation Flask Used:—Ordinary half litre Engler distillation flask made of Pyrex glass.

Fractionating Column:—Two inches of standard glass ring beads supported in platinum or aluminum wire basket resting on hollow glass tubing; the upper end of the glass tubing is bent in the loop and fits the lower end of the stem of the flask, while the lower end rests on the bottom of the distillation flask itself. This glass tubing support with the upper loop end drawn out and sealed and the lower end left open also helps to prevent bumping, by causing a steady stream of fine bubbles of the expanding air within the tube to escape from the contact point at the lower end as the temperature rises.

Condenser:—A short Liebeg water condenser held in position at an angle of about 45 degrees and fitted so that for a high boiling oil the water could be run out from the jacket and a stream of air passed through either by pressure or suction.

Source of Heat:—An electric oven was constructed for the purpose in which the distilling flask was set, leaving only the neck of the flask with its fractionating column of beads exposed. The rate of distillation, which it is important to keep uniform, is controlled by varying the electric current for different oils. Thus the heat increases with the current in the heat equation. Heat = Constant × RC^2T, where R = resistance in ohms, C = current in amperes and T = time in seconds.

Thermometer:—A 360-degree mercury thermometer was inserted so that the top of the mercury bulb was level with the top of the delivery tube opening. The standard correction for emergent stem was added, viz.: $N(t-t^1)\,0.000143$, where N = number of degrees on the part of the mercury column outside the bath, t = temperature read and t^1 = the average temperature of the air surrounding the emergent part of the stem.

Rate of Distillation:—The average rate of distillation was 2.0 to 2.2 grams per minute, running between 90 and 120 drops in the same time, depending on the density of the distillate.

Amount of Sample Used and Fractional Cuts:—350 grams was the usual sample taken and 10% fractions (about 35 grams) were separated, the temperature and time at each cut being noted. Each fraction was collected in a small cylinder stand ¾ inches in diameter and 5 inches high, suitable for taking specific gravity readings.

Specific Gravity and Refractive Index Readings:—Specific gravity readings were taken with a Westphal balance and at room temperature, while the refractive index readings were observed by an Abb refractometer, also at room temperature. All readings were corrected to 15°C; in the case of specific gravity 0.0008 was added to the observed reading for every degree above 15°C, and, in the case of refractive index, 0.000365 was added to the observed reading for every degree above 15°C.

It is evident that in order to check one distillation with another on the same sample a uniform rate of distillation is all important, and a uniform rate of distillation is directly dependent on a uniform rate of heating. Although the best checks were obtained when using an electric oven, remarkably close checks were obtainable with the distilling flask set in a sand bath over a gas flame, which flame could be regulated by a screw pinch cock. This is true and adaptable for oils with boiling point range (say) below 250°C. For higher boiling oils, especially tar oils, a free flame is necessary, but a fractionating column of beads is inadvisable. When using a gas flame, an asbestos box or better an asbestos cloth cover fitted over and around the distillation flask served to give better heat control and resembled more closely the conditions when the electric oven was used.

Although not necessary when a uniform rate of heating is supplied, it was found even for the crude hardwood creosote oils that a fractionating column of beads aided in giving a more uniform rate of distillation; the curves of distillations where beads were used showed more pronounced deflection points and gave much better checks than when no beads were employed.

Determination of Water Content of an Oil Sample:—Where the moisture content of an oil is less than 10% and where only a small fraction of the oil distils below say 150°C, the aqueous fraction will be practically all in the first fractional cut and if collected in a small graduated cylinder can be read off directly. When an oil sample has a high aqueous content it is best first to run a preliminary distillation up to say 200°C and then after noting and separating the water layer return the oil content to the cooled distilling flask and begin again. A few pieces of broken porous porcelain or pumice stone and a small amount of paraffin wax put into the flask with the oil, generally aid greatly in preventing superheating, bumping and excessive frothing when distilling an oil sample containing more or less water.

Oils for Flotation Tests:—1st. Among the first series of oils tested were the original crude oils as collected. These are represented by serial numbers.

2nd. A sample of the total distillate, being the combined fractions from a distillation run, was in each case saved and tried out to see if the removal of free carbon and heavy pitch or coke residue from the oil improved its flotation value. These distillates are represented by an alphabetic letter after the number of oil from which it was derived.

3rd. Individual fractions and groups of fractions were saved for the purpose of determining just what part of a crude oil was of most flotation value.

4th. Preliminary chemical separations of the hardwood creosote oils into neutral and acidic (phenolic and creosotic) constituents were made and the respective flotation values of these two group separates tested.

A description of all the oils submitted for flotation tests is given in Table I. A more detailed description of each of these oils is available at the Forest Products Laboratories where also duplicate samples are in reserve.

TABLE 1.—DETAILS OF THE WOOD OILS COLLECTED AND EXAMINED

F.P.L.[1] No.	Description of Oil	Appearance	Sp. Gr. and Ref. Index at 15° C	Flotation action on Cobalt ores
1	*Pine Oil* G.N.S.[2] No. 5 (same as G.N.S. No. 55 from longleaf southern pine by the steam and solvent process. 95% by wt. distilled between 190° C and 220° C where sp. gr. was 0.890 to 0.946 and ref. index 1.473 to 1.488.	Clear, light amber	0.9330 1.4837	Excellent selective frother; poor collector
2	*Pine Oil* redistilled from G.N.S. No.'s 55 and 4. 100% distilled between 190° C and 220° C.	Clear, light amber	0.9310 1.4848	Same as above
3	*Pine Oil* G.N.S. No. 6 (same as G.N.S. No. 4) from longleaf southern pine by destructive distillation process. 67% distilled between 190° C and 220° C where sp. gr. range was 0.890 to 0.951. Only 90% distilled below 246° C.	Clear, amber	0.934 1.4995	Good selective frother; poor collector
4	*Crude Oil Distillate* P.T.T.[3] No. 350 from southern pine by destructive distillation. 50% by wt. only, distilled below 345° C. On primary distillation only 13% distilled between 190° C and 245° C where sp. gr. range was 0.897 to 0.965.	Black opaque	1.0190	Good frother but non-selective; poor collector
14	*Crude Oil Distillate* from red pine stumps. Yield of this oil is 13.9% by wt. of original wood or 36 Imp. gals. per 2,600 lb. cord. On secondary distillation only 5% of original oil distilled between gravities of 0.890 and 0.965; 28% of this oil is distillable with steam.	Black opaque	1.009	Good frother but non-selective; poor collector

[1] Forest Products Laboratories of Canada.
[2] General Naval Stores Company, New York.
[3] Pensacola Tar and Turpentine Co., Gull Point, Florida.

F.P.L. No.	Description of Oil	Appearance	Sp. Gr. and Ref. Index at 15° C	Flotation action on Cobalt ores
17	*Crude Turps* from western yellow pine stumps. Yield = 10.8 Imp. gals. per 2,600 lb. cord. Primary distillation gave over 60% distilling below 174° C with sp. gr. below 0.870.	Black, opaque	0.9070	Poor frother
18	*Crude Light Oil* from western yellow pine stumps. Yield = 2.4 Imp. gals. per 2,600 lb. cord. Primary distillation gave over 50% distilling below 190° C with sp. gr. below 0.88.	Black, opaque	0.9300	Good frother and fairly selective
19	*Crude Pine Tar Oil* from western yellow pine stumps. Yield = 38 Imp. gals. per 2,600 lb. cord. Less than 12% distilled below 246° C having gravity below 1.01. This oil yields 6.5% of crude pine oil suitable for flotation of Cobalt ore.	Black, opaque		Good frother but non-selective: poor collector
23	*Coal Tar* from the Dominion Tar and Chemical Co., Sault Ste. Marie, Ont.	Black, opaque		Excellent collector
24	*Coal Tar Creosote* from the same company as above. 80% by wt. distilled between 170° C and 325° C.	Black, opaque		Excellent collector
25	*Light Hardwood Creosote Oil* from top of separating tanks after crude pyroligneous acid copper stills and also after lime-lee stills. 35% by wt. distilled below 150° C having gravity below 0.885. Over 90% distilled below 255° C of which gravity was below 1.025.	Black, opaque	0.9550	Good frother and selective, fair collector
25A	*Light Hardwood Creosote* being 35% of No. 25. Distillation range 60°C—150°C Sp. Gr. " 0.880—0.882 Ref. Index " 1.407—1.458	Clear, light amber	0.8880 1.4288	Poor frother

F.P.L. No.	Description of Oil	Appearance	Sp. Gr. and Ref. Index at 15° C	Flotation action on Cobalt ores
25B	*Light Hardwood Creosote* being 57% of No. 25. Distillation range 150°C—255°C Sp. Gr. " 0.882—0.990 Ref. Index " 1.458—1.520	Clear, reddish amber	0.9750 1.5077	Good selective frother; good collector
26	*Heavy Hardwood Creosote Oil* from bottom of same separating tanks as above. Less than 24% including 8.5% aqueous distilled below 200° C. 62% distilled between 200° C and 260° C where sp. gr. range was 1.013 to 1.044.	Black, opaque	1.0375	Very good selective frother; good collector
26A	*Heavy Hardwood Creosote Distillate* being 82% of No. 26. Distillation range 60°C—260°C Sp. Gr. " 0.924—1.036 Ref. Index " 1.434—1.534 75% acidic, 23% neutral.	Reddish amber	1.0300 1.5115	Good selective frother and good collector
27	*Heavy Hardwood Creosote Oil* known as 'acid oil' coming from separating tanks after heavy oil and tar still. Less than 14% including 5.25% aqueous distilled below 200° C. 75.5% distilled between 200° C and 265° C where sp. gr. range was 1.0435 to 1.0675.	Black, opaque	1.0545	Very good selective frother; good collector
27A	*Heavy 'Acid Oil' Distillate* being 87.5% of No. 27. Distillation range 90°C—265°C Sp. Gr. " 1.023—1.063 Ref. Index " 1.479—1.530 90% acidic, 9% neutral.	Reddish amber	1.0430 1.5210	Same as No. 27.
28	*Heavy Yellow Ketone Oil* from the refining of acetone. Of the several ketone oils this sample is the heaviest of the series leaving ketone residue. Over 90% distilled below 120°C where sp. gr. range was 0.81 to 0.82 and ref. index 1.389 to 1.400.	Clear, amber	0.8275	Fair frother, selective action greatly increased by alkali (NaOH)

F.P.L. No.	Description of Oil	Appearance	Sp. Gr. and Ref. Index at 15° C	Flotation action on Cobalt ores
29	*Ketone Residue*, of thick syrupy nature being residue after the refining of acetone and various ketone oils. 70% is distillable below 300° C above which it is hard to proceed under ordinary conditions. Over 60% distilled between 210° C and 300° C where sp. gr. range was 0.91 to 1.014.	Black, opaque	1.0345	Good selective frother and fair collector
29A	*Ketone Residue Distillate* being 70% of No. 29. Distillation range 95° C—310° C Sp. Gr. " 0.910—1.020 Ref. Index " 1.470—1.590	Reddish brown, slightly opaque	0.943	Good frother and fairly selective
30	*Hardwood Tar* being residue left in tar stills after all available acid-alcohol liquor and creosote oils have been removed. Without the aid of a small amount of superheated steam it is difficult to distill more than 30% of this tar. 39% including 9% aqueous distilled below 300° C of which sp. gr. was below 1.132.	Black, opaque and quite viscous		Good frother, but non-selective
30A	*Hardwood Tar Distillate* being 30% of No. 30. Distillation range 90°C—235°C Sp. Gr. " 1.025—1.14 Ref. Index " 1.490—1.50 Roughly—50% acidic	Reddish brown, almost opaque	1.058 1.495	Good frother, poorly selective; and fair collector
31	*Hardwood Creosote Mixture* being mixture in proportion produced of No. 25—Light creosote oil No. 26—Heavy creosote oil and No. 27—Acid oil. See F.P.L. No. 31A.	Black, opaque	0.9985	Good selective frother and good collector
31A	*Hardwood Creosote Mixture Distillate* being 87% of No. 31. Distillation range 55°C—255°C Sp. Gr. " 0.882—1.022 Ref. Index " 1.416—1.524 Roughly—50% acidic, 50% neutral.	Clear, dark amber	0.989	Good frother and selective; fair collector

F.P.L. No.	Description of Oil	Appearance	Sp. Gr. and Ref. Index at 15° C	Flotation action on Cobalt ores
32	*Crude Light Oil* from red pine stumps being oils distilling below 235° C from F.P.L. No. 14 having sp. gr. below 0.995.	Dark amber	0.9293 1.4830	Poor frother in quantities used; poor collector
33	*Rosin and Tar Oil* from red pine stumps being oils distilling between 235° C and 345° C in primary distillation of F.P.L. No. 14 having sp. gr. range 0.995 to 1.017	Reddish amber	1.0150	Poor frother in quantities used.
34	*Turps and Light Oil* from secondary distillation of oil distillate from red pine stumps, being fraction of No. 32 distilling up to 75° C having gravity below 0.886 and refractive index 1.451 to 1.477.	Light amber	0.8900 1.4708	Poor frother in quantities used.
35	*Crude Pine Oil* from red pine stumps being fraction from distillation of No. 32, distilling between 175° C and 215° C (using beads as fractionating column) and having gravity range of 0.886 to 0.995 and Ref. Index range of 1.477 to 1.503. Yield = 4.3 Imp. gals. per 2,600 lb. cord.	Clear, light amber	0.9443 1.49??	Excellent frother and selective; fair collector
36	*Light Rosin Oil* from red pine stumps being fraction on No. 32 distilling between 216° C and 250° C having sp. gr. range 0.995 to 1.03 and ref. index 1.503 to 1.517.	Reddish amber		Good frother; poor selector
37	*Light Hardwood Creosote Oil* (G.N.S. No. 17). 50% of this oil distilled below 150° C with gravity range between 0.875 to 0.885. 90% distilled below 240° C with gravity below 1.002 leaving 10% hard pitch residue.	Black, opaque	0.9370	Good frother in quantities used; fair collector

F.P.L. No.	Description of Oil	Appearance	Sp. Gr. and Ref. Index at 15° C	Flotation action on Cobalt ores
37A	*Light Hardwood Creosote Oil* from primary distillation of No. 37. Distillation range 60°C—240°C Sp. Gr. " 0.87 —1.002 Ref. Index " 1.411—1.523	Clear, dark amber	0.9195 1.4665	Fair frother
38	*Heavy Hardwood Creosote Oil* (G.N. S. No. 18). 63% of this oil distilled below 240° C having gravity range 0.871 to 1.079 leaving 37% hard pitch residue.	Black, opaque	1.0620	Good frother; good selector; good collector
39	*Hardwood Oil Fraction 20% of No. 31* (hardwood creosote mixture). Distillation range 55°C—152° C Sp. Gr. " 0.880—0.890 Ref. Index " 1.410—1.440 28% acidic, 70% neutral.	Clear, light amber	0.8910 1.4297	Poor frother
40	*Hardwood Oil Fraction 18.5% of No. 31.* (Hardwood creosote mixture) Distillation range 152°C—202°C Sp. Gr. " 0.890—0.985 Ref. Index " 1.440—1.505 33.5% acidic; 66.5% neutral	Clear, light amber	0.9623 1.4883	Good frother; good selector; fair collector
41	*Hardwood Oil Fraction 19.5% of No. 31.* (Hardwood creosote mixture) Distillation range 202°C—220°C Sp. Gr. " 0.985—1.020 Ref. Index " 1.505—1.520 66% acidic; 34% neutral	Clear, amber	1.0142 1.5182	Good frother; good selector; fair collector
42	*Hardwood Oil Fraction 20% of No. 31.* (Hardwood creosote mixture) Distillation range 220°C—240°C Sp. Gr. " 1.020—1.025 Ref. Index " 1.520—1.525 69% acidic; 31% neutral.	Clear, dark amber	1.0230 1.5254	Good frother; good selector; fair collector

F.P.L. No.	Description of Oil	Appearance	Sp. Gr. and Ref. Index at 15° C	Flotation action on Cobalt ores
43	*Hardwood Oil Fraction 10% of No. 31.* (hardwood creosote mixture). Distillation range 240°C—255°C 50% acidic; 50% neutral.	Reddish amber	1.0143 1.5240	Good frother; fair selector
44	*Pine Oil* from western yellow pine (from crude turps No. 17) Distillation range 190°C—246°C Sp. Gr. " 0.880—0.9540 Ref. Index " 1.4820—1.508 Yield = 0.75 Imp. gals. per 2,600 lb. cord.	Clear, light amber	0.9320 1.4945	Good frother; comparing with No. 3
45	*Crude Pine Oil* from western yellow pine stumps obtained from crude light oil No. 18 and pine tar oil No. 19. Distillation range 190°C—245°C Sp. Gr. " 0.895—0.989 Yield = 0.35 and 2.6 Imp. gals. per 2,600 lb. cord from No. 18 and No. 19 respectively.	Dark amber	0.9480 1.4960	Same as above.
46	*Light Oils*—turps and light oil from western yellow pine stumps obtained from crude turps No. 17 and crude light oil No. 18.	White to amber	0.8735 1.4780	Very poor frother
47	*Neutral Oil — 50% of No. 31A* (hardwood creosote mixture) after extraction with dilute H_2SO_4 and NaOH.	Amber	0.9260 1.4900	Good frother; fairly selective

	% of No. 47	Dist. Range	Sp. Gr.	Ref; Index
47A	23.4	59°C—150°C	0.8805	1.4442
47B	25.4	150°C—200°C	0.9113	1.4805
47C	42.8	200°C—290°C	0.9585	1.5120

F.P.L. No.	Description of Oil	Appearance	Sp. Gr. and Ref. Index at 15° C	Flotation action on Cobalt ores
48	*Acidic Oil—50% of No. 31A* (hardwood creosote mixture—being portion extracted by dilute NaOH and then recovered by acidifying and distilling. Only about 1% distilled below 200°C. 36% dist. 200–215°C—sp. gr. 1.025 40% " 215–230°C— " " 1.050 23% " 230–255°C— " " 1.050	Dark amber	1.0425 1.5260	Good selective frother

F.P.L. No.	Description of Oil	Appearance	Sp. Gr. and Ref. Index at 15° C	Flotation action on Cobalt ores
48A	*Acidic Oil from No. 26A and No. 27A* (hardwood creosote oils) Distillation gave the following:— % by volume Corrected temperature: up to 200°C — 26A 10.0, 27A 7.5; 200°C—215°C — 26A 31.0, 27A 19.5; 215°C—230°C — 26A 31.0, 27A 37.5; 230°C—255°C — 26A 28.0, 27A 35.5	Dark amber		Same as above
49	*Neutral Hardwood Oil from No. 26A* (heavy hardwood creosote oil) and from 27A (heavy acid oil). 18% of this oil distilled below 200°C	Dark amber	0.9634 1.5090	Same as No. 48
50	*Crude Wood Oil*—a by-product from top of digesters of the alkaline sulphate process for manufacturing paper pulp from Jack pine, spruce, etc. The crude oil is of grease-like consistency while its distillate is a light oil. Both have a very disagreeable odor. Only 11.8% distilled below 250°C. 69.1% by wt. distilled between 250°C and 130°C wheresp. gr. range was 0.920 to 0.935 and ref. index 1.480 to 1.522.—Over 19% remained above 310°C as a hard pitch residue.	Dark, yellow, thick emulsion	0.9820	Unsatisfactory

Pine Oil as a Standard Frothing Oil.—The purest grade of pine oil available (namely G.N.S. No. 5) was chosen as the standard frothing oil in this investigation. In the standard oil mixture adopted the pine oil was 10%, the balance being 80% coal tar creosote and 10% coal tar.

Practically all the pine oil of commerce is obtained from the longleaf southern pine. In this connection a definition of pine oil is interesting. According to specifications as adopted by the United States Navy Department, pine oil must be a properly prepared light straw coloured oil, produced by redistillation of heavy boiling point fractions resulting from the steam distillation of wood turpentines; have a strong aromatic odor resembling turpentine: specific gravity not greater than 0.937 and not less than 0.933 at 60°F. One hundred cubic centimeters of the oil

when subjected to distillation in a standard Engler distilling flask must yield at least 95% of distillate between the temperatures 375°F and 475°F (190.5°C - 246°C).

It is also interesting to note the difference between pine oil produced by the steam and solvent process and pine oil produced by destructive distillation. A good grade of each of these oils is supplied by the General Naval Stores Company, New York, the oils being known as G.N.S. No. 5 and G.N.S. No. 6 respectively. 95% by weight of the pine oil from the steam and solvent process distilled between 190°C and 220°C where the specific gravity range was from 0.890 to 0.946 and the refractive index range from 1.473 to 1.4888, while 67.0% by weight of pine oil from the destructive distillation process distilled between 190°C and 220°C and only 87.0% between 190°C and 246°C where the specific gravity range was from 0.890 to 0.955 and the refractive index range from 1.485 to 1.530. (See Figure 1).

As will be noticed this sample of pine oil from the destructive distillation of southern pine does not conform with the U.S. Navy Department specifications, while pine oil from the steam and solvent process comes well within the above specifications. Judging from actual flotation results, for Cobalt area ore the use of steam distilled pine oil is to be recommended greatly in preference to the destructive distillation grades, and graded specifications approaching 95% distilling between 190°C and 220°C with the proper specific gravity range seem worthy of consideration in buying pine oil for flotation purposes. A pure pine oil is not always necessary for flotation purposes, but in using destructive distillation grades their value appears to be in direct proportion to the pine oil content as defined above.

Pine Oil from Canadian Resinous Woods:—In Canada, the most promising resinous wood materials are the red (Norway) pine stumps of Northern Ontario and the western yellow pine stumps of British Columbia. The old stumps, after the tree has been felled from 10 to 20 years, in many cases have sound hearts rich in oleoresin. Although the resin content is high, the yield of wood turpentine is only fair and the proportion of true oil is small compared with the standard species—the longleaf southern pine. In the Southern States the yield of pure pine oil is 2 to 3.5 U.S. gallons per cord of about 4000 lb. from the best grades

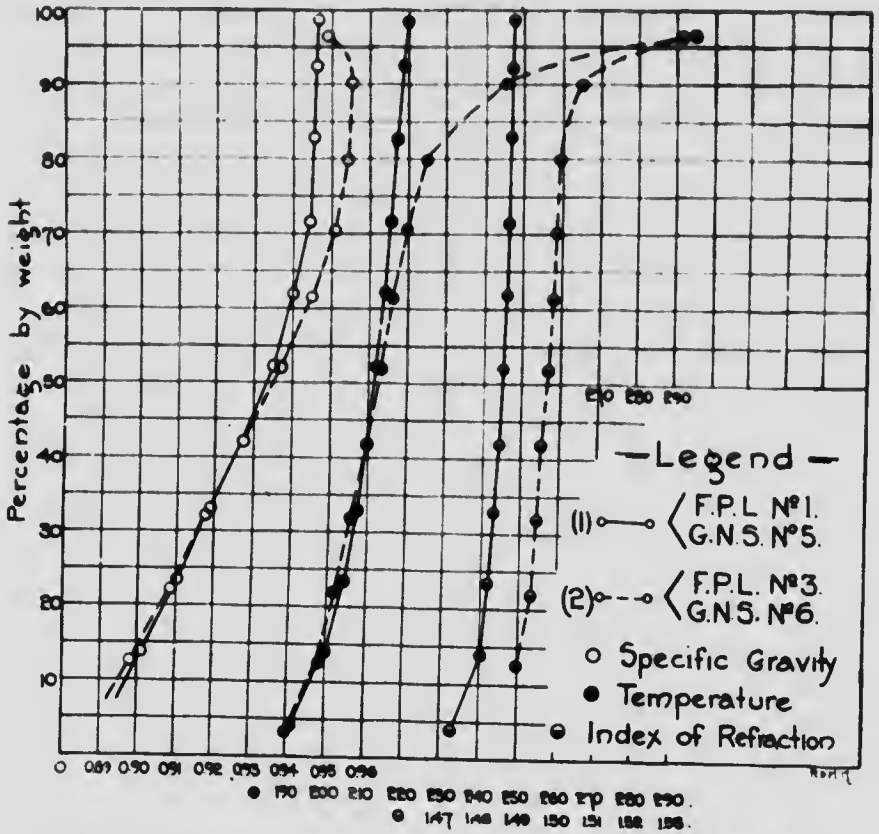


Fig. 1.—Curves showing records of fractional distillation of two different samples of pine oil by steam and solvent process, F.P.L. No. 1 (G.N.S. No. 5); and (2) pine oil by destructive distillation F.P.L. No. 3 (G.N.S. No. 6).

of resinous wood waste. From the above Canadian woods the crude pine oil fraction, containing more or less light oil distilling between turpentine and pine oil proper, amounts to about 4 Imperial gallons per 2600-lb. cord, but only a small proportion of this can be considered as true pine oil. By using two or three times the usual quantity of the sample, fairly satisfactory flotation results were obtained. All attempts to utilize the whole crude oil distillate or its turpentine or resin oil content met with failure in this investigation. As pine oil is essentially a by-product of turpentine and resin recovery from resinous wood waste, and as this recovery industry has not yet shown prospect of profitable establishment in Canada, there is little promise of obtaining a commercial supply of frothing oil from Canadian resinous wood

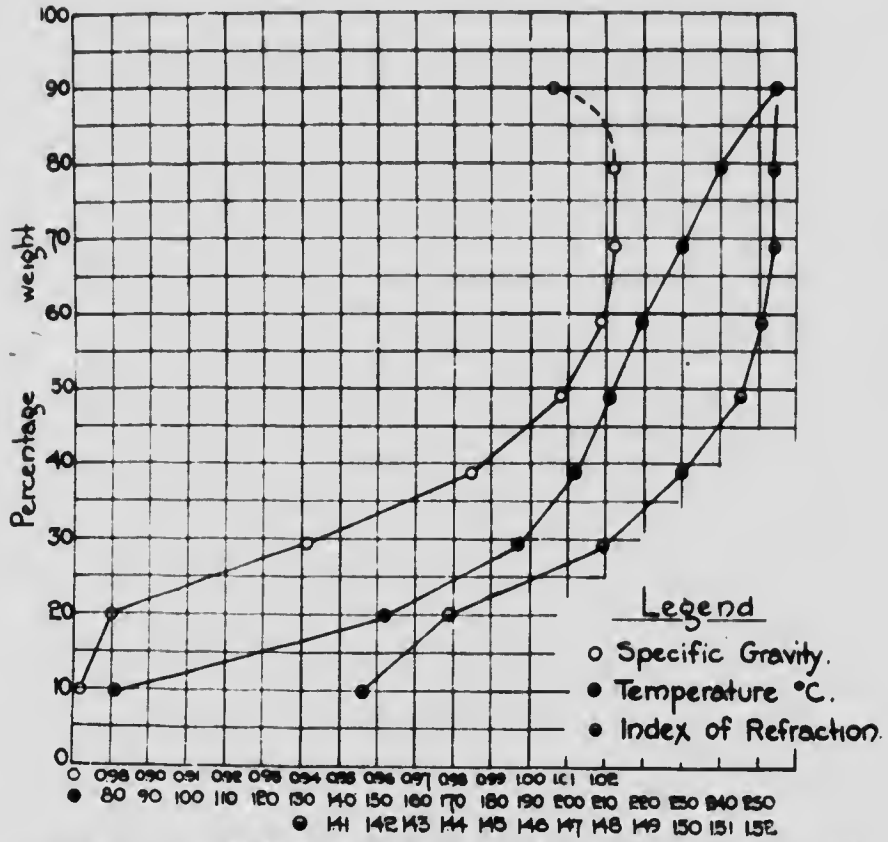


Fig. 2.—Curves showing distillation record of F.P.L. No. 31 (crude hardwood creosote mixture) of which all its fraction except 1 and 2 (i.e. below 20% by weight) gave satisfactory results as a frothing oil in place of pine oil on ore from Cobalt area.

waste suitable for use in the flotation of the ores of the Cobalt area. In this connection the recent statement[1] of Professor H. K. Benson of the University of Washington, who has investigated wood waste industries for the United States Government, is significant, viz.: "The commercial status of the softwood distillation industry is unsatisfactory in the Pacific States, in the Michigan and in the Wisconsin districts." However, considerable commercial progress has recently been made in the Southern States on richer material after a series of failures, and it is to be hoped that technical investigation will in time place the whole resinous wood industry on a sound commercial basis.

[1] U.S. Dept. of Commerce, Bureau of Foreign and Domestic Commerce, Special Agents Series No. 110, "By-products of the Lumber Industry."

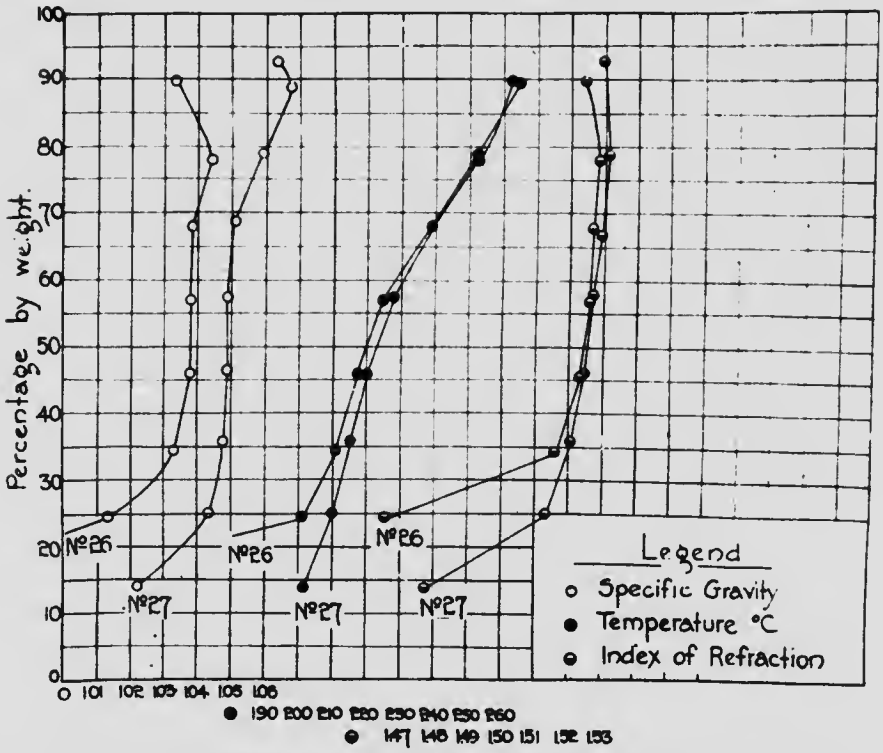


Fig. 3.—Curves showing distillation of crude oils F.P.L. Nos. 26 and 27, heavy hardwood creosote and hardwood 'acid oil' respectively.

Hardwood Oils as Substitutes for Pine Oil.—In the flow sheet (No. 1) for destructive distillation of hardwoods, the creosote oils have been fully outlined as to their source. These hardwood creosote oils, for which there is at present little market value, can be drawn off separately as crude oils in the process of refining the wood alcohol and acetic acid.

The combined production of these three oils, namely F.P.L. Nos. 25, 26, and 27 (combined as oil No. 31), is approximately 2.4 Imperial gallons per 3700-lb. cord and indications are that all three can be used as frothing oils in place of pine oil.

While this yield per cord is about the same as for pine oil from longleaf southern pine, the supply is comparatively large, at present there being over 500 cords of hardwood distilled daily in Canada, and over ten times this amount in the United States, mostly in the border states.

Of the individual hardwood creosote oils heavy hardwood creosote oil No. 26 appeared to give the best laboratory results,

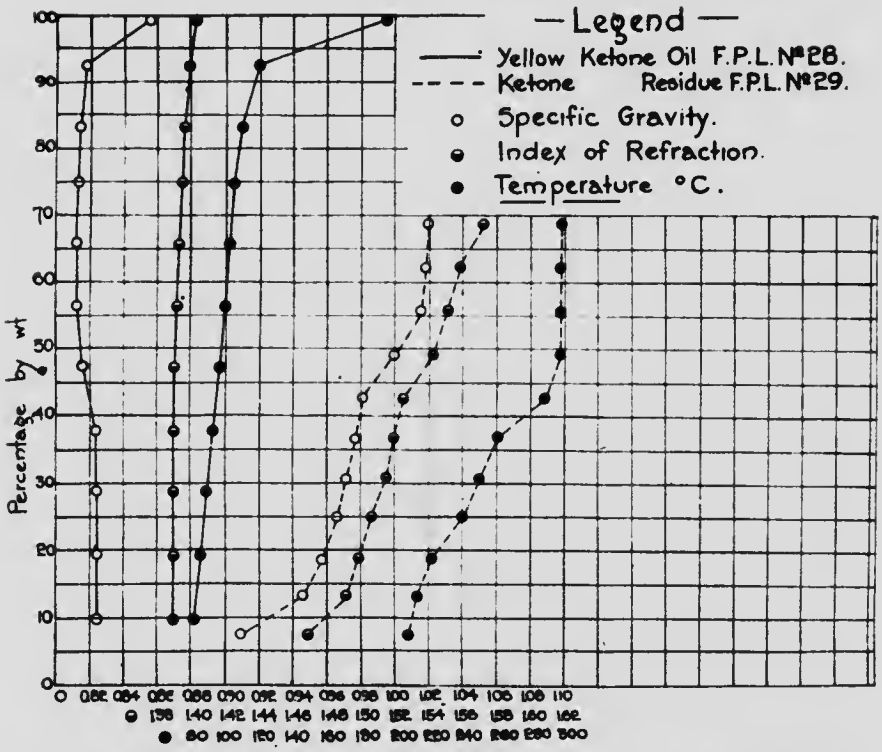


Fig. 4.—Curve showing distillation records of yellow ketone oil F.P.L. No. 28, and crude ketone residue F.P.L. No. 29, both produced in the hardwood distillation refinery.

with acid oil No. 27 nearly as good. Light hardwood creosote oil No. 25, with its lighter fraction boiling below 150°C having gravity below 0.882 removed, gave results comparing favourably with Nos. 26 and 27. This lighter fraction has a disagreeable and penetrating odor and its removal would no doubt make both oils Nos. 25 and 31 (the former oil comprising over 50% of the latter) more agreeable to work with. (See Figures 2 and 3).

Other hardwood oils worthy of mention are heavy yellow ketone oil and ketone residue, by-products of the manufacture of acetone from grey acetate of lime. While the yellow ketone oil is already of considerable value in the industries, its value as a flotation frothing oil is important especially in an alkaline pulp where it gives a high-grade concentrate. Ketone residue, which is black and syrupy in nature, is produced in fairly large quantities and has noticeable collector values, as well as being a good frothing agent. This oil deserves more attention, not only

for use in the treatment of Cobalt area ores, but for use by itself on other ores. (See Figure 4).

PART 2.

FLOTATION TESTS ON SILVER ORE FROM COBALT AREA

In all 185 different tests were made, a summary of which is given in Table No. 2. The slime from the Coniagas Mill, Cobalt, Ontario, chosen as a representative product of the area, was used in these tests. This slime carried 5.7 oz. of silver per ton, and 62% of the silver was contained in the 200-mesh product. 500 grams of slime, ground to pass 100-mesh, were used in each test. A pulp of one part of water to one of slime along with the carefully measured quantity of oil was ground in a pebble mill for 20 minutes, after which the ground pulp was agitated in the Janney experimental flotation machine for 6 minutes. The temperature during each test varied between 5°C and 15°C.

The Janney testing machine used throughout this experimental work consists of a cylindrical agitation chamber fitted with baffles and a spitzkasten or settling chamber in which the froth collects. The agitation is obtained by an impeller running at 1800 revolutions per minute. A complete description of this machine can be found in the January 1st, 1916, number of the *Mining and Scientific Press.*

It has been recognized, especially for the silver-bearing ore of the Cobalt area, that both a frothing oil and a collecting oil (or oils) were necessary. The oil mixture[1] already giving successful commercial results at Cobalt was as follows:

10% pine oil (pure) as selective frothing oil.
80% coal tar creosote } as selective collecting oils.
10% coal tar }

[1] According to information lately received the majority of the mills have increased the percentage of pine oil to 20% of the total mentioned and are obtaining much better results.

Using this as standard oil mixture No. 1 the procedure was as follows:

1. The substitution for pine oil in this standard oil mixture was tried to a certain frothing value of any new oil. If 10% was not satisfactory the percentage was raised. This constituted the first series of tests on each of the several and different oil samples.

2. Substitutes for coal tar creosote and coal tar in standard oil mixture was tried to ascertain collecting value of any promising oil.

3. Successful frothing substitutes and successful collector substitutes were tried together to ascertain if it was possible to obtain an oil mixture from among the wood oils having both frothing and collecting properties.

The Results.—The aim throughout these experiments was to produce comparative results only, using pine oil and coal tar products as frother and collector respectively as a standard oil mixture. In this connection the reader must recall that no special effort was made to produce high-grade concentrates or to obtain high extractions. A rougher tailing and a rougher concentrate only were produced. Commercial tests on the more promising hardwood oils have already been made, the results of which are presented in Part 3 of this paper.

The results of individual tests varied a great deal, and extractions as high as 80% were averaged with tests giving as low as 60% extraction. To the mining man the efficiency of an oil or oil mixture will be more apparent by comparing the amount of froth floated off and the minimum assay of the tailings.

The more striking features of the results summarized in the table (See pages 29 to 37) are as follows:

1. 67.5% was the average extraction of 20 different tests using pure pine oil (G.N.S. No. 5), where the tails averaged 1.90 oz. from 5.7 oz. heads.

2. Tails as low as 1.14 oz. were obtained by the use of 4 lb. of NaOH per ton of dry ore under the same conditions as above.

3. Pine oil (G.N.S. No. 6) by destructive distillation gave satisfactory results on raising its percentage to 15%–20% of the total oil mixture with over 12% of the coal tar present.

4. The crude oil distillate from the destructive distillation of both western yellow pine and red pine stumps used alone was quite unsatisfactory giving 4.00 oz. tails.

5. Crude turps No. 17 from western yellow pine and a corresponding light oil No. 32 from red pine both had too brittle a froth and left 2.7 oz. tails.

6. Pine tar oil No. 19 from western yellow pine and corresponding oils Nos. 33 and 36 from red pine could not be utilized as frothing oils since they lifted too much gangue.

7. Crude pine oils Nos. 44 and 45 from western yellow pine stumps and No. 35 from red pine stumps gave satisfactory results when they comprised 20%–25% of the total oil mixture. Crude light oil No. 18 from western yellow pine gave comparable results.

8. Results using the three different hardwood creosote oils, namely Nos. 25, 26 and 27 are good. Extractions from 65% to 75% were obtained with tails as low as 1.59 oz. Of the three heavy oils heavy hardwood creosote No. 26 gave the best all-round results. Each of the individual creosote oils gave better results than No. 31, the combination of all three.

9. Oils Nos. 25A and 39 are very similar and deserve attention. They are the hardwood oil fractions distilling below 150°C and having gravity below 0.89. This fraction has a disagreeable penetrating odor and its removal greatly improves oils Nos. 25 and 31 in this respect. The flotation value of this lighter and low boiling point fraction is low, giving 3.9 oz. tails.

10 In general the hardwood creosote oils gave better results in the crude state than when refined by primary distillation.

11. Of the oils Nos. 39 to 43 inclusive, which are fractions distilled from No. 31 (hardwood creosote mixture), all except the lowest boiling fraction No. 39 just mentioned gave approximately the same results.

12. Of the neutral hardwood oil No. 47 (see description) the fraction No. 47C distilling above 200°C gave good standard

results, while the fractions Nos. 47A and 47B distilling below 200°C were non-selective, as shown by 3.0 oz. tailings.

13. Oils No. 48 and 48A being the phenolic and creosotetic content of the crude hardwood oils and practically all distilling above 200°C, gave approximately the same satisfactory results as neutral oil No. 47C having the same boiling point range.

14. Yellow ketone oil No. 28 used alone gave very poor results, but the greatly improved results obtained in a pulp alkaline with NaOH were remarkable, where the extraction averaged nearly 80%.

15. Ketone residue No. 29 which is neutral in character, when used to the extent of 20%–30% of the total oil mixture, gave results comparing favourably with both destructively distilled pine oil and the hardwood creosote oils.

16. Increasing the percentage of coal tar up to 25%–30% of the total mixture invariably gave improved results.

17. By the use of crude hardwood creosote oils the proportion of coal tar creosote could be reduced to 60% of the total oil mixture and still give satisfactory results, but all attempts to eliminate coal tar creosote as the selective collecting oil proved unsatisfactory.

18. Best results were obtained with a cold pulp and at the beginning of the series of tests. The Janney flotation machine gradually decreased in efficiency under continual operation for over five months. This fact is all the more reason for considering the above results as comparative only.

Conclusions.—1. Laboratory results show that crude hardwood creosote oils can be substituted satisfactorily for pine oil as a suitable frothing agent for Cobalt area silver ore.

2. Crude ketone residue from the refining of grey acetate of lime is also a satisfactory frothing oil for use with this ore; heavy yellow ketone oil gives highly satisfactory results when used in a pulp alkaline with caustic soda.

3 [illegible] of NaOH (not more than 4 lb. per ton of dry

ore) gave an almost incredible improvement in extraction and grade of concentrate in all oil mixtures tried.

4. Pine oil from the destructive distillation of Canadian resinous wood waste (western yellow pine and red pine stumps) gave results comparing fairly well with pine oil from longleaf southern pine. Double the quantity, however, of the Canadian product was required.

5. All attempts to utilize the whole crude oil distillates from the destructive distillation of Canadian resinous woods met with failure, as they were non-selective in action. This was also found true of the turpentine and rosin oil fractions of the crude oil.

6. The use of coal tar creosote was found indispensable as a selective collecting oil and all attempts to substitute hardwood tar were unsuccessful. By the use of hardwood oils, however, the proportion of coal tar creosote could be reduced considerably.

PART 3. COMMERCIAL FLOTATION TESTS ON HARDWOOD OILS[1]

According to the original plan the most promising wood oils were tested at Cobalt under commercial conditions. Three hardwood oils were given a thorough trial at the Buffalo Mines in comparison with a standard pure pine oil (G.N.S. No. 5). They are as follows:—

F.P.L. No. 26. Heavy hardwood creosote oil.
F.P.L. No. 27. Acid (creosote) oil.
F.P.L. No. 29. Ketone residue.

These oils, which have been fully described in Table No. 1 and Figures Nos. 3 and 4, are quite uniform in the crude state as produced and can be considered standard flotation oils.

Removal of the Aqueous Fraction Advisable.—Samples of the three oils mentioned above when examined at the Forest Products

[1] The hardwood oils used in these commercial tests were supplied from the Longford, (Ontario), plant of the Standard Chemical, Iron and Lumber Company of Canada, Limited (head office, Royal Bank Building, Toronto, Ont.)

Laboratories showed 8.55%, 5.25% and 2.55% water content respectively. The aqueous fractions of the first two oils were distinctly acid in nature and strong enough to have corroding action on ordinary iron metal containers. The water content of the ketone residue was natural. Although these hardwood oils can be used with the small percentage of water present mostly as an emulsion, the removal of the aqueous fraction seems strongly advisable, not only on account of the above objections but by reason of the fact that the acetic acid and its homologues forming the acid content are essentially of no flotation value.

The higher aqueous content of heavy hardwood creosote oil No. 26 compared with acid oil No. 27 is due to its lighter specific gravity. As has been suggested the mixing of these two oils in the proportions in which they are produced commercially would be advisable, since their flotation values are equally satisfactory. In this way a better gravity separation of the water content could be effected than would be possible with oil No. 26 alone.

The yields of these two oils Nos. 26 and 27 as already given are respectively 0.486 and 0.284 Imperial gallons per cord. Figuring on 500 cords of hardwood distilled per day, this means that 385 Imperial gallons of this Canadian wood oil product are available. For about 2000 tons of silver ore treated daily at present, only slightly more than 25% of this oil supply can be consumed in the Cobalt area. Should the demand for these hardwood creosote oils become greater than the supply, it is interesting to note that oil No. 25B according to laboratory results is equally satisfactory. As yet hardwood creosote oil mixture No. 31, comprised of oils Nos. 25, 26 and 27 in proportion produced, has not been tried commercially at Cobalt. Although small scale laboratory experiments on this creosote oil mixture in the crude state show good comparative results, indications are that after the removal of that fraction distilling below 150°C with gravity below 0.89 the mixed residue corresponding to oils Nos. 25B, 26 and 27 would give excellent results with Cobalt area ore. Treating oil No. 31 in this way by a preliminary distillation would also remove all the aqueous content and give a very desirable water-free flotation oil. The commercial supply of this crude hardwood

creosote mixture after such treatment would be over 500 Imperial gallons per day in Canada.

Proposed Specifications for Hardwood Creosote Oils.—Oils Nos. 26 and 27 with 17.5% and 10% respectively distilling below 150°C including 8.55% and 5.25% aqueous content have been found to give satisfactory flotation results when used in the crude state. Calculating to the water-free oil basis this means that these two crude oils contained respectively 9.8% and 4.9% of moisture-free oil distilling below 150°C, according to the standard method of fractional distillation for the examination of crude oils already proposed.

Taking these two crude oils somewhat as a standard and keeping in mind the hardwood creosote oil mixture No. 31 with the aqueous and lighter oil fractions removed as suggested above, it would seem that the following general specifications would be fair restrictions to propose for the buying of hardwood creosote oils, for the purpose of using as selective frothing agents for Cobalt area ore.

1st. The aqueous content shall be less than 5% of the crude oil as received.

2nd. Not more than 10% of the water-free oil shall distill below 150°C (corrected temperature) and with specific gravity below 0.89 at 15°C according to the standard method of fractional distillation already outlined.

3rd. At least 65% of the water-free oil shall distill between 200°C and 265°C, where the gravity shall be between 0.975 and 1.065.

4th. Not more than 15% of the water-free crude oil shall remain as a hard pitch or coke residue.

These specifications would not apply to ketone residue which is somewhat different in nature from the creosote oils. Where a high-grade concentrate is not desired and the aim would be to lift considerably more mineral bearing gangue particles in order to reduce the tailings assay, considerably more pitch residue than

indicated in the fourth specification above may be used. This, however, may be accomplished by adding hardwood tar as such, containing over 70% pitch residue, to the total oil mixture.

Commercial Tests.—The commercial tests, carried on during 42 continuous shifts, were made in the large Callow cells without interruption of the general procedure. During the first 26 shifts the standard pine oil-coal tar products mixture was used. In Tables Nos. 3 and 4 the results are given in full. In the remaining 16 shifts the hardwood oils were substituted for pine oil in order as follows: Heavy hardwood creosote oil No. 26 in 6 shifts, acid oil No, 27 in 5 shifts and ketone residue No. 29 in the last 5 shifts. Tables No. 5, 6 and 7 give the respective results when using these three different hardwood oils.

The tables speak for themselves. It is interesting to note that these commercial tests gave more than 20% higher extractions than were obtained in small scale laboratory tests. This should be borne in mind when studying the comparative results on the fifty different wood oils examined during this investigation.

The operation of the commercial flotation machines needed no special attention during the runs on the hardwood creosote oils Nos. 26 and 27.

When using ketone residue, however, care had to be taken to keep out traces of foreign oil such as lubricating oil which had a deleterious action on the somewhat sensitive though heavy froth.

Conclusions.—1. Crude hardwood oils, the supply of which is abundant, can be substituted for pine oil as a selective frothing agent in the commercial flotation of Cobalt area silver ores.

2. Heavy hardwood creosote oil F.P.L. No. 26 and acid (creosote) oil F.P.L. No. 27 give equally satisfactory results and a mixture of these two oils in proportions as produced is recommended as a standard hardwood flotation oil.

3. Ketone residue in the crude state can also be considered a satisfactory flotation oil for commercial use on Cobalt area silver ore.

TABLE No. 2

[1] The numbers given for the frothing oils in this column are the serial numbers adopted at the Forest Products Laboratories.

Oil Mixture				Per Ton of dry ore		Grams of froth	Assay oz. of silver per ton		Average extraction and remarks
Frothing oil	Per Cent	Collecting oil	Per Cent	Pounds of oil	Reagents		Concentrates	Tails	
No. 1 Pine oil; steam distilled (G.N.S. No. 5).	10	Coal tar Coal tar creosote	10 80	1.5	..	32.0	57.3	1.90	67.5% average of 20 tests
No. 1 Pine oil; same as above	10	Coal tar Coal tar creosote	10 80	1.5	4 lb. NaOH	21.0	105.0	1.14	80.0%
No. 3 Pine oil; Destructive distillation (G.N.S. No. 6)	10	Coal tar Coal tar creosote	10 80	1.5	..	29.0	42.3	3.16	45.0%
No. 3 Pine oil; same as above	15	Coal tar Coal tar creosote	13 72	1.5	..	31.0	61.1	2.04	67.0%
No. 3 Pine oil; same as above	20	Coal tar Coal tar creosote	12 68	1.75	..	49.0	41.7	1.70	72.0% One test only

No. 4 Crude oil from southern pine. (P.T.T. No. 350).	25	Coal tar Coal tar creosote	7.5 67.5	1.5	..	45.0	29.4	2.64	52.5%
No. 4 C de oil; same as above	100	.....	0	1.5	..	65.0	15 2	4.00	36.0%
No. 14 Crude oil from red pine stumps.	100	.....	0	1.5	..	66.0	17.9	4.00	40.5%
No. 17 Crude turps; western yellow pine stumps.	25	Coal tar Coal tar creosote	15 60	1.5	..	23.0	57.0	2.72	50.0%
No. 18 Crude light oil; western yellow pine stumps.	25	Coal tar Coal tar creosote	15 6	2.0	..	35.0	55.6	1.86	69.0%
No. 19 Pine tar oil; western yellow pine stumps.	10	Coal tar Coal tar creosote	18 72	1.5	..	40.0	33.0	2.66	50.0%
No. 25 Light hardwood creosote	30	Coal tar Coal tar creosote	7 63	1.5	..	21.0	77.0	1.64	67.5%
No. 25A Light fraction of No. 25.	40	Coal tar Coal tar creosote	6 54	1.5	..	8.0	79.0	3.90	25.0% very little froth

Oil Mixture				Per Ton of dry ore		Grams of froth	Assay oz. of silver per ton		Average extraction and remarks
Frothing oil	Per Cent	Collecting oil	Per Cent	Pounds of oil	Reagents		Concentrates	Tails	
No. 25B Heavier fraction of No. 25.	30	Coal tar Coal tar creosote	7 63	1.5	..	32.0	59.0	2.10	66.0%
No. 26 Heavy hardwood creosote.	40	Coal tar Coal tar creosote	6 54	1.5	..	29.5	63.3	2.13	65.0% average of 10 tests
No. 26 Same as above.	40	Coal tar Coal tar creosote	30 30	1.75	..	30.0	70.3	1.54	72.0%
No. 26 Same as above.	30	Coal tar Coal tar creosote	7 63	1.5	4 lb. NaOH	7.0	222.5	1.80	63.0%
No. 26 Same as above.	40	Coal tar	60	1.5	..	28.0	48.0	2.70	52.0%

No. 26A Heavy hardwood creosote distilled.	30	Coal tar Coal tar creosote	15 55	1.5	..	22.5	79.3	2.20	63.0%
No. 27 'Acid oil' (or hardwood creosote.)	40	Coal tar Coal tar creosote	6 54	1.5	..	15.0	139.0	1.8	70.0%
No. 28 Heavy ketone oil.	40	Coal tar Coal tar creosote	6 54	1.5	..	8.0	173.7	3.02	50.0% very little froth
No. 28; Same as above.	26	Coal tar Coal tar creosote	7.4 66.6	2.0	4 lb. NaOH	10.0	235.0	1.30	79 0% average of 6 tests
No. 29 Ketone residue. No. 30 Hardwood tar.	15 15	Coal tar creosote	70	1.5	..	....	42.1	1.96	69.5% surplus froth
No. 29 Ketone residue.	20	Coal tar Coal tar creosote	8 72	1.5	..	21.0	84.7	2.04	64.5%

Oil Mixture				Per Ton of dry ore		Grams of froth	Assay oz. of silver per ton		Average extraction and remarks
Frothing[1] oil	Per Cent	Collecting oil	Per Cent	Pounds of oil	Reagents		Concentrates	Tails	
No. 29 Ketone residue.	30	Coal tar Coal tar creosote	7 63	1.5	..	38.0	55.0	1.64	72.0%
No. 30A Hardwood tar distillate. No. 31 Hardwood creosote mixture.	50 50	.....	0	1.0	..	52.0	25.4	2.72	52.0%
No. 31 Hardwood creosote mixture.	30	Coal tar Coal tar creosote	70 63	1.5	..	20.0	87.7	2.34	61.0%
No. 31 Same as above. No. 29 Ketone residue.	25 25	Coal tar creosote	50	1.5	..	35.0	56.7	2.00	70.5%
No. 31A Hardwood creosote mixture distilled.	30	Coal tar Coal tar creosote	20 50	1.5	..	15.5	110.6	2.54	57.3%

No. 39 First fraction of 31A (28% acidic).	40	Coal tar Coal tar creosote	10 50	1.5	..	6.5	192.4	3.32	43.0% very little froth
No. 40 Second fraction of 31A (33.0% acidic).	40	Coal tar Coal tar creosote	10 50	1.5	..	22.0	83.3	2.00	66.0%
No. 41 Third fraction of 31A (66% acidic).	40	Coal tar Coal tar creosote	10 50	1.5	..	37.0	45.3	2.44	60.0%
No. 42 Fourth fraction of 31A (69% acidic).	40	Coal tar Coal tar creosote	10 50	1.5	..	44.0	42.5	2.12	66.0%
No. 43 Fifth fraction of 31A (50% of acidic).	40	Coal tar Coal tar creosote	10 50	1.5	..	40.0	37.4	2.60	55.6%
No. 32 Light oils from red pine stumps.	10	Coal tar Coal tar creosote	10 80	2.0	..	6.0	232.3	2.76	50.5%

Oil Mixture				Per Ton of dry ore		Grams of froth	Assay oz. of silver per ton		Average extraction and remarks
Frothing oil	Per Cent	Collecting oil	Per Cent	Pounds of oil	Reagents		Concentrates	Tails	
No. 33 Rosin oils from red pine stumps.	10	Coal tar Coal tar creosote	10 80	1.5	..	....	....	4.46	Scum only.
No. 34 Wood turpentine from red pine stumps.		Coal tar Coal tar creosote	10 80	1.5	..	....	....	....	No froth
No. 35 Crude pine oil from red pine stumps.	20	Coal tar Coal tar creosote	8 72	1.5	..	32.0	63.3	2.00	68.5% average of several tests
No. 35 Same as above.	10	Coal tar Coal tar creosote	10 80	1.5	4 lb. NaOH	9.0	235.0	1.52	74.0%
No. 36 Light rosin oil from red pine stumps.	30	Coal tar Coal tar creosote	8 72	1.5	..	31.0	35.0	3.06	42.5%

No. 37 Light hardwood creosote (G.N.S. No. 17).	30	Coal tar Coal tar creosote	7 63	1.5	..	31.0	51.0	2.76	55.0%
No. 38 Heavy hardwood creosote (G.N.S. No. 18).	40	Coal tar Coal tar creosote	6 54	1.75	..	27.0	65.3	2.00	65.0%
No. 44 Crude pine oil from western yellow pine stumps.	20	Coal tar Coal tar creosote	13 67	1.5	..	32.0	48.9	2.44	58.0%
No. 45 Heavy pine oil from western yellow pine stumps.	25	Coal tar Coal tar creosote	11 64	1.5	..	26.0	73.3	1.76	69.5%
No. 47 Hardwood neutral oil from 31A 65° C–290° C.	37	Coal tar Coal tar creosote	6.5 58.5	1.5	..	23	72.6	2.34	60.0%
No. 47A Hardwood neutral oil 65° C–150° C.	35	Coal tar Coal tar creosote	6.5 58.5	1.5	..	15.0	65.1	3.20	38.5%
No. 47B Hardwood neutral oil 150° C–200° C.	35	Coal tar Coal tar creosote	6.5 58.5	1.5	..	16.0	81.2	3.08	46.5%

Oil Mixture				Per Ton of dry ore		Grams of froth	Assay oz. of silver per ton		Average extraction and remarks
Frothing oil	Per Cent	Collecting oil	Per Cent	Pounds of oil	Reagents		Concentrates	Tails	
No. 47C Hardwood neutral oil 200° C–280° C.	35	Coal tar Coal tar creosote	6.5 58.5	1.5	..	13.0	128.4	2.00	63.0%
No. 48 Hardwood acidic oil from 31A.	35	Coal tar Coal tar creosote	6.5 58.5	1.5	..	42.0	46.0	2.00	67.5%
No. 48A Acidic oil from 26A and 27A.	35	Coal tar Coal tar creosote	6.5 58.5	1.5	..	32.0	56.7	2.00	66.0%
No. 49 Hardwood neutral oil from 26A and 27A.	35	Coal tar Coal tar creosote	6.5 58.5	1.5	..	26.0	65.7	2.40	60.0%

TABLE No. 3

Oil Mixture—Pine Oil (G.N.S. No. 5)—20 per cent.
Coal tar Creosote 60 " "
Coal Tar 20 " "
Lb. of oil mixture per ton of dry ore—0.98

Date 1917	Shift	Tons of ore treated	Assay oz. of silver per ton				Per cent Extraction
			Heads	Tails	Middlings	Concentrates	
April 16.....	7–3	378	9.8	1.2	16.4	488.0	87.7
	3–7		7.0	1.0	22.2	345.5	85.7
April 17.....	7–3	294	9.4	1.2	20.0	480.0	87.2
	3–7		7.6	1.0	13.4	398.0	86.8
April 18.....	7–3	347	9.2	1.0	12.8	500.0	89.1
	3–7		6.9	1.0	12.0	306.0	85.3
April 19.....	7–3	275	9.8	1.0	12.6	440.0	89.8
	3–7		7.4	1.0	14.0	444.0	86.5
April 20.....	7–3	310	10.4	1.3	14.4	571.5	87.5
	3–7		6.8	1.0	10.6	421.5	85.3
April 21.....	7–3	270	9.6	1.2	11.4	586.0	87.5
	3–7		6–4	1.0	8.8	490.0	84.4
April 22.....	3–7	120	7.0	1.0	11.6	402.0	85.7

TABLE No. 4

Oil Mixture—Pine Oil (G.N.S. No. 5)—20 per cent.
Coal Tar Creosote 60 " "
Coal Tar 20 " "
Lb. of oil mixture per ton of dry ore—1.06.

Date 1917	Shift	Tons of ore treated	Assay oz. of silver per ton				Per cent Extraction
			Heads	Tails	Middlings	Concentrates	
April 23.....	7–3	284	6.2	0.9	8.4	381.0	85.5
	3–7		6.8	1.0	20.0	417.5	85.3
April 24.....	7–3	327	9.0	1.0	9.8	392.0	88.9
	3–7		8.6	1.0	10.0	480.0	88.4
April 25.....	7–3	316	8.6	1.0	10.4	421.0	88.4
	3–7		8.8	0.9	12.8	528.0	89.8
Ap[illegible]o.....	7–3	283	8.2	0.9	8.0	355.0	89.0
	3–7		7.8	0.9	10.0	365.0	88.5
April 27.....	7–3	265	7.8	1.0	8.0	481.5	87.2
	3–7		9.0	0.9	14.9	473.1	90.0
April 28.....	7–3	297	8.2	0.9	9.0	465.0	89.0
	3–7		7.8	0.9	11.6	447.0	88.5
April 29.....	3–7	247	9.0	1.0	16.0	462.5	88.9

TABLE No. 5

Oil Mixture—Heavy Hardwood Creosote Oil (F.P.L. No. 26)—40 per cent.
Coal Tar Creosote 50 " "
Coal Tar 10 " "
Lb. of oil mixture per ton of dry ore—1.06.

Date 1917	Shift	Tons of ore treated	Assay oz. of silver per ton				Per cent Extraction
			Heads	Tails	Middlings	Concentrates	
May 1.....	3–7	172	8.2	1.1	16.0	611.0	86.8
May 2.....	7–3	263	9.4	1.1	17.8	318.0	88.6
	3–7		8.6	1.0	10.0	436.5	88.6
May 3.....	7–3	278	8.8	1.1	15.4	265.0	87.9
	3–7		6.8	1.0	11.2	349.0	85.5
May 4.....	7–3	94	8.9	1.2	18.4	243.5	86.8

Hardwood Flotation Oils for Other Canadian Ores.—Hardwood creosote oils have been tested on a laboratory scale with copper ore from Bruce Mines, Ont. From ore assaying 7.9% copper a mixture of 40% heavy hardwood creosote oil F.P.L. No. 26, 54% tar creosote and 6% coal tar gave 93.1% extraction, leaving tails analyzing 0.8% copper. Other hardwood oils should give equally satisfactory results.

Ketone residue has proved satisfactory for the flotation of low grade copper-nickel ore of the Sudbury district and a commercial demand for the oil has already been effected as the result of this investigation.

Hardwood creosote oils, especially light hardwood creosote oil F.P.L. No. 25, has promising qualities for treatment of the lead-zinc ores and copper ores of British Columbia.

Further investigations of the commercial flotation problems of other Canadian ores, especially those from British Columbia, are now being carried out in the Ore Dressing Division of the Mines Branch, which has secured a complete collection of the Canadian crude wood oils and their fractions.

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TABLE No. 6

Oil Mixture—Hardwood acid (creosote) oil (F.P.L. No. 27)—40 per cent.
Coal tar creosote 50 " "
Coal tar 10 " "

Lb. of ore mixture per ton of dry ore—1.06.

Date 1917	Shift	Tons of ore treated	Assay oz. of silver per ton				Per cent Extraction
			Heads	Tails	Middlings	Concentrates	
May 4	3–7	107	12.0	1.1	92.0	900.0	90.8
May 5	7–3	283	9.6	1.2	15.2	320.0	87.9
	3–7		7.0	1.0	22.8	732.5	85.8
May 6	3–7	125	8.8	0.9	10.6	435.0	89.9
May 7	7–3	80	8.8	0.8	10.6	344.0	91.1

TABLE No. 7

Oil Mixture—Ketone residue (F.P.L. No. 29)——25 per cent.
Coal tar creosote 65 " "
Coal tar 10 " "
Lb. of oil mixture per ton of dry ore—1.06.

Date 1917	Shift	Tons of ore treated	Assay oz. of silver per ton				Per cent Extraction
			Heads	Tails	Middlings	Concentrates	
May 7.....	3–7	160	7.8	1.2	26.6	173.0	85.0
May 8.....	11–7	212	9.4	1.0	14.0	317.0	89.6
May 9.....	7–3 3–7	277	9.2 8.2	1.1 0.9	13.0 7.4	267.5 290.0	88.4 89.3
May 10.....	7–3	90	8.8	0.9	87.6	382.0	90.0