

TP
997
B4

UC-NRLF



B 4 584 545

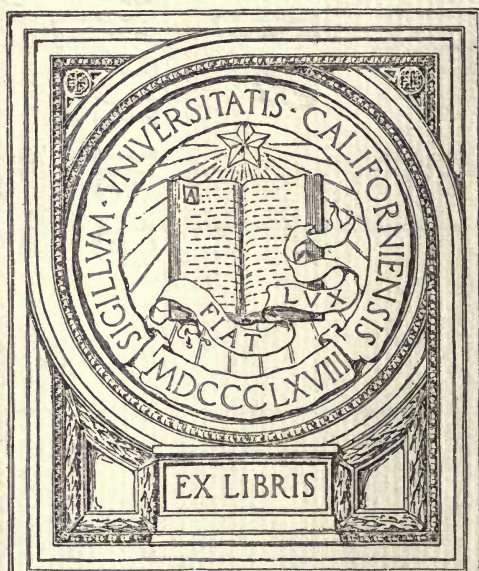
DISTILLATION OF HARDWOODS IN CANADA
DISTILLATION OF HARDWOODS IN CANADA

By: John S. Bates.

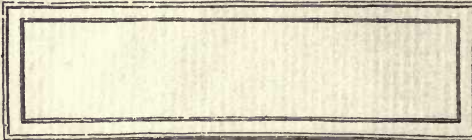
Forestry Branch - Bulletin #74

1922

YD 24846



Agric.-Forestry. Main Library



DEPARTMENT OF THE INTERIOR, CANADA

HON. CHARLES STEWART, Minister; W. W. CORY, Deputy Minister.

FORESTRY BRANCH—BULLETIN No. 74

R. H. CAMPBELL, Director of Forestry

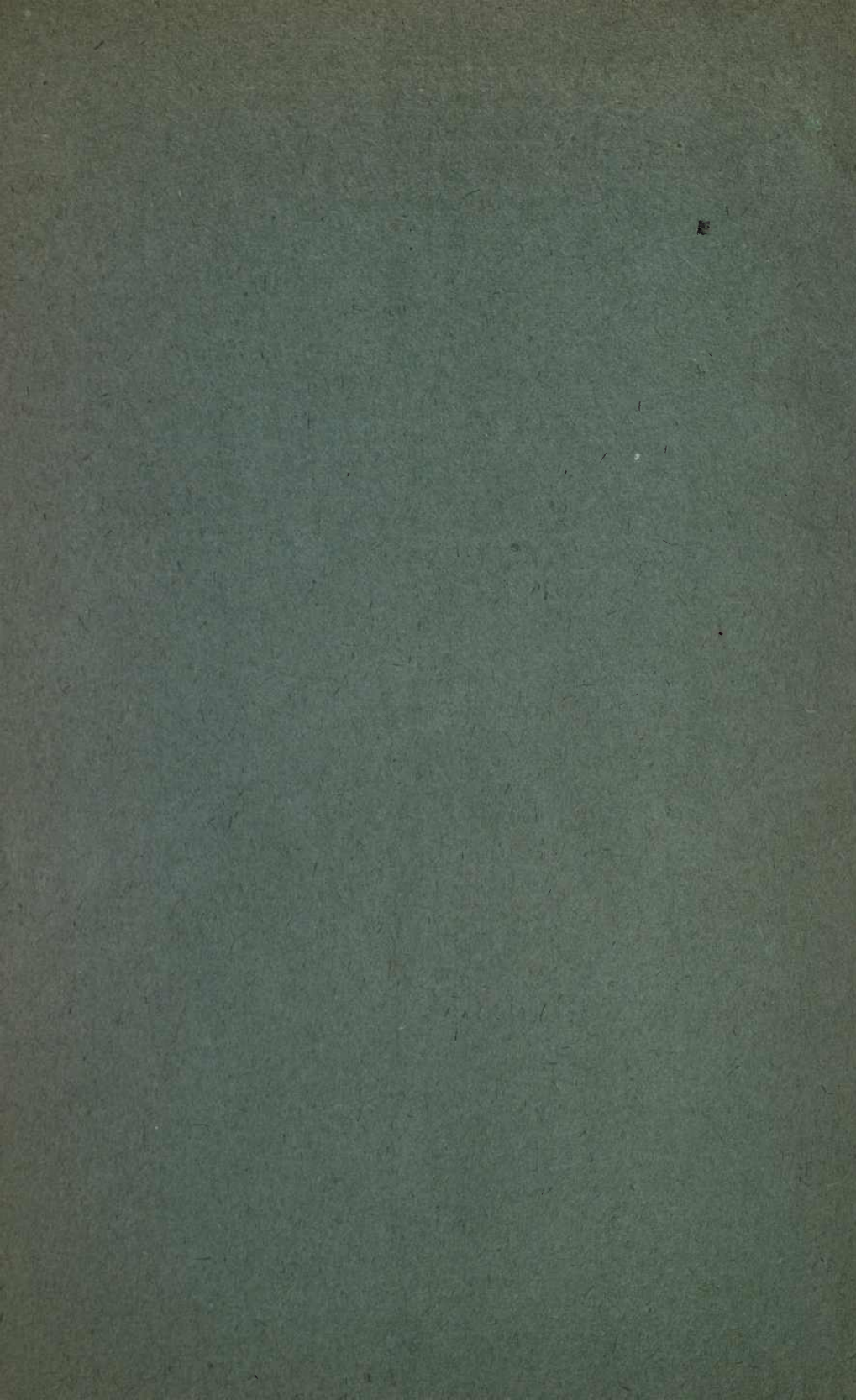
DISTILLATION
OF
HARDWOODS IN CANADA



OTTAWA
F. A. ACLAND
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY

1922

Price, 25 cents



DEPARTMENT OF THE INTERIOR, CANADA

HON. CHARLES STEWART, Minister; W. W. CORY, Deputy Minister

FORESTRY BRANCH—BULLETIN No. 24

R. H. CAMPBELL, Director of Forestry

DEPARTMENT OF THE INTERIOR
FORESTRY
COLLEGE OF AGRICULTURE
UNIVERSITY OF CALIFORNIA

DISTILLATION OF HARDWOODS IN CANADA

by

JOHN S. BATES, Ph.D.,

Formerly Superintendent, Forest Products Laboratories of Canada



CONTRIBUTION FROM

THE FOREST PRODUCTS LABORATORIES OF CANADA

W. KYNOCH, Superintendent

Price: 25 cents.

TO VIND
AUSPICIUM

Agric.-Forestry. Main Library

TP997
B4

CONTENTS

	PAGE
Introduction..	5
Process—	
Wood Supply..	7
Destructive Distillation..	10
Derived Products..	20
Plants—	
Crude Hardwood Distillation Plants..	27
Refining Plants..	28
Production and Disposal—	
Production Statistics..	28
Exports and Imports..	30
Uses of Products..	31
Costs—	
Plant Investments..	33
Operating Costs..	33
Selling Prices..	34
Prospects—	
New Processes..	35
Conclusion..	37
Acknowledgments..	38
Bibliography..	38
Appendix..	40

FLOW SHEET

DESTRUCTIVE DISTILLATION OF HARDWOODS

YIELDS
in Imperial Gallons etc. on 1 Cord basis.

TREES

Mainly maple, beech and birch

Culling, Splitting and Transportation
Storage, Seasoning for 2 Years

CORDWOOD

1 Cord 3700 to 4300 lb. Moisture 20 to 30 %

BUGGIES

OVENS(STEEL)

Capacity 5 to 10 Cords each

Destructive Distillation

Temperature 300 to 370 ° C.

Time 24 to 30 hrs.

Time 24 to 30 hrs.

Time 24 to 30 hrs.

Time 24 to 30 hrs.

Time 24 to 30 hrs.

Time 24 to 30 hrs.

Time 24 to 30 hrs.

Time 24 to 30 hrs.

Time 24 to 30 hrs.

Time 24 to 30 hrs.

Time 24 to 30 hrs.

Time 24 to 30 hrs.

Time 24 to 30 hrs.

Time 24 to 30 hrs.

Time 24 to 30 hrs.

Time 24 to 30 hrs.

Time 24 to 30 hrs.

Time 24 to 30 hrs.

Time 24 to 30 hrs.

Time 24 to 30 hrs.

Time 24 to 30 hrs.

Time 24 to 30 hrs.

Time 24 to 30 hrs.

Time 24 to 30 hrs.

Time 24 to 30 hrs.

Time 24 to 30 hrs.

Time 24 to 30 hrs.

Time 24 to 30 hrs.

Time 24 to 30 hrs.

Time 24 to 30 hrs.

Time 24 to 30 hrs.

Time 24 to 30 hrs.

Time 24 to 30 hrs.

Time 24 to 30 hrs.

Time 24 to 30 hrs.

Time 24 to 30 hrs.

Time 24 to 30 hrs.

Time 24 to 30 hrs.

Time 24 to 30 hrs.

Time 24 to 30 hrs.

Time 24 to 30 hrs.

Time 24 to 30 hrs.

Time 24 to 30 hrs.

COAL
for ovens,
steamboilers,
etc.
800 to 1200 lb

CHARCOAL
2 COOLERS IN SERIES
Time 24 hrs. each
CHARCOAL SHED
Ageing 48 hrs.
Screening

QUICKLIME
65 to 75 lb.
-coproc. lumps
skipped for neutralizing tub.

GASES & VAPOURS
TUBULAR CONDENSER

RAW LIQUOR & TAR
200 to 230 gal.
WOODEN SUMP

COPPER STILLS (1) & (2)

CONDENSERS
SEPARATING TANKS

PYROLIGNEOUS ACID
90 to 220 gal.
[Acetic Acid 5 to 7 % by wt.
Alcohol, etc. 4 to 4.5 % by vol.]

HEAVY OIL
0.5 gal.

NEUTRALIZING TUB (WOODEN)
Acetic Acid converted to Calcium Acetate

LIME LEE STILL (IRON)

WEAK ALCOHOL (10 %)
85 to 95 gal.

CONDENSER

SEPARATING TANKS
at first and last of run

EVAPORATING PANS OR ROTARY DRUMS

DRYING FLOOR OR BELT DRYER

LIGHT & HEAVY OILS

COLUMN STILL

CONDENSER

STORAGE TANKS

WATER discharge

CRUDE WOOD ALCOHOL (95%)
8 to 9 imp. gal. = 65 to 75 lb.
Methyl Alcohol 75 to 80 %
Acetone 8 to 12 %
Esters & Aldehydes 4 to 16 %
Oils, etc. 2 to 4 %

GREY ACETATE OF LIME (80%)
200 to 220 lb.
Calcium Acetate 80 to 85 %
Moisture 3 to 5 %
Organic Impurities, gr. 10 to 15 %

HARDWOOD TAR & OILS
18 to 20 imp. gal. = 190 to 210 lb.

WOOD GAS
7000 to 9000 cu. ft. = 700 to 800 lb.
Carbon Dioxide 30 to 60 %
Carbon Monoxide 30 to 40 %
Methane, etc. 5 to 15 %

CHARCOAL
50 to 54 bush. = 1000 to 1050 lb.
Moisture 2 to 5 %
Ash 15 to 20 %
Volatile 15 to 20 %
Fixed Carbon 75 to 85 %

DISTILLATION OF HARDWOODS IN CANADA

INTRODUCTION

The purpose of this publication is to present a summary of the destructive distillation of hardwoods and the manufacture of derived products with special reference to conditions in Canada.

Hardwood distillation involves the decomposition of the heavier broad-leaved woods by heating in the absence of air followed by refining and further manufacture of the crude products. The products obtained by destructive distillation of the wood in the so-called "crude factories" are charcoal, acetate of lime, and crude wood alcohol, together with wood-gas, hardwood tar, and oils as by-products. The "derived" products manufactured in central refineries and chemical plants are methyl hydrate (wood alcohol) and related materials, formalin (formaldehyde), acetic acid, acetone, and various other direct products and by-products.

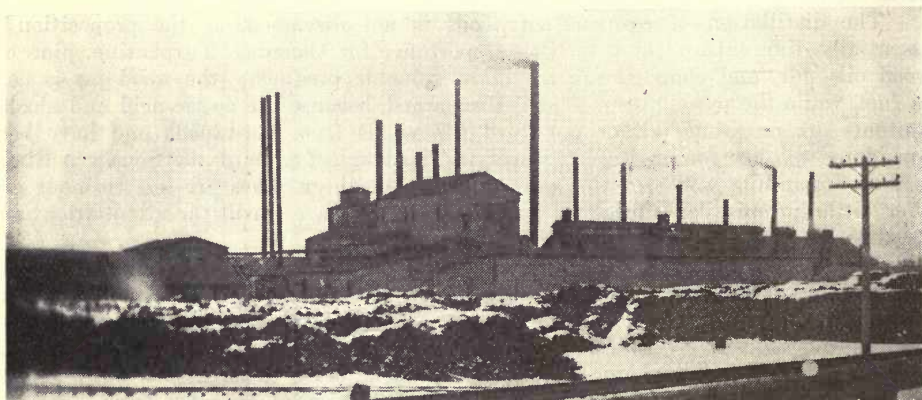
The distillation of resinous softwoods is not discussed, as the proposition is essentially different and of very little importance for Canada. Turpentine, pine oil, wood oils, tar, and charcoal are the main valuable products; the wood-gas is used as fuel, while the pyroligneous acid is discharged, because the acetic acid and alcohol contents are only one-half or one-third the yields from hardwoods and have been considered too low for profitable recovery. The longleaf pine of the Southern States is the outstanding wood for this purpose. The northern pines are less resinous and offer little promise of successful exploitation, at least until the distillation and refining processes are more carefully developed.

The heating or carbonizing of wood to obtain charcoal dates back to early history and has been practised down through the centuries. The first record of distillation (in the strict sense of the term) in America is that of the manufacture of pyroligneous acid at North Adams, Massachusetts, by James Ward, which began in 1830. The first successful wood-distillation plant appears to have been built in 1850 in New York state by John H. Turnbull, an experienced operator from Scotland, who used small cast-iron retorts each holding about half a cord. During the early period the chief product was acetate of lime, the charcoal being largely used at the plant as fuel and the crude wood alcohol finding only a small market. About 1865 a Mr. Pollock, a chemist living near New York city, began refining wood spirit, and this branch of the industry grew steadily. Later the markets for charcoal grew and made it unnecessary to burn charcoal at the distillation plants. The development of the industry has been gradual from the crude operations of the early plants to the scientifically controlled processes of the modern factories. The cylindrical cast-iron retorts have been largely replaced by the modern "ovens," which are large rectangular retorts of steel plate holding up to ten cords each. The only remnant of the early charcoal pit is the large by-product kiln built of brick, still used in Michigan for the production of charcoal for making charcoal iron.

In Canada the hardwood distillation industry is of more recent origin than in the United States and Europe. Destructive distillation plants sprang up in Quebec and Ontario in localities near a suitable wood supply. In time these were for the most part absorbed by the Standard Chemical Iron and Lumber Company of Canada, Limited, so that recent history is largely that of one company. Central alcohol refineries were established at Longford, Ontario, and Montreal, Quebec, acetone plants at Longford and Sault Ste. Marie, Ontario, acetic acid and formaldehyde plants at Montreal, and equipment for the manufacture of other products at various points.

A subsidiary, the Standard Iron Company, Limited, used considerable charcoal at Deseronto, Ontario, for making charcoal iron, and distributing companies were formed to market charcoal in the principal cities as household fuel. With the exception of two crude distillation plants in Ontario the industry in Canada is now controlled by the reorganized Standard Chemical Company, Limited, Montreal.

The plants reflect the gradual growth of the industry over a long period of years. The demand for acetone, methyl hydrate, formalin, and other hardwood distillation products was very great throughout the war period and the industry served the nation in the war crisis to an extent that few realize. The industry enjoys the benefits of competent centralized control and is in a position to make the most of the situation within the limits of the uncertain economic and trade conditions that exist. It is gratifying to note that manufacture is carried beyond the stage of the crude products, where so many of Canada's industrial activities cease, and that the specially refined and derived chemicals are produced in Canada for domestic and export trade. It is a significant fact that a single well organized company handles practically all operations from the cutting of the wood to the manufacture and sale of the finished chemicals. Furthermore, the industry is now on a satisfactory basis of technical control, and science is being applied to the further development of derived products originating in the crude wood distillation.



Canadian wood distillation plant, 84-cord capacity

In the United States the crude plants have in general remained as separate units, while independent refineries, chemical plants, and selling agencies have largely handled the further manufacture and distribution. While conditions in the two countries differ in many respects, the industry in the United States is so large that Canada naturally has to follow more or less in the matter of practice, prices, and trade.

Taking a world view of the industry, we find that the United States controls over 60 per cent of the output. Canada has about one-tenth of the capacity of the United States or from 6 to 8 per cent of the total. The remainder is to be found largely in Europe, principally in the central states. As a basis for rough calculation it may be estimated that the world's capacity is something like 7,000 cords of wood per day or approximately 2,000,000 cords per year.

Hardwood distillation may be looked upon as a minor key industry, because a number of the products cannot be produced by other means and are of an essential nature. Methyl hydrate (wood alcohol) is most significant, as wood is still the only commercial source of this widely used material. Charcoal also has its origin only in wood distillation. Acetic acid and acetone are still largely obtained from acetate of

lime, but new chemical processes established during the war have introduced competition in these products. While the unique position of the industry is not as secure as it was, hardwood distillation remains as an important source of a whole series of materials that are essential in times of peace and war.

The main requirements for the hardwood distillation industry are a plentiful and relatively cheap supply of hardwoods, a satisfactory supply of coal or other fuel, plentiful water, reasonable accessibility to charcoal markets and outlets for other products. The crude distillation plant must be located conveniently to the wood and water supply, even though coal may have to be brought from a distance. As charcoal is the largest product, there must be markets within easy reach in order to dispose of this bulky material at a profit. The other products will bear the cost of transportation to refineries and then to world markets, provided there is the demand.

PROCESS

The flow sheet "Destructive Distillation of Hardwoods" outlines the procedure in the ordinary crude distillation plant for the production of charcoal, acetate of lime, and crude wood alcohol, with wood-gas, hardwood tar, and oils as by-products. The main details concerning materials, form, composition, reactions, conditions, yields, and apparatus are included.

WOOD SUPPLY

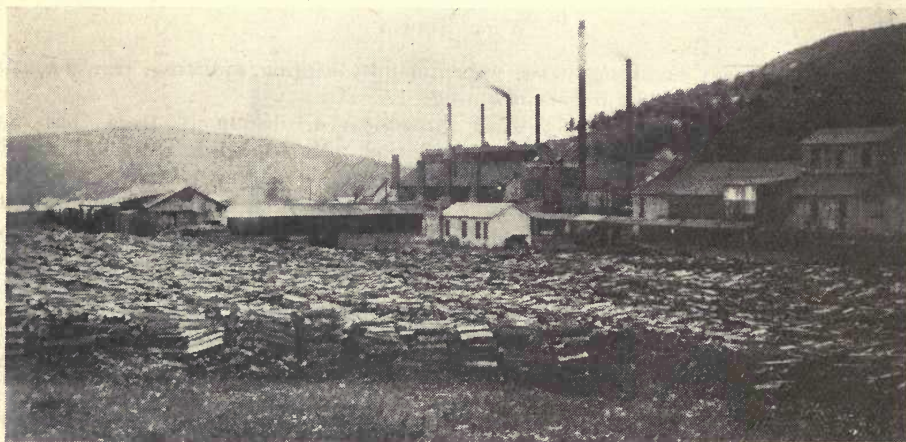
The preliminary handling of the wood includes logging, splitting, transportation to the plant, storage, and further seasoning.

Hardwoods include all species of broad-leaved, deciduous trees, but only the harder, heavier woods are used for distillation. Maple, beech, and birch are the most important in Canada, maple furnishing about 50 per cent of the total wood used, beech 25 per cent, and birch, etc., 25 per cent. Hard, or sugar, maple and beech are considered best, while yellow birch is better than white birch. Hickory is very good and ash is also suitable. Other species also are used in the United States, but do not exist in Canada in large quantities. Oak is important farther south, although the yields are slightly lower. Chestnut suffers by the presence of considerable tannin. Elm is inferior in weight and yields. The lighter hardwoods, such as poplar and basswood, give yields of alcohol and acetate that are too low for competition. The softwoods, or coniferous tree species, such as spruce, balsam fir, white pine, hemlock, etc., are out of the question on account of their light weight, low degree of lignification, and resinous nature, which result in very low yields of alcohol and acetate, together with different character of charcoal and tar.

Wood is such a variable substance that there are many factors to affect yields. It is considered that the northern species are rather better for distillation purposes than the same or corresponding species in the south, so that Canadian maple, beech, and birch represent high-grade raw material. One species may be better than another in alcohol yield and poorer in acetic acid yield; for instance, it is stated that the order of yield for alcohol is beech, maple, birch; and for acid, birch, beech, maple. Sapwood is less desirable than heartwood and bark gives lower yields than solid wood, so that slabs are not as valuable as average wood. Limbs are less effective than trunk wood. Cordwood from mature or virgin trees is, no doubt, better than that from younger second-growth trees. It is also claimed that wood grown on high and dry places gives higher yields than the same species from low or marshy soil. Some operators say that wood cut in winter is better than that cut while the sap is running, but this depends largely on subsequent seasoning. Green or unseasoned wood not only requires more fuel for carborizing and redistillation but also appears to lower the yields compared with well-seasoned wood. There is no doubt that the presence of decay reduces the yields, and the action of wood-destroying fungi in the standing trees and in cordwood during storage is a subject for more careful study in the

industry. In view of the above factors it is clear that variations in quality of wood are to be expected and that care must be used in selecting and handling the wood supply. Solid wood cut especially for the purpose fills the most important place, although the larger forms of logging waste and hardwood saw-mill refuse may be used to good advantage. In fact it is highly desirable to collect the wood supply as far as possible in conjunction with hardwood lumber operations.

Turning to the question of logging there arises the problem of finding a stand of suitable hardwoods that will last for a considerable number of years and permit economical cutting and transportation to a crude distillation plant. Canada is well supplied with the desired hardwoods, especially in various districts of Quebec and Ontario. At the same time conditions are not ideal and in general the wood cost is higher than in many parts of the United States. The hardwoods usually occur in mixed stands with softwoods, the trees are of moderate size, and a fairly large territory has to be covered to collect the necessary material. The wooded country is comparatively rough and thinly settled, and there are limited facilities in the way of good hauling roads and logging railways. Hardwoods have the inherent disadvantage that they cannot be cheaply river-driven for long distances like softwoods, so that the radius of operating is restricted. The hardwood lumber industry still plays but a small part in Canada, with the result that there are few opportunities of obtaining cheap supplies of wood waste for distillation.



Canadian wood distillation plant, 48-cord capacity, showing wood supply

Cutting and hauling are usually done in winter by farmers and other jobbers working on contract with the distillation companies. The wood is sawn into 50-inch or 52-inch lengths, split into cordwood sizes up to about eight inches (with the bark left on) and then stacked. The cordwood is hauled by sled to the railway siding, stacked, and later transported in cars to the distillation plant. Here it is stored in the yard in long piles beside yard tracks for ease in handling. The wood is seasoned in the open for one or more seasons to reduce the moisture content in order to produce more concentrated distillates and higher yields. This has the disadvantage of tying up considerable capital for a year or more and also results in a certain amount of deterioration by rotting. A recent development, not yet introduced into Canada, overcomes this long storage of wood by removing part of the moisture just before distillation in pre-dryers through which circulate hot waste gases from the retorts.

The cordwood ready for distillation is usually measured on the cord basis. This is open to objection owing to inaccuracies in estimating the cordage, variations in the solid volume of wood per cord (depending on lengths and shapes of the pieces

and methods of racking) and fluctuations in the average density of the wood itself. The only really satisfactory basis is to determine the actual weight of the wood and couple this with a statement of moisture content, species of wood, and general condition. As measuring by cords is more convenient, an accurate knowledge of raw material undergoing distillation is seldom obtained, and for this reason there are many variations in reported yields that cannot be otherwise explained. For the purpose of this discussion the average cord will be based on 3,000 pounds of oven-dry (moisture-free) wood representing a mixture of maple, beech, and birch. The so-called "chemical cord" of 50-inch wood piled 8 feet long by 4 feet high may be considered about equal to a true cord of 128 cubic feet, as there are always present a certain number of pieces shorter than 50 inches. When piled in cordwood sizes, this is equivalent to from 85 to 90 cubic feet of solid wood, the voids amounting to from 30 to 35 per cent of the total volume. The species in question have a specific gravity averaging from 0.53 to 0.57, or in other words the oven-dry wood weighs from 33 to 36 pounds per cubic foot, based on the volume when partly seasoned ready for distillation. By calculation this accounts for about 3,000 pounds of oven-dry wood per cord, and it is considered that this is a fair average for the ordinary wood, including bark. Green wood when first cut at, say, 50 per cent moisture content would weigh 6,000 pounds per cord, including 3,000 pounds of water, while seasoned wood such as is ordinarily used at the distillation plants averages about 25 per cent moisture content and weighs 4,000 pounds per cord, including 1,000 pounds of water. The removal of 2,000 pounds of moisture per cord by seasoning is obviously an important step in the process. There is a certain amount of shrinkage in volume due to excessive drying at the surface.

The chemical composition of the oven-dry wood substance is roughly 50 to 60 per cent cellulose, 25 to 30 per cent lignin and related bodies, 15 to 20 per cent lower carbohydrates, gums, tannins, etc., and 0.5 to 1 per cent mineral substances. The ultimate analysis averages approximately 49 per cent carbon, 6 per cent hydrogen, 44 per cent oxygen and 1 per cent ash. The calorific value of the oven-dry wood is close to 8,500 B.T.U. per pound, so that a cord is equivalent to about 25,500,000 B.T.U. This is mentioned for reference in relation to the calorific values of the final products and the exothermic heat of carbonizing, although the real heating value would be reduced somewhat if the wood were burned directly in the moist condition.

As a guide to the direct results of carbonizing wood, Table 1, given below, is offered to show the approximate yields of products from a cord of wood on the oven-dry basis and also to show the heat balance. The figures are chosen to represent conditions as they are at the end of the oven treatment rather than after removal and final recovery. Charcoal is the largest product, accounting for over one-third of the wood substance, more than one-half of the original fuel value and nearly two-thirds of the carbon that existed in the wood. Wood-gas amounts to one-quarter of the weight of wood, carries one-third of the oxygen and in composition resembles the gaseous products of an incomplete combustion as shown by high carbon monoxide content and low heating value. Tar and oils are comparatively high in carbon content and account for over one-tenth of the original calorific value. Acetic acid is the largest yield of pure chemical although small in actual percentage, and is considered to be derived mainly from the lignin and to a slight extent from the cellulose. The wood alcohol mixture is a small fraction of the original wood and is produced entirely from the lignin and other non-cellulose compounds. In this connection it may be noted that the yield of methyl hydrate by destructive distillation is only about one-third of the equivalent methoxy groups present in the wood, indicating to the chemist a possibility of higher yields in the future. Indefinite organic impurities finally appearing in the acetate of lime and water residues are accounted for in the table. Water of decomposition formed during carbonization accounts for one-quarter of the wood substance, carries about one-half of the original hydrogen and oxygen and represents an end product of no calorific value, derived chiefly from the cellulose and to a large extent from the lignin group as well. In general it will be seen that the cellulose

accounts for most of the charcoal, water, tar, and wood-gas. The lignin and related bodies are the really valuable substances for distillation purposes, yielding the methyl hydrate, most of the acetic acid and minor percentages of the charcoal, water, wood-gas, and tar. Considering the high production of water, tar, and wood-gas of little value, the carbonizing process as a method of wood utilization is perhaps rightly called "crude" distillation.

Reference is made to the heat balance because too little attention is ordinarily given to this important aspect of the process. Owing to the general lack of information on the subject the figures may not represent actual conditions very closely. The total heat value of the products based on measurements in a calorimeter at ordinary room temperature is estimated to be 82.4 per cent of the calorific value of the original oven-dry wood, whereas the true figure may be somewhat higher than this. The sensible heat lost by cooling the products from oven temperature to ordinary temperature amounts to about 5 per cent of the original wood value. The surplus heat given off, represented by the exothermic reaction in passing from dry wood to products at oven temperature, is probably over 5 per cent of the original calorific value of the wood. On the other hand external heat has to be provided to raise the wood from ordinary temperature to carbonizing temperature and to evaporate the moisture present in the wood as these two factors are equivalent to rather less than 10 per cent of the calorific value of the wood. The great bulk of the fuel required for firing the ovens is therefore absorbed in heating up the ovens and settings, in radiation and flue-gas losses.

Table 1—Yields of Products and Heat Balance

Material	Weight per cord	Yield on oven-dry wood	B.T.U. per lb.	B.T.U. per cord	Heat Ratio
	lb.	Per cent			Per cent
Wood (oven-dry).....	3,000	100.0	8,500	25,500,000	100.0
Charcoal.....	1,080	36.0	13,500	14,580,000	57.2
Wood-gas.....	720	24.0	2,300	1,656,000	6.5
Tar and oils.....	200	6.7	14,000	2,800,000	11.0
Acetic acid.....	130	4.3	6,800	884,000	3.5
Alcohol.....	70	2.3	9,600	672,000	2.6
Organic impurities.....	40	1.3	10,000	400,000	1.6
Water of decomposition.....	760	25.4			
Total products.....	3,000	100.0			82.4

DESTRUCTIVE DISTILLATION

The "crude plants" scattered about the country near the wood supplies are definite units in the general scheme of hardwood distillation. These plants are comparatively simple in design and operation and can therefore be located in outlying districts, although on this account they suffer from lack of skilled attention in comparison with large centralized plants. Destructive distillation or carbonizing of the wood yields charcoal, wood-gas, and raw liquor mixture. Redistillations and treatments of the raw liquor are carried out to separate the tar and oils and to recover the valuable products, acetate of lime and crude wood-alcohol. These operations represent the simplest means of separating the products into forms convenient for handling. Charcoal is screened and shipped ready for use, acetate of lime is bagged and shipped to chemical plants at home or abroad for the manufacture of acetic acid or acetone, and crude wood alcohol goes in tank-cars to central refineries, while wood-gas and tar are usually burned as fuel at the plant.

Decomposition of the wood is carried out in several types of apparatus, which illustrate the development of the process.

1—KILNS

These are large brick "beehives" holding from 20 to 90 cords of wood and are an outgrowth of the early charcoal pits. Conversion to charcoal is carried out by burning wood or gas in a furnace underneath the pile and also by drawing air through to give a partial burning of the wood itself. As these are "by-product kilns" the vapours from the top are sucked by a fan through a wooden pipe to a condenser for subsequent recovery of acetate of lime and alcohol to the extent of about one-half the yields by the "oven" process. The complete cycle requires from 15 to 25 days and the system is the simplest means of carbonizing wood. The main object is charcoal and the method is still used in the charcoal iron districts of Michigan, but has been of little importance in Canada.

2—RETORTS

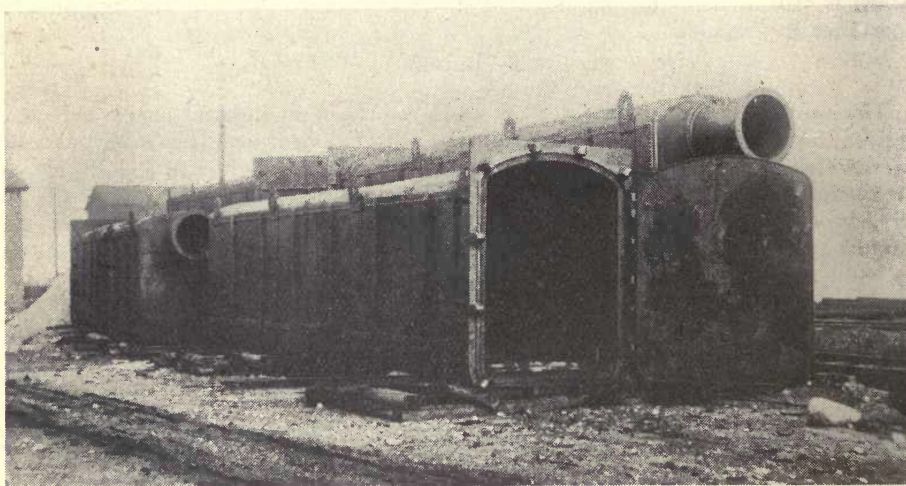
Horizontal cast-iron and, later on, steel retorts of cylindrical shape were standardized for true destructive distillation by external heating. The early cast-iron retorts were 8 feet long by 42 inches in diameter, holding five-eighths of a cord each, and were charged by hand with 8-foot wood, mainly for the production of acetate of lime, the charcoal and tar being used as fuel under the retorts and stills. The retorts were designed to withstand high temperatures and rapid firing, so that two charges were run through in 24 hours. The steel retorts are usually 9 feet long by 50 inches diameter, and rows of retorts are installed in pairs in brick settings. Filling and discharging are done through the single door in front and heating is accomplished from a fire-box below with coal, wood, gas, tar, or charcoal as fuel. The steel retorts are run more efficiently at moderate temperatures and the cycle is from 16 to 24 hours. The charcoal is pulled into air-tight containers for cooling. The yields are rather lower than by the oven process and operation requires more labour. Retorts are still in operation in some United States plants, but not in Canada.

3—OVENS

Rectangular steel ovens have been the standard equipment during the past twenty-five years. The capacity ranges from 5 to 10 cords each, handling is simplified by loading the wood on retort cars, and yields are high by reason of controlled firing at moderate temperatures. The carbonizing cycle is approximately 24 hours. The destructive distillation process will be outlined to show the operations of a typical crude distillation plant using modern ovens.

Plants vary greatly in size, ranging in Canada from 20 to 112 cords capacity per day. Several have eight ovens holding 6 cords each, giving a nominal rating of 48 cords per day. In the United States there are a number of plants distilling from 100 to 200 cords per day. A plant requires from 10 to 40 acres for woodyard and buildings. The woodyard has a series of parallel tracks and roadways with spaces for storage of at least a year's supply of wood undergoing seasoning. There are also tracks for handling the incoming and outgoing materials. The buildings are of fairly substantial construction, being largely of brick in northern climates. The largest building is the one to house the ovens, and the others are the boiler-house, still-house, storage house for acetate, charcoal storage house, warehouse, repair shop, chemical laboratory and office. A shed is needed for the yard locomotive, and in some cases there is a small separate still-house for the tar stills. Open sheds are used for handling and storing the charcoal before shipment. The charcoal coolers are in the open and sometimes the alcohol storage tanks as well. The buildings are more or less connected and the layout is designed to suit convenient handling of materials.

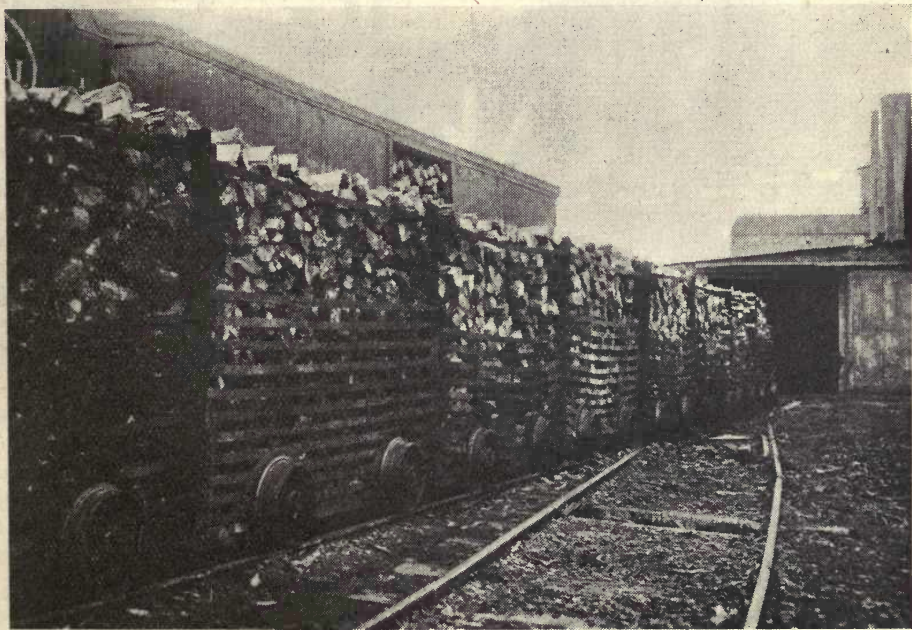
The cordwood from the yard is piled crosswise on retort cars or "buggies" holding 2 or $2\frac{1}{2}$ cords each. These are made of flat, steel bars and equipped with detachable sides. The buggies are moved by hand, winch, or locomotive, and three or four loaded buggies are run on tracks into an oven. Usually the well seasoned cordwood is taken for distillation. Some plants in the United States are now equipped to take greener wood and run the loaded buggies into a rectangular brick dryer placed in line with the oven, whereby the moisture content is reduced to the desired degree just before distillation by circulating waste flue-gases from the oven stacks. For ease in drying, this has led to cutting the wood into pieces a foot or so in length, and no doubt this innovation will stimulate the more general use of short wood which would otherwise be lost as waste in the harvesting of the wood supply.



Ovens of six-cord capacity awaiting installation

The ovens are 6 feet 3 inches wide by 8 feet 4 inches high by 26 to 54 feet long with capacities varying from 5 to 10 cords each. The steel used in the shell is $\frac{3}{8}$ -inch, while the bottom is of $\frac{1}{2}$ -inch material. The best arrangement is with cast-iron doors at both ends in order that the wood may be loaded in at one end and the charcoal pulled into the coolers at the other end. Many ovens, however, have a door at one end only with a track system for handling both charcoal and wood. The doors and frames are of cast-iron and the hinged doors are tightly closed by steel tapered keys. The door joints are tongued and grooved and made tight with asbestos packing. Steel hangers are riveted to the sides of the oven and the oven is suspended by U bolts from T rails laid across the brick setting at the top to allow for expansion and contraction. Inside the oven are rails which carry the wood cars. At the end or on one side are riveted one or more 30-inch cast-iron nozzles leading to the vertical tubular condenser. The ovens are set singly or in pairs in brick settings and a storm door protects the oven door. Below the ground-level is a furnace at one or both ends of the oven and distribution of heat is effected by means of a brick arch with port-holes so that the hot gases pass evenly under and around the sides of the oven. Coal is the usual fuel and the ovens are also equipped for burning part of the wood-gas and tar. Natural gas (in the United States), wood waste, and fine charcoal ("breeze") are also used when conditions permit. The coal required is approximately 350 pounds per cord of wood on the average.

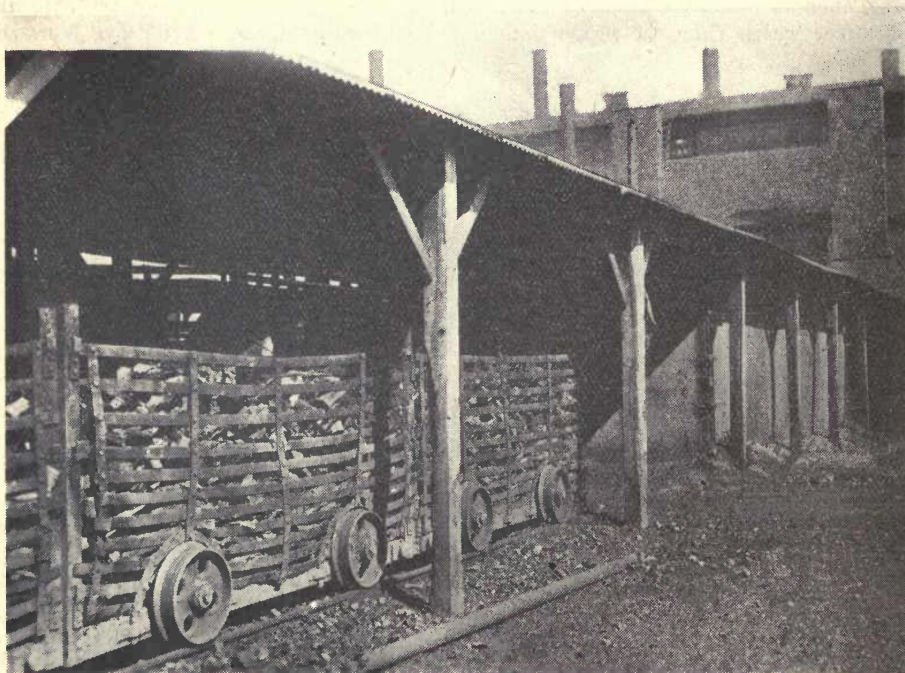
The wood is run into the warm oven, the door closed and firing controlled during the period of distillation which lasts about 24 hours. The fire underneath the oven is kept vigorous at first, in order to heat the wood rapidly and to drive out some of the moisture prior to destructive distillation. Later the firing is reduced in order to control the speed of distillation during the spontaneous or exothermic decomposition of the wood. The use of steam in the oven prior to and during this stage is a common practice, giving better control of the reaction. The operation is watched by the flow and colour of the raw liquor from the condenser and by reading temperatures of gas-filled thermometers placed in the vapour-outlet nozzles. When the wood reaches 100° C. (212° F.) the moisture distils and the first dissociation begins, so that during the first few hours there appears a distillate of a light yellow colour containing a small amount of acid. Gradually the proportions of acid and alcohol increase until the acid content reaches 12 or 14 per cent, at about the fifteenth hour, after which time the proportion of acid decreases again. After five hours or



Cars charged with wood ready for oven

more some light tar appears and the tar steadily increases throughout most of the operation. In the earlier stages the gas which is evolved is mostly carbon dioxide, later becoming a mixture of increasing fuel value. In approximately six hours the pyroligneous acid begins to flow, showing dissociation of wood substance into the water and other products. It has been found that wood begins to decompose rapidly with liberation of heat at about 270° C. (518° F.) This exothermic reaction becomes very pronounced and is evidenced by a steady flow of distillate without the application of further external heat to the oven. On this account it is necessary to use care in firing so that temperature control will bring the wood up gradually in from 6 to 9 hours to the exothermic stage without overheating and without too rapid decomposition in the last stages. As it is impossible to measure temperatures directly in the pieces of wood, a general idea is obtained from the temperatures of the mixed vapours leaving the oven. It is estimated that the temperatures at this point are perhaps fifty degrees Centigrade or a hundred degrees Fahrenheit lower than the

corresponding temperatures of the decomposing wood. The wood probably carbonizes largely between 300° and 370° C. (570° and 700° F.) when the temperature at the vapour outlet reaches a maximum of 300° or 320° C. (570° or 600° F.) Yields depend partly on the way the wood is carbonized. Excessive heat increases the gases and tar at the expense of the charcoal and breaks down some of the alcohol and acid. Rapid firing without excessive temperature seems to give more acid and less alcohol, while slow, even temperature for 24 hours gives the best alcohol yield and only slightly less acid. In Canada the usual practice is to run the oven slowly, so that the cycle requires from 24 to 30 hours. Allowing for Sundays, holidays, and time down for repairs, etc., it is estimated that the normal operation of an oven permits, on the average, about twenty charges per month.



Cars with charcoal from ovens and coolers

Charcoal.—At the end of a run steam is turned into the oven to drive out the gases and vapours which might cause an explosion. The door is opened, a cable is attached to the end car and the string of buggies is pulled into the first charcoal cooler. When exposed to the air the charcoal sparks and often bursts into flame. There is an appreciable loss by combustion as well as by fine charcoal dropping from the buggies into the bottom of the oven and on the ground. The charcoal cooler is a light steel oven similar in shape to the carbonizing oven. It is placed in line with the oven and is set on the ground outside having a door at each end and tracks so that the buggies can be run right through. The charcoal remains in the first cooler for 24 hours in order to radiate its heat through the closed shell to the air. The buggies are then pulled into a second cooler for another 24 hours. The charcoal must then stand in the open air under shed roofs for a further period of 48 hours, during which time the porous charcoal takes up oxygen and moisture to reach a state of equilibrium with the air. This ageing or seasoning of charcoal is an important step taken to obviate the danger of spontaneous combustion, especially in the case of “punky” pieces, and the traffic regulations regarding charcoal are very strict.

The charcoal is finally removed from the buggies, screened to eliminate the finer material or "breeze," loaded in freight cars in bulk or measured into large paper bags each holding one-third of a bushel ready for the retail domestic fuel trade. As a further precaution against fire the charcoal must be left standing in the freight cars for at least 12 hours before shipping. A storage shed is also provided to hold charcoal that cannot be shipped immediately. The fine charcoal that is separated is usually burned as fuel at the plant, but is sometimes sold for special purposes or briquetted as high-grade fuel. In the handling of the charcoal a certain proportion of incompletely carbonized pieces of wood called "bones" are met with and these are returned to the ovens for a second distillation.

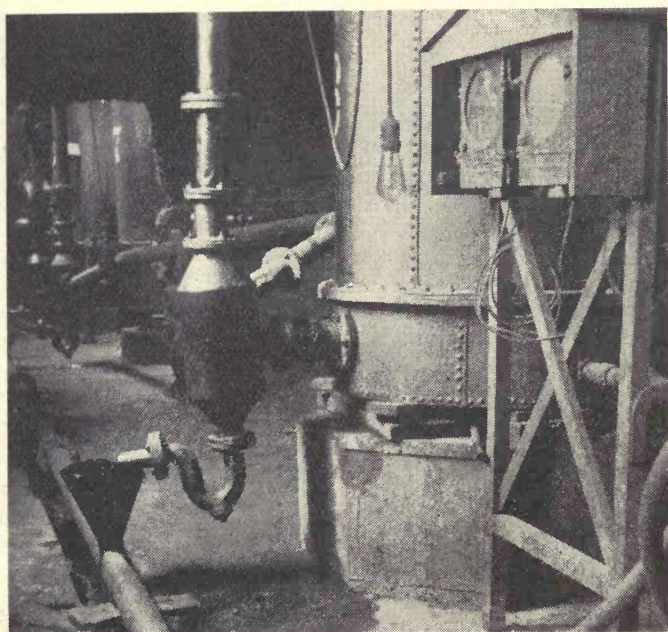
The charcoal actually produced during distillation probably totals 1,080 pounds per cord or 36 per cent by weight of the oven-dry wood. The recovered charcoal has suffered mechanical and combustion losses, while on the other hand it has gained in weight somewhat by the taking up of oxygen and moisture from the air. The final product averages about 1,040 pounds per cord or 34.6 per cent by weight of the oven-dry wood. The yield is calculated in bushels and amounts to about 52 Imperial bushels weighing 20 pounds each. The volume has been reduced to about one-half that of the original wood, so that charcoal weighs approximately two-thirds as much as an equal volume of oven-dry wood. The composition is approximately 5 per cent moisture, 3 per cent ash, 17 per cent volatile matter and 75 per cent fixed carbon. The ease of kindling, absence of smoke and low ash content make charcoal a very high-grade fuel. The calorific value is 12,500 B.T.U. per pound or higher, being nearly the same as coal. It is important to note that the fuel value of the original wood is largely concentrated in the final charcoal. The 1,040 pounds of charcoal obtained from a cord of wood contain a total of 13,000,000 B.T.U., equivalent to about 50 per cent of the calorific value of the original oven-dry wood or actually equivalent to from 55 to 65 per cent of the fuel value of the corresponding wood if burned in the moist condition.

Wood-gas.—To revert to the carbonizing operation, the gases and vapours issue from the large nozzles at the back or side of the oven and pass downward through a copper tubular condenser cooled by water in a cylindrical steel jacket. The non-condensable gases are trapped off at the bottom outlet into a pipe which branches to the oven furnace and to the steam-boilers, in order that the gases may be burned as fuel, where desired. In some cases the gases are first passed through water scrubbers for the recovery of small quantities of alcohol and other substances.

The wood-gas is rather indefinite in quantity and composition. Variations are obtained by different methods of firing and the composition changes during the progress of distillation. Furthermore, the flow of gas is seldom measured and analyzed. On the average the yield is perhaps 720 pounds per cord, or 24 per cent by weight of the oven-dry wood, although this conclusion has been reached by calculating the yield by difference based on dry gas left after accounting for total charcoal, pyro-ligneous acid, and tar. For purposes of calculation it is assumed that the average composition by volume is approximately 55 per cent carbon dioxide, 35 per cent carbon monoxide, 7 per cent methane, 2 per cent ethylene, and 1 per cent hydrogen. On this basis 1 cubic foot of gas weighs 0.1 pound at standard temperature and pressure (0°C. and 760 mm.), so that the total volume of gas would be 7,200 cubic feet per cord, under standard conditions of measurement, or 7,730 cubic feet, measured at the ordinary temperature of 20°C. and ordinary atmospheric pressure of 760 mm. On the same basis the calorific value figures 230 B.T.U. per cubic foot under standard conditions, equivalent to 215 B.T.U. under ordinary conditions, so that the total gas accounts for 6.5 per cent of the heating value of the original oven-dry wood. In the literature on the subject the figures are reported somewhat indefinitely, the higher yields being from 10,000 to 14,000 cubic feet per cord and the calorific values ranging from 150 to 500 B.T.U per cubic foot.

Raw Liquor.—The condensed mixture of pyroligneous acid and tar flows continuously from the bottom of the condenser through a simple gooseneck pipe, where the flow may be watched. This yellowish-green, ill-smelling "raw liquor" then runs through a copper main to a large wooden tub or "sump" set in the ground, which serves as a reservoir.

Pyroligneous acid-tar mixture is the third direct product from the carbonizing of wood and is merely intermediate to the recovery of the valuable products—tar, oils, acetate of lime, and crude wood alcohol. The weight is about 2,200 pounds from a cord of wood distilled at 25 per cent moisture content and may be considerably more from greener wood, or slightly less than this from more thoroughly seasoned wood. The volume averages about 210 Imperial gallons per cord, the specific gravity being about 1.05. The tar and oils, which for the most part will



Lower part of condenser, gooseneck, and temperature recorders

settle on standing, amount to at least 200 pounds. The pyroligneous acid analyses 5 to 7 per cent acetic and other acids by weight and 4 to 4½ per cent methyl alcohol and related substances by volume, the balance being largely water together with dissolved tar and 2 or 3 per cent of organic impurities which carry over into the final products. Water originating from 25 per cent moisture in the wood amounts to 1,000 pounds per cord, or nearly half of the total mixture. Water actually formed during distillation by decomposition of the wood substance amounts to perhaps 760 pounds per cord, or 25.4 per cent by weight of the oven-dry wood. The crude liquor formed from the actual wood therefore runs about 1,200 pounds per cord or 40 per cent by weight, while the total liquor is considerably more, depending on the amount of moisture in the wood distilled.

Hardwood Tar and Oils.—The raw liquor is often pumped to a series of wooden tanks for the purpose of allowing the tar to settle in order that the tar from the bottom may be drawn off to a wooden tar still for refining by steam distillation. It is common Canadian practice, however, to feed the whole raw liquor directly into the primary copper stills. These have a capacity of 3,000 or 4,000 gallons and are

supplied with a copper steam-heating coil, copper neck and copper tubular condenser. The liquor is fed continuously into one or two of these copper stills, whereby the alcohol, acid, water, and some organic impurities are separated by distillation from the free and dissolved tar. As there is roughly a ton of distillate per cord of wood, the steam required is 2,000 pounds or the equivalent of about 300 pounds of coal as fuel. The tar accumulates in the still, and at intervals the feed of liquor is switched to another copper still and the tar is "boiled" or steamed by admitting live steam through a jet or ring to drive off the last portions of acid and light oils. The steamed tar is drawn off to a storage tank, leaving the still ready for continuous distillation again, so that in this way the two or three copper stills are operated in rotation. The tar is ordinarily fed under the steam-boilers or used elsewhere at the plant as fuel.

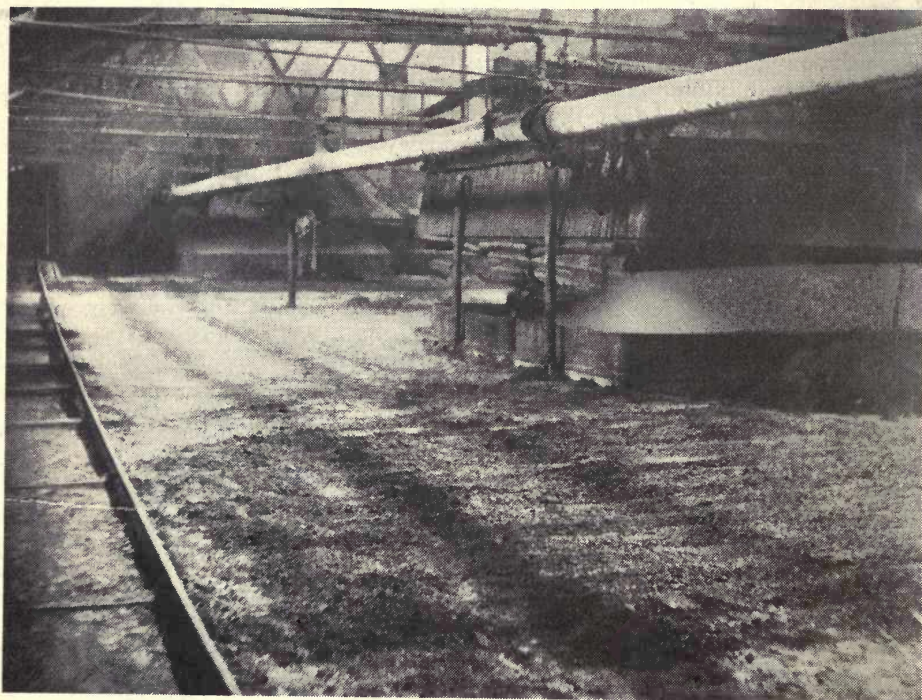
The hardwood tar totals about 175 pounds per cord or 16 Imperial gallons at approximately 1.1 specific gravity. The tar is seldom analyzed and is an indefinite, complex mixture of phenol and creosote bodies, hydrocarbons, and many undetermined compounds. The various tar oils, known as "light oil," "heavy oil," "creosote oil," and "acid oil," are separated farther along in the process and total about 25 pounds per cord or nearly 3 Imperial gallons. These oils are lighter than tar and have a higher fuel value, and lend themselves to profitable recovery for a variety of uses. The combined yield of tar and oils is about 200 pounds per cord or 6.7 per cent by weight of the oven-dry wood. The calorific value averages about 14,000 B.T.U. per pound, so that the total fuel value is 11 per cent of the original wood.

Acetate of Lime.—The distillate from the copper stills amounts to about 200 Imperial gallons per cord of wood and is collected in separating tanks for the drawing off of light and heavy oils. The liquor by this time is a fairly pure aqueous solution of acetic acid and alcohol. The next operation introduces the only real chemical treatment into the process and involves the fixation of the acetic and other acids by neutralizing with lime. The mixing tub is built of wood and is usually from 12 to 14 feet in diameter and 4 feet high, having a heavy wooden stirring arm turned slowly by motor. Slaked lime is slowly added to the liquor in the tub until the free acid has been converted to calcium acetate and a slight excess of lime provided to decompose most of the methyl acetate in order that it may be recovered as methyl alcohol and acetate of lime. This neutralization requires skilled attention in order that exactly the right amount of lime may be added, otherwise losses of product and troubles in operating are encountered. The operator is guided by the changes to a wine colour and finally to a yellow or straw colour, due to the presence of natural indicators in the mixture and the end point is confirmed by rapid laboratory test. The lime required is approximately 1 bushel or about 70 pounds of quicklime per cord of wood. $2\text{CH}_3\text{COOH} + \text{Ca}(\text{OH})_2 = (\text{CH}_3\text{COO})_2\text{Ca} + 2\text{H}_2\text{O}$.

The neutralized liquor is now free from corrosive acid and may be handled thereafter in cheaper iron equipment. The solution is next distilled in a large periodic steel still called a "lime lee" still, equipped with a copper steam-heating coil and a copper tubular condenser. The volatile alcohol is distilled over with more or less water vapour, the alcohol in the distillate running from 20 to 40 per cent for some time and gradually decreasing to zero. The distillate usually amounts to 90 Imperial gallons per cord and contains about 10 per cent alcohol by volume. The steam requirement of the lime lee still is therefore about 900 pounds of steam or the equivalent of 125 pounds of coal as fuel. The weak alcohol goes to storage tanks to await redistillation.

The liquor remaining in the lime lee still is a 15 per cent solution of calcium acetate and amounts to about 1,400 pounds or 135 Imperial gallons per cord. The acetate liquor is blown or pumped to a steel settling tank in which excess lime and other insoluble impurities settle out. The clear solution is then drawn off and the sludge is filtered and washed. The acetate solution goes to flat, steam-jacketed evaporating pans located above the ovens and the water is carefully evaporated until

the acetate has been "seeded down" to a thick mass of crystals. For this operation it will be seen that the steam required is about 1,400 pounds, equivalent to 200 pounds of coal as fuel. The wet acetate is then shovelled out on the "drying floor" built of brick, tile or concrete over the tops of the ovens and the material is turned over from time to time for thorough drying by the waste heat. This "grey acetate of lime," in coarse granular form, is now ready for sacking and shipment.



Floor (over ovens) for drying acetate of lime

In various American and European plants the French Huillard drying process is now employed to advantage. The acetate liquor is fed continuously to cylindrical rotary evaporators of iron heated internally by steam. A thin film of liquor is carried up on the outer surface of the shell, most of the water evaporated and the pasty acetate scraped into a wooden trough through which passes a chain conveyor. The acetate paste is carried to the feed trough of the Huillard belt dryer. Passing up through the trough is an endless woven wire belt, somewhat resembling the ordinary bed spring, and this carries a coating of acetate up and down between baffles through a brick drying chamber against a counter current of hot gases. The dry acetate is finally shaken off the belt by making several sharp turns over idlers and the finished product is ready for sacking. The method is continuous and labour-saving. The hot gases for drying should be fairly clean, and may be supplied by burning hardwood tar in a small furnace adjoining the drying chamber.

In connection with evaporating acetate liquor the development of multiple-effect evaporators should also be mentioned, although they are not yet in use in Canadian plants. A typical example is the quadruple-effect evaporator for primary distillation of pyroligneous acid in the first and third effects, and evaporation of acetate liquor in the second and fourth effects. Low-pressure exhaust steam heats the first effect, alcohol-acid-water vapour from the pyroligneous acid heats the second effect, water vapour from the acetate liquor heats the third effect, pyroligneous acid vapour

heats the fourth effect, and water vapour from the acetate liquor of the fourth effect is drawn into a jet condenser to maintain the highest vacuum. The combined pyro-ligneous acid distillates coming over from the first and third effects are ready for neutralization with lime and removal of alcohol in a lime lee still, while the thin tar remaining in these effects goes to the wooden tar still. The concentrated acetate liquor drawn from the second and fourth effects is fed to drum evaporators and Huillard dryers. The arrangement is subject to considerable variation and the above is only a brief outline of operation. While the system has all the advantages of economy in steam consumption, the apparatus is expensive to instal and more difficult to operate than the simple copper stills and evaporating pans. At the same time the evaporation of one-half ton of moisture from a cord of wood in the carbonizing oven and the subsequent double evaporation of a ton or more of liquor to separate the final acetate of lime and crude wood alcohol are heavy fuel items in the ordinary process, and improved efficiency in preparing the crude products is receiving closer attention in the industry.

Grey acetate of lime averages about 210 pounds per cord in Canadian practice, this yield being very favourable, compared with yields elsewhere. This is equivalent to an acetic acid yield of about 130 pounds per cord, or 4.3 per cent by weight of the oven-dry wood. Acetate of lime is sold in the trade on the basis of 80 per cent calcium acetate, while the actual composition of the product averages about 82 per cent calcium acetate, 4 per cent moisture, and 14 per cent organic impurities and excess lime. A small proportion of propionic acid and other higher fatty acids are present. The acetic acid equivalent in 80 per cent acetate of lime is nearly 61 per cent by weight.

At this point reference should be made to the earlier practice and to special cases at the present time whereby crude "brown acetate of lime" is produced. Pyro-ligneous acid, after settling out the tar, is neutralized directly with lime without primary distillation in copper stills. The alcohol is then distilled off in lime lee stills and the acetate solution is used for special purposes or evaporated. The brown acetate contains only 65 to 70 per cent calcium acetate and has a large proportion of organic impurities arising from the dissolved tarry bodies present in the raw pyro-ligneous acid.

Crude Wood Alcohol.—The weak alcohol distillate obtained from the lime lee still in the ordinary process must be rectified to concentrate the alcohol for shipment. The 10 per cent alcohol is fed to a steel alcohol still equipped with copper steam coil, copper fractionating column, separator, and condenser, in which the alcohol distils over and the water is left behind to be discharged. In this operation the steam requirement is comparatively small. From the "heads" and "tails" of the distillate small amounts of oil are separated. In Canadian plants the product is usually 95 per cent crude wood alcohol, while in the United States the alcohol is often weaker and is commonly sold on the 82 per cent volume basis. The alcohol is stored in steel tanks and finally shipped in tank cars to central refineries.

Crude wood alcohol on the 95 per cent volume basis averages about 8.5 Imperial gallons per cord in Canadian practice. The specific gravity is approximately 0.82, so that the yield is 70 pounds per cord or 2.3 per cent by weight of the oven-dry wood. This is equivalent to 11.8 U.S. gallons of 82 per cent alcohol per cord and is rather better than the results given by many plants to the south. The ordinary method of specifying the strength is to determine the specific gravity of the product and to report the corresponding percentage by volume from ethyl alcohol tables, although this is not strictly accurate for the equivalent methyl alcohol mixture. The composition of 95 per cent crude wood alcohol averages on the volume basis approximately 77 per cent methyl alcohol, 10 per cent acetone, 5 per cent methyl acetate, aldehydes, etc., 5 per cent oils, and 3 per cent water. The exact analysis is difficult to state, as there are variations with practice, and the mixture contains numerous chemical compounds, including some of indefinite composition.

Fuel.—After the wood, fuel is the important raw material required in a crude factory. Under average conditions throughout the year in a northern climate such as Canada with equipment of the type now installed, the total coal amounts to about 1,000 pounds per cord of wood distilled. In conjunction with this the wood-gas is equivalent to about 120 pounds of coal per cord and the tar to about 210 pounds, or together a total of 330 pounds coal equivalent. In terms of coal consumption the carbonizing ovens account for about 350 pounds per cord, the copper stills 300 pounds, the lime lee stills 125 pounds and the acetate evaporators 200 pounds, while the alcohol stills, steam-engines, pumps, heating system, etc., take the remaining 355 pounds.

DERIVED PRODUCTS

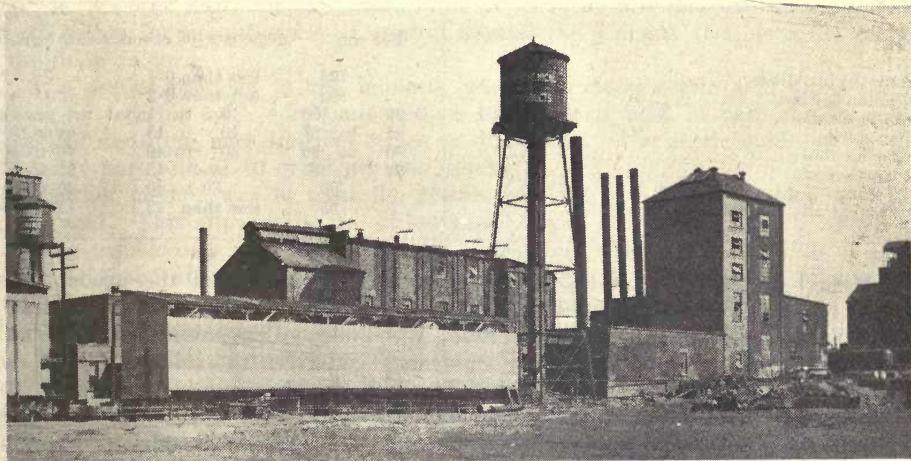
While some of the crude distillation products, such as charcoal, wood-gas, and tar, are utilized in their original forms, the crude wood alcohol and acetate of lime must be further manufactured to obtain the derived products for final use. Crude wood alcohol is redistilled, to give refined methyl hydrate, acetone-alcohol mixtures, and by-product oils. Acetate of lime is largely used for the production of either acetic acid or acetone, while acetate solution may be used for making sodium acetate. These simple derived products are in turn used in other processes to a considerable extent for the production of related chemicals, which may be further converted into a whole series of final products. Refined methyl hydrate is the source of formalin. Acetic acid is used in the manufacture of numerous organic and inorganic acetates, such as methyl acetate, ethyl acetate, lead acetate, iron acetate, etc. Acetone may be converted into iodoform or chloroform. Sodium acetate is used for making acetic anhydride, which in turn produces cellulose acetate for airplane dope, non-inflammable films, and one variety of artificial silk. Hardwood tar and oils are in some cases fractionated and then manufactured into "beechwood creosote," flotation oils, and wood preservatives. These examples by no means exhaust the list of derived products originating in hardwood distillation. The more important processes which are sometimes carried out under the control of hardwood distillation companies are outlined below.

REFINING OF CRUDE WOOD ALCOHOL

In Canada the wood alcohol is refined in a central distilling plant to which the crude alcohol is shipped in tank cars from the scattered crude distillation plants. In the United States most of the crude wood alcohol is redistilled in central refineries which are not under the control of the wood distillers, although several large hardwood distillation plants have their own refineries on the ground. The main equipment of a refining plant includes a series of large copper column stills, storage tanks, and steam-boilers. Distillation is a highly developed process requiring complicated apparatus and expert attention. On the other hand, labour is a small factor, and raw materials are moderate items. Coal is used to generate the steam for distillation purposes, water is needed for boilers and condensers, and chemicals such as caustic soda and sulphuric acid are purchased in small quantities for removing impurities from the crude alcohol.

Crude wood alcohol is a pale yellow or brownish liquid and is a variable mixture of several volatile substances of value, together with numerous impurities, some of which are indefinite in composition. On the 95 per cent basis the composition is usually from 75 to 80 per cent methyl alcohol, 8 to 12 per cent acetone, 2 to 4 per cent methyl acetate, 2 to 3 per cent aldehydes and related compounds, 2 to 4 per cent water and 5 to 10 per cent higher alcohols (allyl, propyl, butyl, amyl, etc.), oils, amines, tarry substances, etc. Methyl alcohol boils at 64.5° C., acetone at 56.4° C., methyl acetate at 54° C., acetaldehyde at 20.8° C., and allyl alcohol at 97° C. These differences in boiling points allow fairly sharp separations of the main constituents by fractional distillation. The chief drawback is that the acetone fraction carries

with it a large proportion of methyl alcohol, due to the formation of a mixture of constant boiling point. Chemical treatment with alkali, such as caustic soda, is used in the still to remove the aldehyde "heads" by forming aldehyde resins, to decompose some of the methyl acetate and to neutralize any acids. In a special lead-lined section of the still the vapours are brought in contact with sulphuric acid to remove amines and other impurities of alkaline nature. The stills are usually of the continuous type, rather than periodic, and include purifying column, exhausting column, rectifying column, dephlegmators, condensers, and other attachments.



Canadian refinery, showing house for alcohol stills, formaldehyde plant, and alcohol tanks

Refining practice varies with the market requirements, the type of still, the grade of crude alcohol and other conditions. Sometimes several redistillations are employed to obtain the final products. The following outline will serve as a guide to common Canadian practice. On the first distillation of the 95 per cent crude wood alcohol in a continuous column still the light fraction amounts to about 35 per cent and consists of acetone-alcohol running 30 per cent acetone, the middle fraction amounts to 50 per cent and consists of methyl alcohol running about 0.5 per cent acetone ("formalin-alcohol" or "crude Columbian spirits"), and the heavy fraction amounts to about 10 per cent and consists of allyl alcohol, oils, etc., mixed with some methyl alcohol. Redistillation of the first fraction produces a moderate amount of heads running high in acetone and a large amount of methyl alcohol containing about 10 per cent of acetone. Redistillation of the second fraction (crude Columbian spirits) produces a moderate amount of heads containing several per cent acetone, a large amount of pure methyl alcohol and Columbian spirits (frequently termed, incorrectly, "Columbian" spirits) running less than 0.2 per cent acetone, and a small amount of oils consisting of higher alcohols, etc. The various fractions are isolated, or mixed, or redistilled, as desired, in order to obtain the largest yields of marketable products.

The following table represents in a general way the commercial fractions that are separated for the various requirements of the trade. The name of each product gives some idea of its nature. The "alcohol equivalent" is based on the specific gravity referred to ethyl alcohol tables and is an indication of the content of methyl alcohol, acetone, etc. The acetone content is a common specification and is given on the weight basis (grams per hundred cubic centimetres). The bromine number is

often specified to show the amount of unsaturated compounds present as impurities and is defined as the number of cubic centimetres of alcohol mixture necessary to absorb 0.5 grams of bromine.

Table 2—Products from Crude Wood Alcohol

Product	Alcohol equivalent	Acetone content	Bromine number
	Per cent	gms. per 100 ccs.	ccs. to 0.5 gr. Br.
Pure methyl hydrate.....	100	less than 0.1	.....
Columbian spirits.....	100	less than 0.2	.....
Formalin-alcohol.....	99.5 to 100	0.5 to 1	.....
Shellac spirits.....	95 to 97	10 to 15	over 100
Acetone-alcohol.....	90 to 95	30 to 40	40 to 50
Acetone-alcohol.....	90 to 95	over 45	25 to 30
Royal spirits (for burning).....	90	30 to 40	40 to 50
Government alcohol (for denaturing).....	95	less than 12	15 to 30

“Methyl hydrate” (coupled with the word “poison”) is the official name required by law in Canada to designate methyl or wood alcohol, while “methanol” is the official name in the United States. Wood alcohol is poisonous and highly dangerous to drink, and these special names have been given to avoid confusion with ordinary ethyl or grain alcohol, which is used in intoxicating beverages. “Pure methyl hydrate” and “Columbian spirits” are the usual Canadian terms for methyl alcohol of highest purity, while other names such as “Diamond spirits,” “Columbian spirits,” etc., are used in the United States and elsewhere. “Formalin-alcohol” is the grade used for making formalin, “shellac spirits” are used as solvents in the shellac and varnish industries. “Acetone-alcohol” is the common term for mixtures of acetone and methyl alcohol, although “methyl acetone” is often used, especially in the United States. “Royal spirits” is the grade used for burning in alcohol lamps and is a substitute for ordinary “methylated spirits,” consisting of ethyl alcohol mixed with considerable methyl alcohol denaturant. “Government alcohol” is the grade specified by the Canadian and British Governments for denaturing ethyl alcohol. “Oils” are the by-products of the refining process and consist of allyl alcohol, etc.

Refining involves a loss of about 5 per cent of aldehydes, etc., and also eliminates the water, so that the yield of products is usually from 90 to 95 per cent of the volume of 95 per cent crude wood alcohol distilled.

FORMALIN

The conversion of methyl alcohol into formaldehyde is carried out at the alcohol refinery in Canada. The grade of methyl alcohol is sometimes called “formalin-alcohol” and contains about 0.5 per cent acetone. The apparatus includes alcohol evaporator, air feed, reaction tubes, condensers, and scrubber. A carefully regulated mixture of methyl alcohol vapour and air passes continuously through a series of tubes each containing a 4-inch copper spiral of wire mesh. The temperature in the reaction zone is maintained between 400° and 500°C. and the copper catalyzer brings about the oxidation of methyl alcohol to formaldehyde in the presence of the air ($2 \text{ CH}_3\text{OH} + \text{O}_2 = 2\text{HCHO} + 2\text{H}_2\text{O}$). The resulting vapours and gases (formaldehyde, water, methyl alcohol, nitrogen, etc.) are fractionally condensed in such a way as to recover the commercial formaldehyde direct, while the excess methyl alcohol is finally condensed for recovery and the discharge gases are scrubbed with water.

Formalin is the commercial product and is sold on the basis of 40 per cent formaldehyde by volume. The approximate composition by weight is 37 per cent formaldehyde, 15 per cent methyl alcohol (left in for stability) and 48 per cent water. The yield of formalin is about 150 pounds from 100 pounds of methyl alcohol.

ACETIC ACID

The manufacture of the various grades of acetic acid from acetate of lime is carried out at special plants operated by the hardwood distillation companies and also at independent chemical plants. As acetate of lime is a convenient material to ship, the practice has been to transfer this acetic acid raw material to domestic or export points for manufacture at central plants. In Canada the Montreal refinery is the main factor.

The earlier practice in the industry was to produce acetic acid from sodium acetate by treating with sulphuric acid or hydrochloric acid in cast-iron or copper stills, and distilling with indirect steam or direct fire. The acetic acid coming over was fairly pure and of 80 or 90 per cent strength.

Another method was to treat the acetate of lime with liquid or gaseous hydrochloric acid. This allowed the use of low-grade brown acetate of lime, the impurities not being troublesome with the moderately strong acid used. The high cost of hydrochloric acid, the dilution of the acetic acid, and the heavy depreciation of apparatus caused this process to give place to the modern sulphuric acid method.

As already mentioned, grey acetate of lime contains about 80 per cent calcium acetate and a small proportion of calcium salts of higher acids, such as propionic, butyric, etc., while the balance is made up of impurities in the form of tarry bodies, soluble carbohydrates, aldehyde resins, excess lime, and moisture. The process is based on the liberation of acetic acid by strong sulphuric acid and the separation of volatile acetic acid by distillation. $(\text{CH}_3\text{COO})_2\text{Ca} + \text{H}_2\text{SO}_4 = 2 \text{CH}_3\text{COOH} + \text{CaSO}_4$. Conversion is carried out in a cast-iron, steam-jacketed "decomposer" about 6 feet in diameter by 4 feet high. There is a heavy stirrer, driven from above, a man-hole feed at the top, and a man-hole discharge near the bottom. The vapour outlet pipe at the top leads to a dust collector, a non-corroding "duriron" condenser, and a storage tank. A vacuum pump is attached beyond the condenser to allow distillation of the acetic acid under reduced pressure. The heating jacket is supplied with live steam and the decomposer is lagged on the outside. Theoretically 100 pounds of 80 per cent acetate of lime require 50 pounds pure sulphuric acid, while practically it is necessary to use slightly more than this equivalent. The usual charge is 1,200 pounds acetate of lime and about 650 pounds commercial sulphuric acid. The substances gradually interact to form acetic acid and calcium sulphate. The stirring arm keeps the mixture in motion, the indirect heat raises the acetic acid to the boiling point, and the vacuum of 5 or 10 inches of mercury facilitates the distillation of the crude product. At first the acetate remains in granular form, then becomes a soft pulp, then a stiff paste, and finally an easily stirred powder. The acid vapours are condensed and the crude acetic acid mixture is collected in a storage tank. The operation usually takes about 6 hours. The crude calcium sulphate residue discharged from the bottom man-hole at the end of the run amounts to about 75 pounds per 100 pounds acetate of lime. This is a waste product and consists of calcium sulphate with small quantities of calcium sulphite, calcium sulphide, free sulphuric acid, unconverted calcium acetate, and organic impurities.

The crude acetic acid amounts to about 75 pounds per 100 pounds acetate of lime and is of 80 per cent strength. At this stage the actual acetic acid yield is therefore 60 per cent, or very close to the theoretical amount. The impurities are water, higher organic acids, sulphurous acid, organic matter, etc. The water content originates from the moisture in the acetate of lime, water in the sulphuric acid, and water formed by decomposition of organic matter in the presence of strong sulphuric acid. The sulphurous acid is formed by the action of sulphuric acid on organic

impurities. It is necessary to purify the crude acetic acid by redistillation. This refining process is carried out in a periodic still heated by a steam-coil and fitted with a duriron fractionating column. A typical example is a charge of 1,000 gallons of crude acetic acid, yielding 200 gallons of "heads," running 65 per cent acetic acid; 300 gallons of "technical" acid, running 75 per cent; 325 gallons of refined acid, running 80 per cent; 100 gallons of "tails," running 90 per cent; and 75 gallons of residue, running 70 per cent. The heads and tails are mixed with a fresh batch of crude acetic for redistillation, while the middle fractions are pure enough to meet the tests required by the trade. The residues from several distillations are saved for a special rerunning to recover the acetic acid content. The commercial recovery of acetic acid is from 92 to 95 per cent of theoretical, amounting to 55 or 57 pounds of actual acetic acid per 100 pounds acetate of lime.

The ordinary commercial grades are 80 per cent, 56 per cent, and 28 per cent acetic acid, and the two last-mentioned products are obtained by diluting 80 per cent acid with water. These grades are usually shipped in oak barrels coated with paraffin. The manufacture of glacial acetic acid over 99 per cent requires further treatment. The stronger fractions from crude acid distillations are redistilled in a copper-column still, fitted with acid-resisting condenser in such a way as to obtain a concentrated and highly purified product at the last end of the run. Chemical purification with potassium permanganate is sometimes employed to remove impurities, and a second distillation may be necessary to raise the strength of the acid.

ACETONE

The production of acetone from acetate of lime was greatly stimulated during the war on account of the British demand for cordite solvent, and during this period the bulk of the Canadian acetate production was used in this way in two central plants. Under normal conditions a minor proportion of the acetate is sufficient to meet the acetone requirements and there is at present one acetone plant operating in Canada in connection with the hardwood distillation industry.

Conversion of acetate of lime is based on decomposition to calcium carbonate and acetone by external heating in closed retorts. The main reaction is $(\text{CH}_3\text{COO})_2\text{Ca} = \text{CH}_3\text{COCH}_3 + \text{CaCO}_3$. As acetate of lime contains only 80 per cent of calcium acetate, the impurities have a considerable effect on the process. The tarry bodies and aldehyde resins decompose into gases, oils, etc. The calcium salts of organic acids above acetic form ketones higher in the series than acetone. Other conditions, such as local overheating of acetate and vapours, cause side reactions resulting in the lowering of the acetone yield. Water, amines, and other impurities are also distilled over and contaminate the product. The process is carried out in various types of apparatus, as described below.

1 *Kettles*.—The older unit, which in some cases was applied to good advantage during the war emergency, consists of a cast-iron kettle, approximately 6 feet in diameter by 5 feet deep, fitted with stirrer and equipped with man-hole feed at the top and man-hole discharge near the bottom. The kettles are arranged in a battery in brick settings and fired with natural gas or other fuel. Each kettle has a capacity of about 550 pounds acetate and the cycle required about 5 hours. Considerable lime dust is carried over by the acetone vapours into the condenser and receiving tank, and the removal of calcium carbonate residue is a dusty operation. The installation has the advantage of cheapness, but is not generally used on account of lower efficiency.

2 *Rotary Retorts*.—The most recent development is the horizontal rotary cast-iron retort about 6 feet in diameter by 8 feet long. A man-hole at one end serves for charging and discharging. The retort revolves slowly at about one revolution per minute, inside baffles help the mixing, and the vapours escape through hollow trunnions. The retorts are supported in brick settings and fired with coal, the fuel

consumption being from 200 to 250 pounds of coal per 100 pounds of acetone produced. Each retort holds a charge of 1,000 pounds acetate and the cycle requires about 8 hours. The temperature of the mass is under good control and the yield of acetone is favourable.

3 Meyer Ovens.—The equipment used in Canada is the Meyer oven, which was first developed in Europe some years ago. These rectangular, steel oven retorts are about 2½ feet high by 3 feet wide by 10 feet long and are installed in pairs in a brick-work muffle furnace, designed for temperature control. The fuel requirement is about 250 pounds of coal per 100 pounds of acetone. The acetate is spread about 1 inch deep on shallow steel trays which are piled on retort trucks and wheeled into the ovens. The charge for each oven is about 1,000 pounds of acetate and the cycle requires about 8 hours. The brick setting holds the heat from run to run and firing is done with care so that the heat is well distributed by means of ports and flue passages around the oven. Decomposition of the acetate is accomplished in the main stage at a maximum flue-gas temperature of about 400°C. Live steam is injected into the oven at a slow rate for better heat distribution and steady removal of acetone vapours. At the end of the run a larger supply of steam is admitted to sweep out the inflammable gases before discharging the oven.

The crude acetone collected from the condensers is a dark-brown liquid containing acetone, methyl ethyl ketone, higher ketones, and oils, aldehydes, amines, acids, and tarry matter, etc., as well as considerable water originating from the moisture in the acetate and from the steam used in the ovens. In the settling tank a thin layer of crude oil separates at the top and is collected for separate refining, while the crude acetone of 35 or 40 per cent strength is drawn off from the bottom. Refining practice varies more or less, but the following description will serve as a guide. Separation of the final products is based on fractional distillation in column stills either of the periodic or continuous types, coupled with chemical purification.

The crude acetone is distilled in periodic copper stills, using caustic soda to neutralize acids and decompose aldehydes; and by passing the vapours through sulphuric acid in a separate section of the column alkaline impurities, such as amines, are removed. This operation separates about 40 per cent of the acetone in pure form, 40 per cent of commercial grade and 20 per cent of impure heads and tails. The commercial grade is redistilled in much the same way to obtain pure acetone and small amounts of impure fractions, which are collected for further distillation. The heads and tails mentioned above are treated with water and common salt to separate the oils, and each of the two layers is purified by further distillation. The various acetone fractions are gradually rerun with succeeding batches until purified to the high quality required by the trade. The standard specification is that used by the British War Office for cordite solvent. The crude oil from the first settling tank and the oils separated at different stages are also purified by a series of distillations in a separate oil still. For the lighter fractions which are miscible with water it is necessary to add calcium chloride to absorb the water content before redistillation. The oil products are not sharply defined, but are usually known as methyl ethyl ketone, white ketone oil (or light acetone oil), and yellow ketone oil (or heavy acetone oil).

The yield of acetone varies from 18 to 20 pounds per 100 pounds of acetate of lime. Theoretically the yield should be 29.4 pounds of acetone per 100 pounds of acetate of lime containing 80 per cent calcium acetate, and this large discrepancy between practical and theoretical yields is the subject of continued investigation on the part of those engaged in the industry. The total yield of refined ketone oils is about 4 pounds per 100 pounds of acetate, equivalent to 20 per cent of the acetone yield. The tarry "ketone residue" from the stills amounts to 1 or 2 pounds per 100 pounds of acetate, and finds some use as fuel, etc. The crude calcium carbonate from the acetone retorts totals from 50 to 55 pounds per 100 pounds of acetate and is discharged as a waste product, although in some cases it is disposed of as a fertilizer.

SODIUM ACETATE

A good deal of the sodium acetate of commerce is made by the simple process of neutralizing acetic acid with soda ash and crystallizing the acetate by evaporation. Weak acetic acid fractions are sometimes available for this purpose. $2 \text{CH}_3\text{COOH} + \text{Na}_2\text{CO}_3 = 2 \text{CH}_3\text{COONa} + \text{H}_2\text{O} + \text{CO}_2$.

Another important process is directly connected with the crude hardwood distillation plant. The desired amount of 15 per cent acetate of lime solution coming from the lime lee still is treated in a mixing tank with the calculated amount of soda ash to convert calcium acetate into sodium acetate and to precipitate calcium carbonate.

$(\text{CH}_3\text{COO})_2\text{Ca} + \text{Na}_2\text{CO}_3 = 2\text{CH}_3\text{COONa} + \text{CaCO}_3$. The theoretical requirement of pure sodium carbonate is 53.5 pounds per 100 pounds of 80 per cent acetate of lime, or 39 pounds per 100 pounds of sodium acetate crystals $(\text{CH}_3\text{COONa} \cdot 3\text{H}_2\text{O})$. The actual requirement of commercial soda ash is somewhat higher, especially in terms of recovered sodium acetate. When the reaction is complete the calcium carbonate sludge is separated in a filter press and discharged as a waste product. The crude sodium acetate solution is concentrated in an evaporator or in steam-heated pans and is allowed to cool in large steel crystallizing pans. The mother liquor is drained off for further treatment, while the sodium acetate crystals are shovelled into a conveyor leading to a centrifuge. If necessary, the material is redissolved and recrystallized to obtain a pure product and the dry sodium acetate crystals from the centrifuge are packed in barrels ready for the market. The crystals contain about 60 per cent anhydrous sodium acetate and the equivalent of 44 per cent acetic acid, showing a high degree of purity. Theoretically the yield of crystallized sodium acetate $(\text{CH}_3\text{COONa} \cdot 3\text{H}_2\text{O})$ should be 138 pounds per 100 pounds of 80 per cent acetate of lime, but the actual yield varies from 100 to 120 pounds, depending on the efficiency of recovery from the mother liquor. The process involves some difficulties in the removal of tarry impurities and as yet is not extensively practised in this country.

ACETIC ANHYDRIDE

The production of acetic anhydride, $(\text{CH}_3\text{CO})_2\text{O}$, may be mentioned on account of the process being operated to some extent in connection with the refining of wood-distillation products. Up to the present time the manufacture of acetic anhydride has been of little importance in Canada. The starting point is usually sodium acetate which has been dehydrated and purified by fusing. One method involves the treatment of sodium acetate with sulphur monochloride, while a more satisfactory method is the use of phosphorus trichloride or pentachloride.

METHYL ACETATE

This product has also been made to some extent in connection with the wood-distillation industry in Canada. Methyl acetate is produced by combining methyl alcohol and acetic acid in the presence of sulphuric acid, or the process may be simplified by mixing methyl alcohol and acetate of lime and treating with sulphuric acid direct. The product is recovered by distillation. $(\text{CH}_3\text{COOH} + \text{CH}_3\text{OH} = \text{CH}_3\text{COOCH}_3 + \text{H}_2\text{O})$.

REFINING OF HARDWOOD TAR AND OILS

The hardwood tar and oils produced at the crude hardwood distillation plants are for the most part used directly as fuel. However, more and more attention is being given to the manufacture and marketing of valuable products from this large quantity of raw material. Certain oil fractions now find a profitable outlet and the prospects are promising for a further development of processes and products in this

branch of the industry. While the possibilities do not appear as great as in the case of coal tar, it is to be expected that considerable progress will be made. Hardwood tar is a very complex mixture of organic compounds and its composition is known only in a general way. In addition to heavy tarry bodies there are phenol and cresol compounds, hydrocarbons, oils, and other substances of indefinite chemical composition. No attempt will be made to give more than a brief discussion of the subject.

In the regular operations of the crude distilling plant there is a certain amount of fractionation of the tar and oils. The products known as light oil, heavy oil, creosote oil, and acid oil are separated in small quantities in connection with the distillations in copper stills, lime lee stills, and alcohol stills. These oil fractions may be used direct for certain purposes such as ore flotation, etc.

By distilling the hardwood tar at elevated temperatures in a fire a still more pronounced fractionation can be obtained. The distillate contains most of the creosote bodies, oils, and related substances boiling at moderate temperatures, while the residue is a thick pitch, which may be burned as fuel or used for special purposes. The creosote fraction may be further refined by a series of chemical treatments and redistillations to obtain several fairly well defined products. The acid nature of the phenol and creosote compounds allows the separation of these bodies by neutralizing with caustic soda or soda ash, dissolving in water and treating again with acid to recover the creosote oils. By a suitable combination of treatments there may be obtained such products as beechwood creosote and guaiacol (of importance in the drug trade), flotation oils (for ore flotation in the mining industry), and wood preservatives (for preservative treatment of shingles, poles, and other wood products).

PLANTS

The names, locations and capacities of the crude hardwood distillation plants and refining plants in Canada are given below. Reference is also made to conditions in the United States on account of the rather close commercial connection.

CRUDE DISTILLATION PLANTS

Table 3—Crude Hardwood Distillation Plants

Name	Location	Capacity
		Cords per day
Standard Chemical Co. Ltd.	Sault Ste. Marie, Ontario.	112
Standard Chemical Co. Ltd.	Longford Mills, Ontario.	84
Standard Chemical Co. Ltd.	South River, Ontario.	72
Standard Chemical Co. Ltd.	Thornbury, Ontario.	48
Standard Chemical Co. Ltd. (Wood Products Co. Ltd.)	Donald, Ont.	48
Standard Chemical Co. Ltd. (Canada Chemical Co. Ltd.)	Parry Sound, Ontario.	48
Standard Chemical Co. Ltd.	Cookshire, Quebec.	48
Standard Chemical Co. Ltd.	Fassett, Quebec.	48
Standard Chemical Co. Ltd. (Laurentian Chemical Co. Ltd.)	Lac Mercier, Quebec.	48
Standard Chemical Co. Ltd. (Weedon Chemical Co. Ltd.)	Weedon, Quebec.	24
Dominion Wood & Lumber Co. Ltd.	Trout Creek, Ontario.	20
Hodgson Bros. Chemical Co. Ltd.	Lindsay, Ontario.	20
		620

The nominal capacity of the 12 Canadian plants is 620 cords per day. As the carbonizing cycle averages over 24 hours and as the plants can never be maintained at rated capacity, it is figured that the maximum capacity is at the rate of 20 charges per month for each oven. On this basis the capacity is 12,400 cords per month or 148,800 cords per year, equivalent to about 500 cords per day at 300 nominal

working days per year. Actual performance has never been quite as high as the above estimates.

In the United States there are approximately 100 hardwood distillation plants with nominal capacities totalling about 5,500 cords per day. On account of an appreciable proportion of kiln plants and the lack of accurate information under changing conditions, it is not possible to give a close comparison with Canadian figures, but the equivalent capacity in the United States is probably about 5,000 cords per day.

REFINING PLANTS

The only wood alcohol refining plant in Canada is that of the Standard Chemical Company, Ltd., Montreal, Quebec. The capacity is sufficient to handle the total Canadian production of crude wood alcohol, which reaches about 4,000 Imperial gallons per day. The former refinery at Longford Mills, Ontario, has been dismantled. In the United States there are something like 20 wood alcohol refining plants scattered throughout the country.

Formalin is manufactured in Canada at the Montreal refinery of the Standard Chemical Company, Ltd. The normal capacity is about 3,000,000 pounds per year.

Acetic acid is produced from acetate of lime at the Montreal refinery of the Standard Chemical Company, Ltd., and at the plant of the Grasselli Chemical Company, Ltd., Hamilton, Ontario. The nominal capacity totals approximately 2,000,000 pounds of crude acetic acid per year. In the United States there are some 20 plants.

Acetone is produced from acetate of lime at the distillation plant of the Standard Chemical Company, Ltd., Longford Mills, Ontario. During the war a second plant was erected at this company's Sault Ste. Marie works and operated until the armistice. The combined capacity of these two plants is approximately 1,800 tons of acetone per year. In the United States there are 15 or more plants.

PRODUCTION AND DISPOSAL

PRODUCTION STATISTICS

The Dominion Bureau of Statistics has reported the following industrial census figures for the calendar years 1917 and 1918:—

Table 4—Wood Distillation, 1917

Materials used	Unit of measure	Quantity	Cost value at works	Value per unit of measure
			\$	\$
Raw materials—				
Hardwoods.....	cords	137,466	945,362	6.88
Partly manufactured materials—				
Lime.....	bush.	154,784	39,260	0.253
Caustic Soda.....	lb.	176,353	5,298	0.030
Sulphuric acid.....	lb.	955,861	9,255	0.009
Soda ash.....	lb.	282,395	5,195	0.018
Acetate of lime.....	lb.	20,990,429	711,574	0.034
Wood alcohol, crude.....	gal.	425,900	437,265	1.030
Other miscellaneous materials.....			16,652	
Total cost of materials.....			2,169,821	

Classes of Products	Unit of measure	Quantity	Cost value at works	Value per unit of measure
			\$	\$
Wood alcohol, crude (sold as such).....	gal.	934,874	980,316	1.049
Wood alcohol, refined (sold as such).....	gal.	615,087	818,065	1.33
Acetone-alcohol.....	gal.	214,548	285,348	1.33
Acetate of lime.....	lb.	27,440,947	945,232	0.034
Acetic acid, crude (sold as such).....	lb.	1,562,775	90,799	0.058
Acetic acid, refined (sold as such).....	lb.	168,676	38,458	0.228
Acetate of soda.....	lb.	301,406	47,019	0.156
Acetone.....	lb.	3,515,477	780,503	0.222
Formaldehyde.....	lb.	1,717,909	281,737	0.164
Ketone oils.....	lb.	1,276,266	196,135	0.154
Other acids.....	lb.	49,634	48,492	0.977
Methyl acetate.....	lb.	150,930	45,279	0.300
Other miscellaneous products.....	lb.	.....	127	.....
Charcoal.....	bush.	7,276,066	703,666	0.096
Total value.....			5,261,176	.....

Table 5—Wood Distillation, 1918

Materials used	Unit of measure	Quantity	Cost value at works	Value per unit of measure
			\$	\$
Raw materials—				
Hardwoods.....	cords	128,097	1,321,893	10.32
Partly manufactured materials—				
Lime.....	bush.	140,420	57,423	0.408
Caustic soda.....	lb.	186,900	7,709	0.041
Sulphuric acid.....	lb.	1,050,240	11,527	0.011
Soda ash.....	lb.	234,191	13,637	0.058
Acetate of lime.....	lb.	20,868,427	829,675	0.040
Wood alcohol, crude.....	gal.	1,081,837	1,071,227	0.99
Other miscellaneous materials.....	lb.	445,986	6,640	.....
Total cost of materials.....			3,319,731	.....

Classes of Products	Unit of measure	Quantity	Cost value at works	Value per unit of measure
			\$	\$
Wood alcohol, crude (sold as such).....	gal.	875,024	981,535	1.12
Wood alcohol, refined (sold as such).....	gal.	1,070,928	1,531,356	1.43
Acetate of lime.....	lb.	25,998,139	1,017,465	0.039
Acetic acid.....	lb.	1,772,223	170,173	0.096
Acetic anhydride.....	lb.	44,981	60,515	1.35
Acetate of soda.....	lb.	295,572	51,389	0.174
Acetone.....	lb.	3,458,810	909,570	0.263
Formaldehyde.....	lb.	1,154,902	159,263	0.138
Ketone oils.....	lb.	792,864	211,440	0.266
Methyl acetate.....	lb.	132,121	29,350	0.222
Other miscellaneous products.....	lb.	.....	537,460	.....
Charcoal.....	bush.	6,472,925	1,575,701	0.244
Repairs to machinery and plants by own employees.....			398,905	.....
Total value.....			7,634,122	.....

These records are not as clear as they might be, owing to the uncertainties regarding intermediate products. The primary products of hardwood distillation go through a succession of refining processes, and it is difficult to separate all the stages in terms of production statistics. However, the figures give a general idea of the production obtained in the industry during the latter part of the war. Earlier statistics are not available, and the more recent figures have not yet been compiled. It is understood that production fell off in 1919 to a basis of about 60,000 cords, recovered somewhat in 1920 to a basis of about 90,000 cords, and will probably not exceed half of this in 1921.

In the United States the Bureau of the Census, Department of Commerce, takes a census of manufactures every five years. The statistics for the period 1899-1919 are available in bulletin form, "Census of Manufacture: Chemicals and Allied Industries." As a rough basis of comparison it may be assumed that the production figures for the United States are about ten times the corresponding figures for Canada.

EXPORTS AND IMPORTS

The exports of acetate of lime, wood alcohol, and charcoal to different countries may be found in detail in the annual reports of the Department of Trade and Commerce, Part I, "Canadian Trade—Imports into and Exports from Canada." The total quantities and values of exports of Canadian produce during the fiscal years ending March 31, 1912-19, are summarized below:—

Table 6—Exports of Acetate of Lime

Fiscal Year	Quantity	Value	Calculated rate per 100 lb.
	lb.	\$	\$
1912.....	11,914,284	218,277	1.84
1913.....	15,018,951	311,376	2.07
1914.....	14,709,568	316,481	2.15
1915.....	15,139,007	269,591	1.78
1916.....	6,933,700	140,174	2.02
1917.....	9,538,300	311,419	3.26
1918.....	4,648,600	164,493	3.54
1919.....	4,328,600	203,084	4.60

Table 7—Exports of Wood Alcohol

Fiscal Year	Quantity	Value	Calculated rate per gallon
	Imp. gal.	\$	\$
1912.....	477,537	200,310	0.419
1913.....	839,493	309,625	0.369
1914.....	457,757	256,869	0.561
1915.....	500,338	231,283	0.462
1916.....	406,730	229,978	0.565
1917.....	500,067	411,288	0.823
1918.....	450,696	490,837	1.088
1919.....	327,313	606,550	1.853

Table 8—Exports of Charcoal

Fiscal Year	Value	Fiscal Year	Value
	\$		\$
1912.....	8,231	1916.....	25,467
1913.....	11,338	1917.....	50,277
1914.....	3,073	1918.....	14,060
1915.....	3,878	1919.....	9,522

Before the war Canada exported from 50 to 70 per cent of the total acetate of lime production, chiefly to Great Britain and other European countries and the United States. During the war period Great Britain received fairly large supplies, but the bulk of the acetate was retained in Canada and converted into acetone for export as cordite solvent. Exports of wood alcohol have usually ranged from 50 to 75 per cent of the total production, the chief markets being Great Britain and France. Only small quantities of charcoal are exported and the trade is almost entirely with the United States. The exports of derived products are not detailed in the government reports. Moderate quantities of acetic acid and acetone are shipped to Great Britain, United States and elsewhere; formaldehyde to France and other countries; ketone oils chiefly to the United States, and miscellaneous products to various countries.

Imports of hardwood distillation products into Canada are relatively small and are practically all from the United States. As in the case of exports, the classification of items in the reports of the Department of Trade and Commerce is not sufficiently extensive to show much detail.

The exports and imports of certain hardwood distillation products for the United States may be found in the annual reports of the United States Department of Commerce, Bureau of Foreign and Domestic Commerce, "Foreign Commerce and Navigation of the United States" for the fiscal years ending June 30. Before the war exports of acetate of lime represented from 40 to 60 per cent of the total production, and the chief markets were Belgium, Germany, the Netherlands, Japan, and Italy, in the order named. During the war the shipments fell to very much lower figures, the bulk of the acetate being retained for conversion to acetone and acetic acid. In normal times about 15 per cent of the wood alcohol production was exported, mainly to Germany, Great Britain, the Netherlands, Canada, and Japan. The quantities were maintained fairly well through the war, but were largely diverted to Great Britain and France. The exports of charcoal have been small and the trade is mostly with Canada. The exports of derived products are not recorded, but are probably small, compared with the shipments of primary products. Imports of hardwood distillation products into the United States are small and are practically all from Canada.

USES OF PRODUCTS

Charcoal in Canada is largely marketed for use as domestic fuel in cities within easy reach of the crude distillation plants. For this purpose the lump charcoal is usually distributed to the retail trade in paper bags, each holding one-third of a bushel. Lump charcoal is also used for making charcoal iron and in the United States this is the most important outlet. Charcoal also has other special uses as fuel to some extent. The screenings ("breeze") are burned at the distillation plant in some cases. Lump charcoal or breeze is used in the electric smelting of iron and nickel ores, and charcoal briquettes give promise of increased demand as high-grade fuel in dining-cars, hotels, etc. The other uses of charcoal are varied and more or

less important. The lump or powdered material is used for making gunpowder, chicken feed, artificial fertilizer and certain pigments, also as a deodorizer, absorbent of gases, decolorizer of liquids, insulator, etc.

Wood-gas is essentially a by-product and is burned at the plant under the retorts and steam-boilers. Minor uses, such as gas supply for the chemical laboratory, are also found in some cases.

Hardwood tar and oils are still in the by-product class for the most part. The tar is usually burned at the plant under the retorts and steam-boilers, or in furnaces for drying acetate of lime where belt dryers are installed. The various oils find some outlet in ore flotation, treating shingles, etc. The markets for hardwood tar and derived products are not well established, but the prospects are becoming more promising for the production and sale of beechwood creosote and guaiacol in the drug trade, wood preservatives, oils for ore flotation in the mining industry, binders for briquetting purposes, pitch for roofing felts, lubricating mixtures, and certain chemical derivatives.

Acetate of lime is an intermediate product and is practically all used as raw material for producing acetic acid or acetone, although small quantities are manufactured into sodium acetate and other acetates.

Acetic acid is one of the most important chemicals and has many uses. A large number of acetates are made, such as the acetates of lead (white lead), sodium, potassium, aluminium, iron, copper, and chromium. Acetic acid enters into the manufacture of methyl acetate, ethyl acetate, acetic anhydride, cellulose acetate, coal-tar dyes, drugs, and numerous other chemicals. It is also used in dyeing, tanning, photography, making artificial vinegar, and in many other ways.

Acetone is a colourless, volatile liquid of high chemical purity and is a widely used product. As a solvent it is used for making British cordite and other explosives, aeroplane dope, photographic films, artificial leather, celluloid, compressed acetylene, paints and varnishes, and for rubber recovery, etc. It also enters into the manufacture of chloroform, iodoform, and other chemicals. The ketone oils recovered with acetone from acetate of lime have special uses as solvents.

Crude wood alcohol furnishes a series of commercial products which have very extensive and well established uses. The purer grades of methyl hydrate are used as solvents in the manufacture of photographic films, celluloid, artificial leather, gas mantles, explosives, transparent soap, and many other products. Methyl hydrate also enters into the manufacture of formaldehyde, methyl acetate, coal-tar dyes, and other chemicals. The various acetone-alcohol fractions are important solvents for paints and varnishes, rubber, acetylene, etc. Acetone-alcohol is the most common denaturant for ethyl alcohol. It is also used in special ways for heating and lighting. Among the many other uses of methyl alcohol are to preserve specimens and to stiffen hats. The oils which are recovered as by-products in the refining of crude wood alcohol also have special uses.

COSTS

The subject of costs is difficult to discuss, owing to the great variations in conditions that exist. The wide fluctuations of the last few years make it still harder to arrive at representative figures. What the conditions will be during the next few years is also a matter of speculation. However, reference will be made to the more important items that enter into costs and to the ranges of values that have applied in the industry. In general it may be said that hardwood distillation was a fairly profitable business before the war. In 1914 the industry was depressed, and during the war there was a boom period, although profits were limited by government control. At present business is again dull.

PLANT INVESTMENTS

A crude hardwood distillation plant to produce charcoal, acetate of lime, and crude wood alcohol could be built before the war at a cost of from \$2,500 to \$3,000 per cord capacity per day. The cost of construction, equipment and labour rose rapidly until during the past year the estimates have been from \$6,500 to \$7,500 per cord capacity. The investment represented by a typical 100-cord plant has therefore ranged from \$250,000 to \$750,000 during the last ten years. It is not likely that new plants will be built until installation costs are again moderate. Small plants are naturally more expensive per unit production and it is considered that the size should be at least 50 cords per day for reasonable economy, and preferably 100 cords or more. The various buildings such as retort-house, still-house, boiler-house, repair-shop, pump-house, office, and laboratory, etc., account for 20 or 30 per cent of the total cost; the carbonizing equipment such as ovens, settings, cars, charcoal coolers, etc., from 20 to 25 per cent; the still-house equipment such as stills, columns, evaporators, acetate dryers, wooden tanks, steel tanks, iron and copper piping, etc., from 25 to 30 per cent; and the remaining items such as boilers, electrical units, reservoir, water-tanks, yard tracks, etc., from 20 to 30 per cent. The above figures do not include allowance for timberland and wood handling. Plants using cylindrical retorts cost somewhat less than oven plants, while kiln plants are of course very much cheaper.

Distilling plants for refining crude wood alcohol would probably cost at the present time \$50,000 to \$75,000 on the basis of handling the output of a 100-cord hardwood distillation plant, about 850 Imperial gallons of 90-95 per cent crude alcohol per day. A large central plant would be less expensive per unit capacity, although a smaller refinery, erected in conjunction with a crude distillation plant, has some advantages. The main items are buildings, copper stills and columns, iron tanks and steam-boilers.

Acetic acid plants are rather expensive and would probably cost at the present time from \$200,000 to \$250,000, on the basis of handling the entire acetate output of a 100-cord crude distillation plant or about 20,000 pounds of acetate of lime per day (yielding 11,000 pounds of actual acetic acid per day). The more important items are buildings, iron decomposers, column stills, condensers, vacuum pumps, tanks and boilers.

Acetone plants are somewhat more moderate in price and might be built under present conditions for \$100,000 or \$150,000, on the basis of handling the entire acetate output of a 100-cord crude distillation plant, or about 20,000 pounds of acetate of lime per day (yielding 4,000 pounds of acetone and 800 pounds of ketone oils per day). The main items are buildings, steel retorts, copper column stills, oil stills, condensers, tanks, and steam-boilers. The cost depends on the type of equipment and on the general scale of building costs, as in the case of the other conversion plants. As the installation costs of all these plants have been much lower in the past, it is to be expected that the estimates will again become more reasonable.

OPERATING COSTS

The cost of operation of a crude hardwood distillation plant varies greatly with conditions. With wood at about \$5 per cord and labour at pre-war figures, the operating costs were usually from \$8 to \$10 per cord of wood distilled. During the last few years the costs have risen to \$20 or more per cord in many cases. Large modern plants have a decided advantage and it is not unlikely that competition will force out of business some of the numerous small plants with their old-style equipment. Wood for carbonizing is the main item and has varied from \$5 to \$15 per cord during recent years. The charges include stumpage, cutting, splitting, stacking, hauling, railway transportation, and storage at the plant, together with interest on capital invested in timberlands, logging equipment, and wood during

storage. The importance of reducing wood costs and making economical use of wood waste will be apparent. Labour is the next item and it is here that the modern plants have made a considerable saving. The ordinary workmen include oven firemen, boiler firemen, still operators, acetate men, pipe fitters, mechanics, labourers in woodyard and oven-house, etc. In a large plant there is required one man for approximately two cords daily capacity, while in a small plant the proportion is nearer one man per cord capacity. The staff is comparatively small and includes superintendents, chemist, office-men, etc. Coal for ovens and boilers may be figured at about 1,000 pounds per cord of wood. Quicklime for making acetate of lime amounts to about 1 bushel (say 75 pounds) per cord. Water for boilers, condensers, and other purposes is roughly 20,000 gallons per cord. Electrical power is a moderate item. Repairs and supplies are comparatively small. Replacements form a heavy item of expense, recurring periodically as the life of much of the apparatus is extremely short. Depreciation is usually figured at 10 per cent, interest at 6 per cent, insurance at 2 per cent, and taxes up to 1 per cent. General overhead expenses such as administration, general management, and selling are variable but should not be high. It is impossible to divide the operating costs accurately among the primary products, as they are produced together in the carbonizing operation. However, by tracing through the process it will be seen that the charcoal must bear the expense of cooling and handling; acetate of lime, the cost of evaporating and drying; crude wood alcohol, the charges for concentration by distillation. Cost analyses of this kind are useful in relation to selling prices of the crude products to determine the proper practice which should be followed at the plant under the conditions prevailing at the time.

The cost of refining crude wood alcohol is hard to specify, but under normal conditions is probably from 10 to 15 cents per Imperial gallon of 90-95 per cent crude alcohol treated. The main items are steam, plant carrying charges, labour, and chemicals.

The production of acetic acid requires nearly 2 pounds of acetate of lime per pound of actual acetic acid obtained, and the cost of this raw material is the controlling factor in the price of the acetic acid. The conversion charges are roughly from 2 to 4 cents per pound of actual acetic acid produced, depending on conditions. Labour is a small item. Sulphuric acid is important and about 1 pound of the commercial grade is required per pound of acetic acid produced. Steam is needed in moderate quantity for the various distillations, and water for boilers and condensers. Depreciation is often figured as high as 15 per cent, interest usually at 6 per cent, insurance at 2 per cent, and taxes up to 1 per cent. Incidental and overhead expenses are low. Shipping containers such as wooden barrels and glass carboys are rather expensive, but are usually charged extra.

The manufacture of acetone requires at least 5 pounds of acetate of lime per pound of acetone obtained, and the cost of the acetate largely determines the price of the acetone. The conversion charges are approximately from 2 to 4 cents per pound of acetone produced, making allowance for the ketone oil by-products which share the burden. Labour is a moderate item. About 2.5 pounds of coal for the retorts are required per pound of acetone, and considerable steam is used in the stills, etc. Water is needed for boilers and condensers. Chemicals, repairs, electrical power, and contingencies are minor items. Depreciation amounts to about 10 per cent, interest 6 per cent, insurance and taxes 2 or 3 per cent.

SELLING PRICES

Hardwood distillation products have fluctuated rather widely in selling prices during the past ten years. Furthermore, it has often happened that one product has been high while another product has been low, or in other words it has been necessary at times to charge enough for products in strong demand to make up for the low profit or actual loss on other products, in order that the industry could keep

going. In the early days of wood distillation, charcoal was the important product. Later acetate of lime was the valuable item, and finally wood alcohol rose to prominence. In general each of the three primary products now represents a financial return roughly equal to one-third of the total per cord of wood. Information regarding average selling prices in Canada is limited, as trade reports have not been fully published and the quotations in trade journals are apt to represent odd lots rather than large contracts. Many factors affect the selling prices, and it is impossible to estimate the values that will apply during the coming years.

Charcoal in normal times is worth at least 10 cents per bushel (equivalent to \$10 per ton) at the crude distillation plant. Early in the war the price fell lower, then rose to 15 cents, and for several years the net returns have averaged 25 cents or more per bushel. When distributed in paper bags for use as domestic fuel the retail prices are often from 40 to 60 cents per bushel.

Acetate of lime sold at about 2 cents per pound before the war. With the tremendous demand for acetone as cordite solvent the price of acetate in Canada rose to between 3 and 4 cents per pound during most of the war period, while in the United States quotations were as high as 7 cents per pound for a time until Government control fixed the price at 4 cents in 1918. With the competition of new processes for making acetic acid and acetone, it is to be expected that selling prices of acetate will be fairly low in the future.

Crude wood alcohol was valued at 35 or 40 cents per Imperial gallon before the war and then rose to 75 cents and \$1 per gallon with the strong war demand, while in 1920 the value went as high as \$3 per gallon. The price is likely to remain well above the pre-war figure on account of the large demand for methyl alcohol products being supplied only by means of wood distillation.

The prices of the derived products during the past ten years have varied in line with the prices of crude products. Refined methyl alcohol has varied from about 70 cents per Imperial gallon before the war to \$4 per gallon for a time during 1920. Acetic acid (in terms of pure glacial acid) has ranged from about 10 cents per pound to 30 cents or more per pound during the war. Acetone sold for 15 cents or less per pound before the war and the Government held the prices in Canada between 20 and 25 cents per pound for the most part during the war period, although some was sold considerably higher. Prices of hardwood oils, ketone oils, and other miscellaneous products of the refining processes are difficult to state. As a guide to the comparative values of certain derived products it may be of interest to list the various prices fixed by the United States Government during 1918 after careful investigation of the relations between raw materials and final products in each case. With 82 per cent crude wood alcohol fixed at 50 cents per United States gallon the prices of derived products were: pure methyl alcohol, 86 cents per U.S. gallon; methyl acetone, 86 cents per gal.; refined 97 per cent methyl alcohol, 82 cents per gal.; refined 95 per cent methyl alcohol, 79 cents per gallon. At the same time the price of 90 per cent denatured ethyl alcohol was fixed at 79 cents per U.S. gallon. With acetate of lime fixed at 4 cents per pound the price of glacial acetic acid was 19.5 cents per pound and the price of acetone 25.5 cents per pound.

PROSPECTS

NEW PROCESSES

While hardwood distillation may still be looked upon as a minor key industry, the tremendous war demand for acetone, acetic acid, and methyl alcohol resulted in the development of several new processes and some of these have survived. Furthermore, the gradual development of applied science has introduced methods of distilling wood waste which give promise of commercial success. Until a few years ago old-line hardwood distillation occupied the unique position of being practically free

from competition, but today there are new commercial factors that must be reckoned with. Acetone is now produced successfully from corn and during the war was also made from ethyl alcohol, calcium carbide, kelp, and spent soda-pulp liquor. Acetic acid is now manufactured synthetically on a large scale from calcium carbide and was also made from ethyl alcohol and kelp. Methyl alcohol has been recovered to some extent from spent soda-pulp liquor and attempts are also being made to develop new synthetic processes, although hardwood distillation is still in a strong position in relation to this important product.

The destructive distillation of hardwood waste from saw-mills and logging operations has met with many failures, but several plants are now operating with some success in the United States and elsewhere. The Seaman process involves the "hogging" of wood waste, drying in rotary dryers, and continuous distillation in horizontal rotary retorts, heated externally by producer gas or other fuel. The advantage is apparently in connection with cheap wood raw material rather than plant investment and operating costs. (Seaman Waste Wood Chemical Company, 17 Battery Place, New York; plant under the name of West Virginia Waste Wood Chemical Company, Gauley Mills, West Virginia, U.S.A.) The Badger-Stafford process involves the chipping of cordwood or wood waste, drying in rotary dryers and continuous carbonizing in stationary vertical retorts, without the application of external heat. This process is interesting in that the dry wood is spontaneously carbonized by means of the exothermic heat of decomposition. (E. B. Badger & Sons Company, Boston, Mass.; plant under construction by Tennessee Eastman Corporation, Kingsport, Tennessee, U.S.A.)

One of the most striking chemical developments of the war period was the synthetic production of acetic acid and acetone from calcium carbide. Quicklime and coke are combined in the electric furnace to form calcium carbide, which in turn unites with water to produce acetylene gas. In the presence of sulphuric acid and a mercury compound as catalyst, the acetylene is converted into acetaldehyde. By oxidizing with air in the presence of another catalyst, the purified acetaldehyde is next converted into acetic acid of high strength, and one distillation of the crude product produces glacial acetic acid. The process has also been carried another step by the conversion of superheated acetic acid vapour into acetone in the presence of lime as catalyst, although this stage is hardly logical under normal conditions. The successful establishment of this series of processes was one of Canada's most valuable war contributions in industry and it is not unlikely that this method will survive as the most important factor in glacial acetic acid production. (Canadian Electro Products Company, Limited, Shawinigan Falls, Quebec. Corresponding plants have also been built in Switzerland and Germany.)

Alcohol fermentation, whereby molasses is fermented to ethyl alcohol, then fermented to vinegar, neutralized with lime to form calcium acetate and the evaporated acetate distilled to produce acetone, was a large producer of acetone during the war. However, the cost of acetone production by this process is inherently high on account of the valuable raw material used and the intermediate acetic acid is too weak for cheap recovery. As the process has been diverted to the usual basis of producing industrial alcohol and special by-products, it will hardly be a competitor of the hardwood distillation industry in the future. (United States Industrial Chemical Company, Curtis Bay, Baltimore, Maryland, U.S.A.)

Special fermentation of corn with direct production of acetone and butyl alcohol was first successfully developed on a large scale in Canada during the war emergency. The conversion of butyl alcohol by a three-stage process into methyl ethyl ketone was also established on a commercial basis and gave for the first time a large production of this solvent, which is a substitute for acetone. More recently the industry has been transferred to the United States and the fermentation stage has been modified by means of new ferments to yield ethyl alcohol along with acetone and butyl alcohol. This simple and comparatively cheap method of obtaining acetone from low-grade

corn will no doubt remain as a competitor of the acetate of lime process, while the large proportions of associated products also affect certain other hardwood distillation products to some extent. (British Acetones Toronto, Limited, Toronto, Ontario; Commercial Solvents Corporation, Terre Haute, Indiana, U.S.A.)

The harvesting and natural fermentation of kelp (giant seaweed), followed by distillation and refining, involves a series of processes for the recovery of acetic and other acids, acetone and related ketones, esters, potash, and various other chemical products. This industry has been established on the Pacific coast and may have some bearing on competition. (Hercules Powder Company, Potash, San Diego, California, U.S.A.)

A new process more closely related to wood distillation is the destructive distillation of spent soda-pulp liquor for the production of acetone, methyl alcohol, and other solvents. When wood chips are "cooked" in caustic soda solution to obtain soda pulp, the lignin and other non-cellulose constituents amounting to about one-half of the wood substance are dissolved in the liquor. These organic bodies (which yield the acetic acid and methyl alcohol in the regular wood distillation process) are usually lost in the pulp industry by incinerating the evaporated liquor to reclaim the valuable soda alkali. The recovery system has been modified by concentrating the spent liquor, adding excess quicklime, and destructively distilling the dry material in horizontal rotary retorts to obtain a distillate of methyl alcohol, acetone, etc., while the residue is leached with water to recover the usual yield of caustic soda, and the lime mixture is calcined to reclaim the quicklime for use again in the next cycle. While the process is not yet an important commercial factor, it may be that the method will become a partial competitor of ordinary wood distillation and at the same time will represent a more efficient utilization of wood in connection with the pulp and paper industry. (West Virginia Pulp and Paper Company, Mechanicsville, New York, and Tyrone, Pennsylvania, U.S.A.)

CONCLUSION

In general it may be assumed that there will be a widening outlet for the products represented by hardwood distillation by reason of the steady expansion of chemical industries. Wood distillation is also strengthened by a multiplicity of products which are continually increasing in variety and uses. At the same time it is to be expected that the competition of new processes and materials will be considerable in one way and another. Methyl alcohol is perhaps the most significant product and wood is still practically the only commercial source of this widely used substance; on the other hand it is maintained that ethyl alcohol, etc., could largely replace wood alcohol as a solvent in the paint and varnish industry and elsewhere, while other denaturants are fast replacing methyl alcohol in the preparation of industrial alcohol. Charcoal also has its origin only in wood distillation and the markets for use as domestic fuel, ore refining, etc., can no doubt be further stimulated, but coke is steadily gaining ground as a cheaper fuel in certain lines, such as iron manufacture, and other fuels also enter into competition. As has already been outlined, acetate of lime now faces competition in various directions, although there should be an expanding market for the vital chemical products, acetic acid and acetone. Hardwood tar has not the attractive possibilities of coal tar, but it may yet have an important bearing on the success of the hardwood distillation industry.

After gradual progress over a long period of years the industry appears to have entered a new period of scientific development. Improvements in processes are being made, operation is becoming more efficient, and new products are being found. It is possible that new methods will considerably change the aspect of the industry and may make it better able to withstand the competition of other processes. However, the numerous small plants with old equipment now have a more discouraging outlook than before the war and it is hard to say how successful the wood distilling industry will be in the way of future profits and expansion.

The common hardwoods, maple, beech, and birch, are plentiful in Canada. About 95 per cent of the lumber cut is made up of softwood species, with the result that large areas are being converted into hardwood stands of little value. Foresters are calling for increased utilization of hardwoods, especially birch, in order that the forests can be more easily reproduced in valuable conifers. From the point of view of the conservation of natural resources, therefore, there is no restriction on such an industry as hardwood distillation.

ACKNOWLEDGMENTS

In conclusion the writer wishes to thank the officials of the Standard Chemical Company, Limited, for their courtesy and co-operation in placing valuable information at his disposal and in providing illustrations. Credit is also due to various authors listed in the bibliography for the use of data already published.

BIBLIOGRAPHY

- ACREE, S. F. What chemistry has done to aid the utilization of wood. *Journal of Industrial and Engineering Chemistry*, New York, vol. 7. Nov., 1915, p. 913-915.
- BENSON, H. K. By-products of the lumber industry. U.S. Department of Commerce, Bureau of Foreign and Domestic Commerce. Special agents series, no. 110, Washington, 1916, p. 20-32.
- BROWN, N. C. The hardwood distillation industry in New York. New York State College of Forestry, Syracuse, N.Y., Technical publication, no. 5, Jan., 1917.
- BROWN, N. C. Forest products, their manufacture and use. John Wiley and Sons, Inc., New York, 1919.
- CAMPBELL, C. L. The wood distilling industry. *Metallurgical and Chemical Engineering*, New York, vol. 8, 1910, p. 155-159.
- CANADA, DOMINION BUREAU OF STATISTICS. Census of Industry, 1917; part 4, section 5. Wood distillation, 1917.
- CHUTE, H. O. American progress in dendro-chemistry. *American Institute of Chemical Engineers, Transactions*, 1920. D. Van Nostrand Co., New York.
- DARRIN, MARC. The production of acetone from pyrolygneous acid. *J. Ind. Eng. Chem.*, vol. 7, Nov., 1915, p. 927-929.
- DUMESNY, P. AND NOYER, J. Wood products; distillates and extracts, part 1. The chemical products of wood distillation. Translated from the French by Donald Grant. Scott, Greenwood and Son, London, 1908.
- FRENCH, E. H., AND WITHROW, J. R. The hardwood distillation industry in America. *American Institute of Chemical Engineers, Transactions*, vol. 7, 1914, p. 203-246; *J. Ind. Eng. Chem.*, vol. 7, Jan., 1915, p. 47-55.
- GEER, W. C. Wood distillation. U.S. Dept. of Agric., Forest Service, Circular 114, Washington, 1907.
- GILMORE, R. E. The chemist and the crude factory in the hardwood distillation industry. *Canadian Chemistry and Metallurgy*, vol. 5, no. 2, p. 37-41, Toronto, Feb., 1921.
- GILMORE, R. E., AND PARSONS, C. S. Canadian wood oils for ore flotation. *Canadian Mining Institute, Bulletin*, 1917, p. 856-875, 927-949.
- HARPER, W. R. The utilization of wood waste by distillation. Pub. by St. Louis Lumberman, St. Louis, Mo.
- HAWLEY, L. F. Efficiency studies in the hardwood distillation industry. *J. Ind. Chem. Eng.*, vol. 5, June, 1913, p. 445-447.

- HAWLEY, L. F., AND PALMER, R. C. Yields from the destructive distillation of certain hardwoods. U.S. Dept. of Agric., Bulletin 129, Washington, 1914, 16 p.
- HAWLEY, L. F. Hardwood distillation industry. Chemical and Metallurgical Engineering, New York, vol. 25, no. 4, p. 137-140; no. 5, p. 195-199; no. 6, p. 237-241. July 27, Aug. 3, Aug. 10, 1921.
- KLAR, M. Technologie der Holzverkohlung. Julius Springer, Berlin, Second ed., 1910, 429 p.
- KLASON, P., HEIDENSTAM, G. VON, AND NORLIN, E. Theoretical investigation into the carbonizing of wood. (I) Dry distillation of cellulose. (II) Dry distillation of fir, pine, birch, and beech wood. Arkiv. Kemi. Min. Geol., vol. 3, no. 1, p. 1-34; no. 10, p. 1-17, Stockholm, 1908.
- LAWRENCE, J. C. The distillation of wood. Journal of the Society of Chemical Industry, London, vol. 37, no. 1, Jan. 1, 1918, p. 5-15T.
- PALMER, R. C. A statistical study of the growth of the hardwood distillation industry. Amer. Lumberman, Chicago, Feb. 21, 1914, p. 182.
- PALMER, R. C. Effect of pressure on yields of products on the destructive distillation of hardwoods. J. Ind. Eng. Chem., vol. 6, Nov., 1914, p. 890-893.
- PALMER, R. C. Preliminary experiments on the effect of temperature control on yields of products in destructive distillation of hardwoods. J. Ind. Eng. Chem., vol. 7, Aug., 1915, p. 663-669.
- PALMER, R. C. Temperature control in wood distillation. J. Ind. Eng. Chem., vol. 8, March, 1916, p. 196.
- PALMER, R. C., AND OTHERS. Miscellaneous wood oils for flotation. Trans. Amer. Inst. Mining Eng. Sept., 1916.
- PALMER, R. C. Yields from the destructive distillation of certain hardwoods. U.S. Dept. of Agric., Bulletin 508, Washington, 1917, 8 p.
- PALMER, R. C. The effect of catalysers on the yields of products in destructive distillation of hardwoods. J. Ind. Eng. Chem., vol. 10, April, 1918, p. 260-262.
- PALMER, R. C., AND CLOUKEY, H. The influence of moisture on yields of products in destructive distillation of hardwoods. J. Ind. Chem. Eng., vol. 10, April, 1918, p. 262-264.
- PALMER, R. C. Effect of incomplete distillation on the yields of products in the destructive distillation of birch. J. Ind. Eng. Chem., vol. 10, April, 1918, p. 264-268. (vol. 205, No. 4, p. 425-426)
- SEAMAN, S. E. U.S. Patent no. 1,108,403, Aug. 25, 1914. Destructive distillation of wood.
- SEAMAN, S. E. U.S. Patent no. 1,115,590, Nov. 3, 1914. Apparatus for destructive distillation of wood. (vol. 211, No. 1, p. 41-42)
- STAFFORD, O. F. Canadian Patent no. 182,877, March 12, 1918. Wood distilling process.
- THORPE, SIR EDWARD. A dictionary of applied chemistry. Longmans, Green & Co., London.
- U.S. DEPARTMENT OF COMMERCE, BUREAU OF THE CENSUS. Census of manufacture, 1914. Chemicals and allied industries, Washington, 1918.
- VEITCH, F. P. Chemical methods for utilizing wood. U.S. Dept. of Agric. Bur. of Chem., Circular 36, Washington, 1907.
- WITHROW, J. R. The chemical engineering of the hardwood industry. J. Ind. Eng. Chem., vol. 7, no. 11, p. 912-913, New York, 1915.

APPENDIX

Statistics relating to the Hardwood Distillation Industry in Canada for the years 1919 and 1920, furnished by the Mining, Metallurgical, and Chemical Branch of the Dominion Bureau of Statistics, Ottawa.

Capital Invested

	1919	1920
Land, buildings and plant equipment	\$3,180,205	\$3,163,822
Materials, fuel, supplies and products, finished or in process	2,566,773	814,251
Cash, trading and operating accounts and bills receivable	13,417	26,949
	<u>\$5,760,395</u>	<u>\$4,005,022</u>

Employees, Salaries, and Wages

	1919	1920
Salaried employees, male	30	38
Salaried employees, female	1	4
Salaries paid	\$ 39,006	\$ 69,814
Wage earners, male	410	542
Wage earners, female	2	1
Wages paid	\$355,742	\$608,971

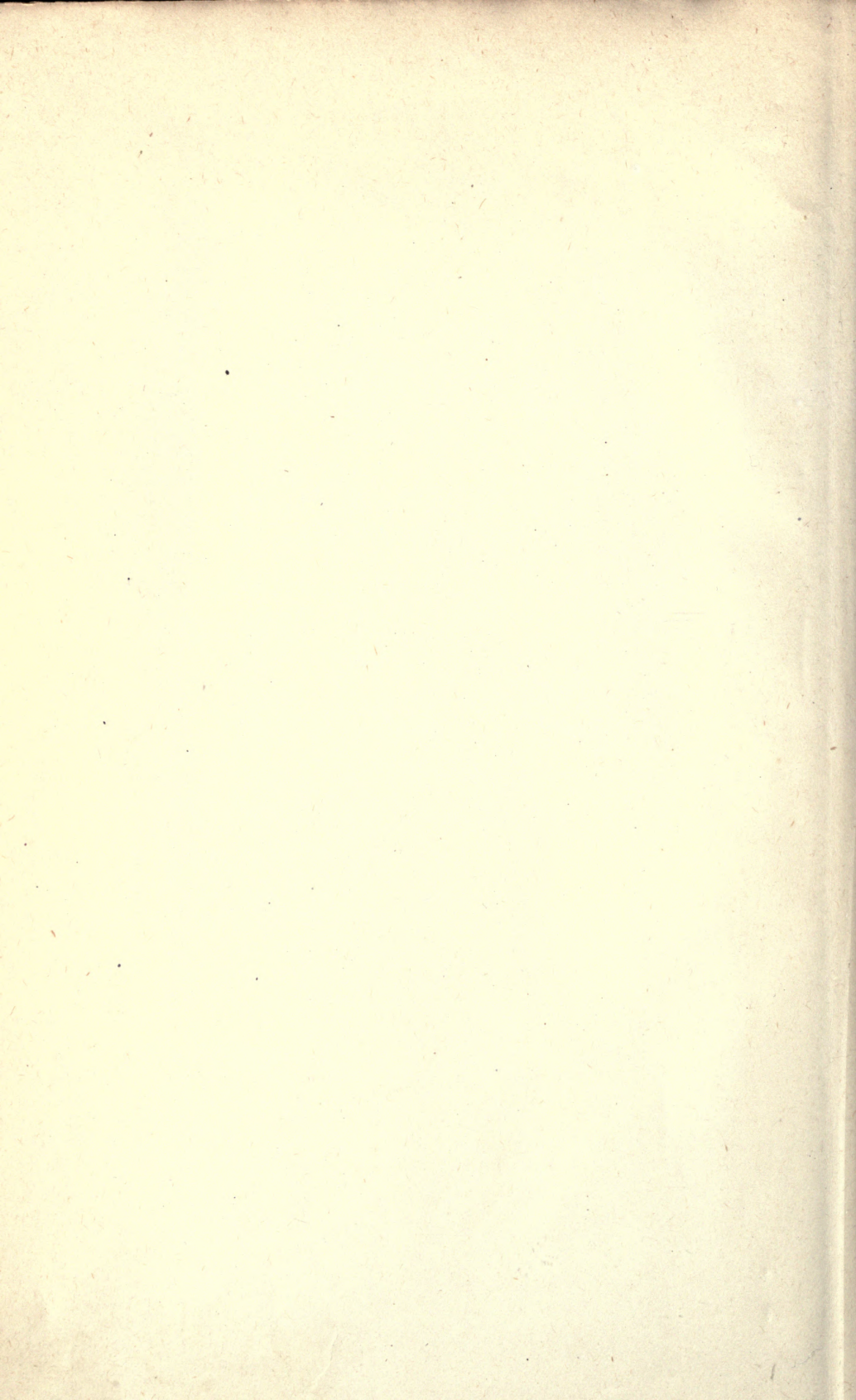
Materials Used

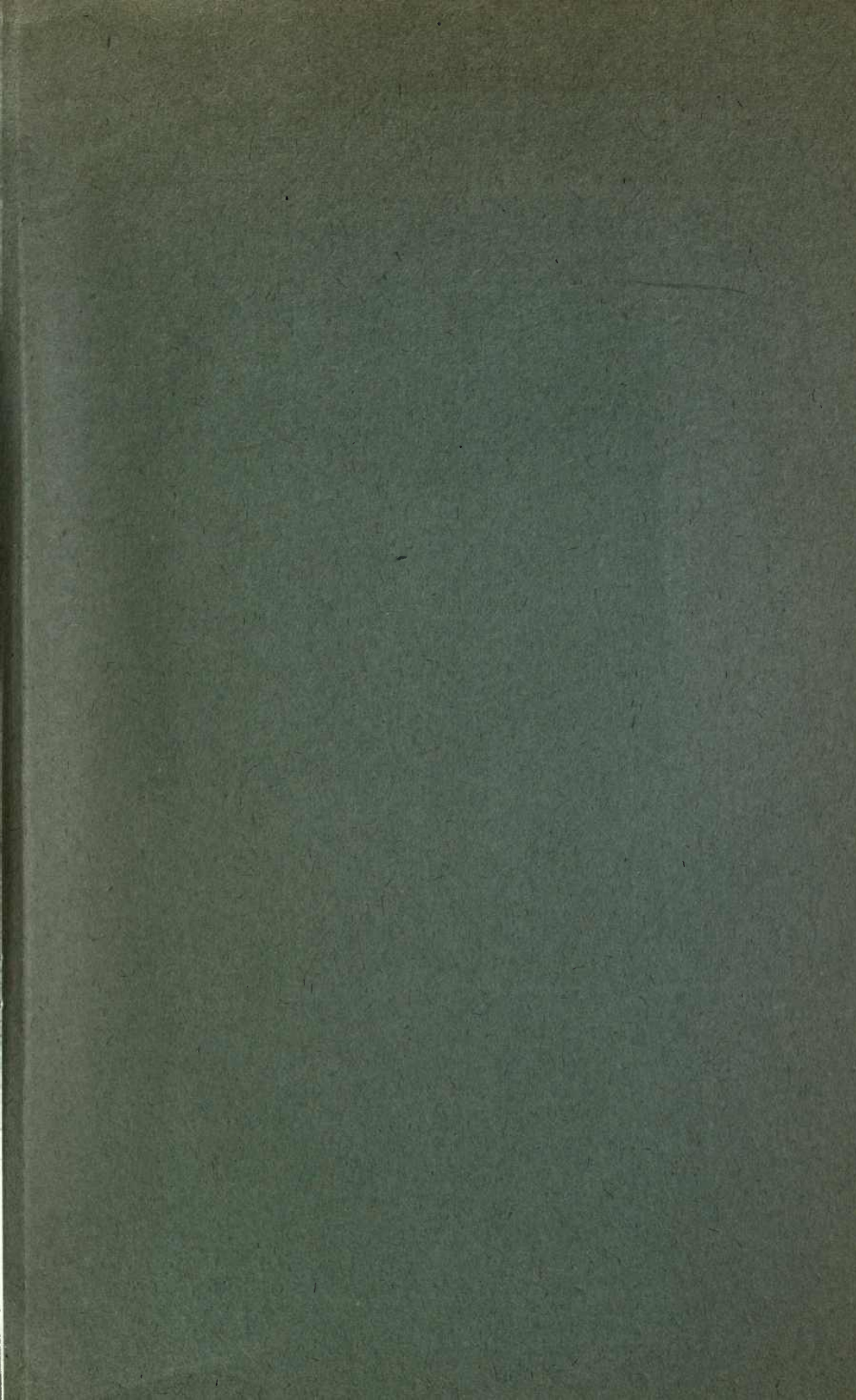
Kind	Unit of Measure	1919		1920	
		Quantity	Cost at Works	Quantity	Cost at Works
<i>Primary Materials—</i>			\$		\$
Hardwood.....	Cords	69,958	717,214	100,347	1,092,842
Resinous Woods.....	Cords	300	1,200		
Lime.....	Bush.	67,100	27,571	98,647	39,838
Salt.....	Lb.	30,800	308	18,300	183
Calcium Chloride.....	Lb.	17,600	270	10,800	155
Sulphuric Acid 60° Be.....	Lb.	493,280	6,067	506,861	6,234
Soda Ash.....	Lb.	87,539	3,064		
Caustic Soda.....	Lb.	30,000	1,350	35,631	2,492
Other Materials.....			27		530
Total Primary Materials used.....			\$ 757,071		\$ 1,142,272
<i>Intermediates used—</i>					
Gray Acetate of Lime.....	Lb.	2,959,078	66,889	3,034,911	93,507
Acetic Acid 28%.....	Lb.	237,947	6,540		
Crude Methyl Hydrate.....	Gals.	570,520	570,520	578,749	578,749
Refined Methyl Hydrate.....	Gals.	155,579	205,197	220,131	283,397
Total Intermediates used.....			849,146		955,653
Total Materials used.....			\$ 1,606,217		\$ 2,097,925

Products Made

Kind	Unit of Measure	1919		1920	
		Quantity	Selling Value	Quantity	Selling Value
			\$		\$
<i>Products Made for Sale—</i>					
Charcoal.....	Bush.	3,589,275	714,660	5,116,171	1,287,580
Gray Acetate of Lime.....	Lb.	10,300,203	217,875	15,071,589	424,498
Methyl Hydrate—95%.....	Gals.	323,448	561,993	302,820	317,678
Methyl Hydrate—pure.....	Gals.			252,678	727,712
Columnian Spirits.....	Gals.	17,221	51,531	10,767	49,413
Methylated Spirits.....	Gals.	2,484	3,424		
Acetone Oils.....	Lb.	113,533	19,300	80,104	17,622
Acetone.....	Lb.	384,769	65,829	385,289	104,028
*Wood Creosote.....	Gals.	7,947	1,986	*213,859	10,946
Acetic Acid, 28%.....	Lb.	220,027	9,781	772,445	33,215
Acetic Acid, 80%.....	Lb.	156,643	30,445	313,302	43,369
Methyl Acetate.....	Lb.	4,760	1,074		
Formaldehyde.....	Lb.	1,011,019	308,132	1,866,343	858,517
Acetic Anhydride.....	Lb.	322	435		
Sodium Acetate.....	Lb.	266,886	17,510		
Total Finished Products.....			\$ 2,003,975		\$ 3,874,578
<i>Intermediates made for use—</i>					
Gray Acetate of Lime.....	Lb.	3,585,962	76,440	3,159,310	101,106
Acetic Acid 28%.....	Lb.	237,947	6,540		
Crude Methyl Hydrate.....	Gals.	512,585	512,585	640,623	640,623
Refined Methyl Hydrate.....	Gals.	155,579	205,197	220,131	283,397
Wood Tars.....	Lb.	100,000	2,000		
Charcoal.....	Bush.	2,500	300		
Total Intermediates made for use.....			\$ 803,062		\$ 1,025,126
Total Production of the Industry.....			\$ 2,807,037		\$ 4,899,704

*Wood Creosote was reported in pounds in 1920.





DEPARTMENT OF THE INTERIOR, CANADA

PUBLICATIONS ISSUED BY THE FORESTRY BRANCH

(Correspondence in regard to bulletins listed below should be addressed to the
Director of Forestry, Ottawa)

Annual Report of the Director of Forestry, 1914-15-17-18-19-20-21	
Bulletin 1	Tree-planting on the Prairies
" 11	Forest Products of Canada, 1909: Lumber, Square Timber, Lath and Shingles
" 14	Forest Products of Canada, 1909: Cross-ties
" 22	Forest Products of Canada, 1910: Cross-ties
" 23	Forest Products of Canada, 1910: Timber used in Mining Operations
" 27	Forest Products of Canada, 1910: Cooperage
" 34	Forest Products of Canada, 1911: Lumber, Square Timber, Lath and Shingles
" 35	Forest Products of Canada, 1911: Poles and Cross-ties
" 36	Wood-using Industries of Ontario
" 38	Forest Products of Canada, 1912: Pulpwood
" 39	Forest Products of Canada, 1912: Poles and Cross-ties
" 40	Forest Products of Canada, 1912: Lumber, Square Timber, Lath and Shingles
" 46	Forest Products of Canada, 1913: Pulpwood
" 48	Forest Products of Canada, 1913: Lumber, Lath and Shingles
" 49	Treated Wood-block Paving
" 51	Game Preservation in the Rocky Mountains Forest Reserve
" 52	Forest Products of Canada, 1913. (Being Bulletins 46, 47 and 48)
" 53	Timber Conditions in the Smoky River Valley and Grande-Prairie Country
" 54	Forest Products of Canada, 1914: Pulpwood
" 56	Forest Products of Canada, 1914: Lumber, Lath and Shingles.
" 57	Forest Products of Canada, 1914 (Being Bulletins 54, 55, and 56)
" 58a	Forest Products of Canada, 1915: Lumber, Lath and Shingles
" 58b	Forest Products of Canada, 1915: Pulpwood
" 58c	Forest Products of Canada, 1915: Poles and Cross-ties
" 59	Canadian Woods for Structural Timbers
" 60	Canadian Douglas Fir: Its Mechanical and Physical Properties
" 61	Native Trees of Canada. (Price, 50 cents, post-free)
" 63	Wood-using Industries of Quebec
" 65	Forest Products of Canada, 1917: Poles and Cross-ties
" 66	Utilization of Waste Sulphite Liquor. (Price, 50 cents, post-free)
" 67	Cresote Treatment of Jack Pine and Eastern Hemlock for Cross-ties
" 68	Forest Fires in Canada, 1917
" 69	The Care of the Woodlot
" 70	Forest Fires in Canada, 1918
" 71	Canadian Sitka Spruce: Its Mechanical and Physical Properties
" 72	Success in Prairie Tree Planting
" 73	Tree-Repairing
" 74	Distillation of Hardwoods in Canada. (Price, 25 cents, post-free)
ircular 5	Planning a Tree Plantation for a Prairie Homestead
" 6	Preservative Treatment of Fence-posts
" 8	The Forest Products Laboratories
" 9	Chemical Methods for Utilizing Wood Wastes
" 12	The Empire Timber Exhibition
" 13	The Cascara Tree in British Columbia
" 14	Commercial Forest Trees of Canada
" 15	Historical Sketch of Canada's Timber Industry
Manual	Methods of Communication Adapted to Forest Protection. (Price, \$1, post-free)
Dominion Forestry Branch Message Code. (Price, 10 cents, post-free)	

YD 24



8000957057

LOAN PERIOD 1 HOME USE	2	3
4	5	6

1-month loans may be renewed by calling 642-3405
6-month loans may be recharged by bringing books to Circulation Desk
Renewals and recharges may be made 4 days prior to due date

DATE	NAME OF SELLER	PURCHASE PRICE
MAR 10 1986		
REC-CIRC MAR 10 1986		

FORM NO. DD6, 60m, 3/80 BERKELEY, CA 94720

