THE IMPREGNATION OF SAP PINE LUMBER

WITH ROSIN EMULSIONS

A Thesis

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of

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by

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ABSTRACT

Sap pine lumber was impregnated with rosin emulsions stabilized by ammonium resinate.

From absorption gradients it was determined that maximum absorption with the wood and emulsion used was 3.3 pounds per cubic foot of rosin.

The treatment was found to increase the strength fifty per cent though other physical properties were practically unchanged.

Toxicity tests show that rosin has little effect on wood-destroying molds.

INTRODUCTION

The practice of treating timber to preserve it is over a century old. The first cross ties were treated in this country in 1838. These were treated by dipping in bichloride of mercury solutions and it was not until 1865 that creosote came into use. The fact that early treatments were effective is easily demonstrated. In fact, there are structures in use today that stand as monuments to the craftsmanship of the wood treaters of half a century ago. The trestle across Lake Pontchartrain, belonging to the Southern Railway, rests upon creosoted piles. This structure was built in 1883 and now, fifty four years later, most of the original pile are still in use.

The many years of treating operations have seen the introduction of a large number of impregnating agents. Some of the more important are creosote, creosote petroleum oil mixtures, creosote tar mixtures, zinc chloride, sodium fluoride and zinc meta arsenate. New comers to the field are paraffin (1), sulfur (2), bakelite (3) and rubber (4).

(1) Ind and Eng Chem : 27, 543 (1933).
(2) P-Brit #272781, Dec. 16, 1926 - T. L. Allison and B. Brown
(3) J Compredon, Genie Civil: 98, 426 - C. A. 276 (1932)
(4) P-Brit #340, 814 Jan. 23, 1930 - A. J. Plant

There are two general pressure processes that have been used in the impregnation of wood. These are the Bethell and the Rueping processes(5). In the Bethell process the wood is evacuated and the impregnating agent, usually creosote, is forced in under pressure. This leaves the fibre cells of the wood full of oil which is responsible for the name 'full cell' that is sometimes applied to this treatment. In the Rueping process the air that is first forced into the wood is followed by oil which is under a yet higher pressure. When sufficient penetration is obtained the pressure is released, the extra oil drained off and a vacuum pulled. This permits the air trapped in the wood to expand forcing some of the oil out but leaving the cell walls coated. The Rueping process is sometimes called an 'empty cell' treatment.

Penetration and absorption are, of course, closely tied up with the structure of the wood itself. By far the greater portion of the void volume of softwoods is found in the fibre cavities(6) or cells which are really long tubes closed at both ends and lying parrallel to the resin ducts and approximately perpendicular to the medulary rays. In pine sap wood the average length and diameter of these cells is .3 centimeters and .003 centimeters respectively.

(5) L. W. Morrow Elect World:99, 357
(6) Alfred J. Stamm J Phy Chem : 36,312 (1932)

In the walls of these cells and connecting them to the adjoining ones are from thirty to three hundred pits, known as the 'bordered pits'. Stretched across the bottom of these pits and hindering flow of liquids from one fibre cell to the other are membranes, known as 'pit membranes'. These are not membranes in the true sense of the word since they are porous. In the hardwoods these pores are small but in pine sap wood the average pore radius as determined by Stamm(6) is 9.7×10^{-4} cm. It is through these membrane pores that the penetrating liquid must pass on it's way from one cell to the next. If temperature and pressure of penetration are too high(7) or if drying conditions are drastic these pit membranes will collapse against the pit walls thereby closing the pores and preventing penetration.

It should be mentioned here that other avenues open to penetration are the resin ducts and the ray cells(8) and that obstructions such as resin deposits in these passages also hinder penetration.

Ernest Bateman(9), J. D. MacLean(10, 11, 12, 13) and A. M. Howald(14) have studied the rates of penetration

(7) J. D. MacLean Proc Am Wood Pres Assoc: 44, (1929)
(8) Stanley Buckman J Phy Chem : 39, 103 (1935)

of creosote, creosote oil mixtures and zinc chloride
solutions into sap wood. Their studies and discussions
have been largely confined to the effects of temperature
and viscosity on penetration rates. Though there has
been much disagreement a large mass of evidence has been
presented that points to the fact that temperature plays
a more important role than simply that of a viscosity
lowering agent. MacLean found that as temperature increased
a marked increase in rate of penetration was obtained even
with zinc chloride solutions. Since the change of viscosity
of these solutions with temperature was practically negligible
he concluded that temperature must have some other effect.
This has not yet been explained. There seems to be a
limiting temperature, however, above which one may not
go since the wood itself will be injured. Bateman
developed formulas involving penetration and viscosity for
fixed time and pressure but since wood varies so much these
are of doubtful value.

Absorption, as it is expressed, refers to total
absorption as pounds per cubic foot. Average creosote
treatments are eight pounds per cubic foot by the Rueping
process or twelve pounds per cubic foot by the Bethell

(9) Chem and Met Eng : 22, 359 (1930)
(10) Proc Am Wood Pres Assoc : 20, 44 (1924)
(11) Ibid   22, 147 (1926)
(12) Ibid   , 23, 52 (1927)
(13) Ibid   24, 52 (1928)
(14) Chem and Met Eng :   34, 353

process. It is thought that these two treatments offer
approximately equal protection.

In naming a treatment, such as an eight pound
treatment, nothing is implied as to the distribution of
the oil in the wood though certain minimum depth of
penetration is usually required. Only two workers,
Stanley Buckman(15) and J. A. Vaughan(16) have determined
absorption gradients in treated wood. Both have worked
with wood treated by the Rueping process. The curves
that Vaughan obtained from poles that has been given
an eight pound treatment show an average absorption of
around twenty two pound per cubic foot in the first quarter
of an inch and a sharp decrease from there in to six
pounds per cubic foot at two inches.

Some work has been done on the relation of toxicity
to composition of commercial organic impregnating agents
(17,18,19,20,21,22) but no a priori assumption may be made
as to the effectiveness of a given chemical. Moreover
toxicity alone is not an adequate yardstick of this

(15) Ind and Eng Chem : 28, 474 (1936)
(16) Proc Am Wood Pres Assoc : 1, (1934)
(17) Henry Schmitz Ind and Eng Chem : 24, 772
(18) E Bateman   Proc Am Wood Pres Assoc : 17, 50 (1921)
(19) E Bateman Ibid   20, 33 (1924)
(20) E Bateman Ibid   21, 22 (1925)
(21) Ira Hatfield   Ibid   27, 128 (1931)
(22) Ira Hatfield   Ibid   28, 120 (1932)

effectiveness. Such factor as chemical stability, volatility and leachability must be considered(23). The only reliable test of the value of an impregnating agent is it's actual use in timber. To this end, large telephone, railroad and wood treating companies maintain extensive 'gardens' in which are planted poles and ties that have been given test treatments.

The opinion has often been expressed that fat pine heart stock resists decay better than the lean sap wood. In 1911 F. J. Hoxie and C. H. Smith(24), after making an extensive study of timbers used in factory construction, reported that rosin content might be used as a rough indicator of durability. These men believed that wood containing more than 5% rosin was, in general, sound and durable. They pointed out that rosin in wood offered resistance, probably largely mechanical, to the growth of fungus mycelium and claimed that it's use as an impregnating agent had been suggested.

It should be noted that one interested in introducing rosin into wood has a choice of at least three methods of accomplishing this objective. The first of these is the introduction of molten rosin under pressure. The objection to this is obvious. Rosin does not become sufficiently

fluid until such a high temperature is reached that the wood would probably be injured.

A second method might be the introduction of rosin as a solute in some cheap solvent. Unfortunately the only solvent that would seem feasible here is naphtha and this will not mix well with water encountered in the fibre cavities.

A third method could be by dissolving rosin in naphtha and dispersing this solution in water with the aid of an emulsifying agent such as ammonium resinate. The emulsion should be of the oil-in-water type. This is the procedure followed in the work reported here.

Since creosote does not mix well with water, creosoters are troubled with water in wood. Buckman(25) has shown that even below fibre saturation an increase in moisture increases resistance to penetration by creosote. The term fibre saturation describes the condition that exists when the moisture content is such that the cell walls are saturated but there is no free moisture in the cavities themselves. For sap pine wood this is from 25 to 30% on the dry basis. Some wood coming to the creosoter contains as much as 100% moisture on this basis. The

(23) Henry Schmitz Ind and Eng Chem, Anal Ed:2, 361 (1930)
(24) Eng News : 66, 727 (1911)
(25) J Phy Chem : 39, 103 (1935)

moisture content of this must be lowered by air drying
and steam and vacuum conditioning before it can be
successfully creosoted.

Vaughan(16) has obtained better penetration and
lighter colored poles, that do not bleed, by introducing
the lecithins, which are emulsifying agents, into the wood
along with the creosote thereby lowering the interfacial
tension between the oil and any water met in the wood.
This indicates the advantage of an oil-in-water emulsion
over an oil. With the emulsion the outside phase is
homogeneous with water encountered in the fibre cavities.

The work that is reported here divides itself
naturally into four parts. The first part deals with the
production and properties of the emulsions while the second
has to do with the actual impregnation of the wood. In
order to determine the penetrability of pine sap wood
by these emulsions, absorption gradients were run and
penetration estimated from these. The third part is
concerned with tests made on the physical properties of
the treated wood as compared to untreated samples. The
fourth part discusses the effectiveness of rosin as a
protective agent as indicated by standard toxicity tests.

(16) Loc. cit.

PART 1

THE EMULSIONS

A thirty percent solution of K grade gum rosin, acid number 163, in naphtha was made. The naphtha was that sold by the American Mineral Spirits Company under the name of 'Naphtholite'. It's boiling range is from 230°F. to 300°F. The solution thus produced was milky which was probably due to the presence of coagulated rosin. W. Schlick(26), F. Sanders(27) and J. Scheiber(28) have discussed the colloidal nature of benzine solutions of rosin. Six liters of this solution were dispersed in four liters of water to which sufficient ammonium hydroxide had been added to neutralize one fifth of the rosin. The ammonium resinate which is the emulsifying agent, is formed in solution.

Preliminary experiments showed that larger ratios of ammonia to rosin increased the stability of the emulsions but also increased the tendency to form emulsions of the water-in-oil type. These were jelly-like in structure.

The first of these emulsions was made in a colloid mill at the University of Georgia by Dr. Whitehead but a special sort of agitator was soon designed that was capable of turning out a ten liter batch in a few minutes. A

(26) Farben, Ztg : 27, 1439 (1922)   C.A. : 16, 2032
(27) Farbe, U Loch : (1932) 643   C.A. : 27, 1527
(28) Farbe, U Loch : (1932) 644   C.A. : 27, 1527
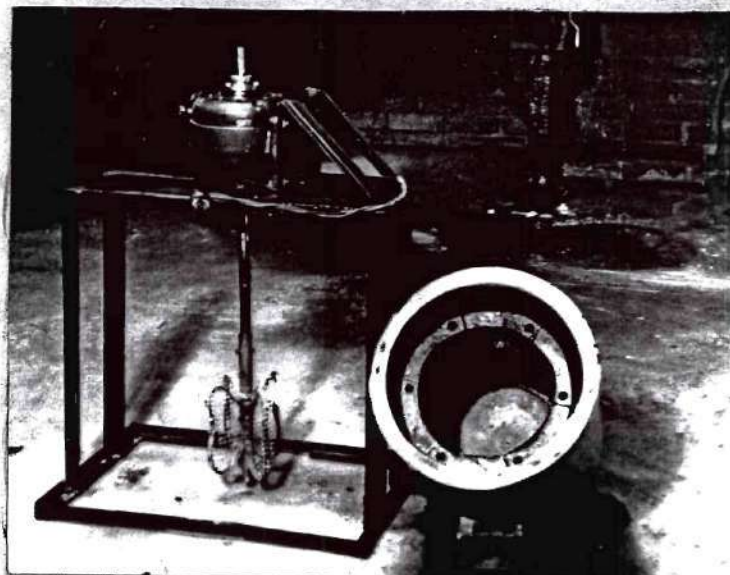
picture of the mill is shown in Fig. 1.

Fig. 1

It consisted of a five gallon crock, with an
outlet at the bottom, in which was placed a cylindrical
squirrel-cage stator. The inside of this stator was
covered with fine mesh screen wire. The rotor was made
by splitting the wall of a quarter inch pipe into four
strips for a distance of seven inches up the pipe and then
turning these strips back upon the upper part of the pipe
forming four approximately circular inclosures. These
inclosures were covered with hardware cloth. The rotor
was connected directly to a quarter horse power motor and
was supported by a brass thrust bearing that rested on the
bottom of the crock.

Emulsions prepared according to the formula given above had a density of .90 and a viscosity of 2.09 centipoises at 80° F. Density was determined picnometrically and viscosity was determined in an Ostwald viscosimeter. that has been standardized against distilled water. The rosin content of the emulsion was 15.8%. This was determined by weighing a sample into a tared 100 ml. beaker and distilling off the naphtha and water on an electric hot plate above which the air was kept in motion by an electric fan.

The average droplet diameter was estimated by a method given in Volume 1 of Alexander's Colloidal Chemistry. This consists of placing the emulsion on a haemocytometer which is so arranged that a volume of the liquid four millimeters by four millimeters by one tenth of a millimeter can be observed. When this is placed under a microscope with dark field illumination the droplets in this volume show up as tiny stars. These are counted and if the weight of the dispersed phase in this volume and it's density are known the average partical diameter may be calculated on the assumption that the drops are spherical.

In using this method with the rosin emulsion it was necessary to dilute the emulsion one million times to make

counting possible. Twenty counts were made on the above volume and the average number of droplet found was 154. The density of the benzine rosin solution as determined picnometrically was found to be .78.

Calculations follow—

Grams of benzine rosin solution per cubic millimeter of diluted emulsion $= \dfrac{.158 \times .90}{.30 \times 1000 \times 1000000} = 4.74 \times 10^{-10}$

Cubic millimeters of rosin solution in the volume of diluted emulsion observed $= \dfrac{4.74 \times 10^{-10} \times 1000 \times 4 \times 4 \times .1}{.78}$

$= 9.77 \times 10^{-7}$

The average volume of each droplet $= \dfrac{9.77 \times 10^{-7}}{154}$

$= 6.33 \times 10^{-9}$ cu. mm.

Volume $= 1/6 \, \pi \, d^3$

$6.33 \times 10^{-9} = 1/6 \, \pi \, d^3$

$d = 3.37 \times 10^{-3}$ millimeters

Some of the larger ones measured with a calibrated micrometer eye piece had a diameter of 4×10^{-3} millimeters.

It should be noted here that this is smaller than the average diameter of the pit membrane pores, as determined by Stamm, which is 19.4×10^{-3} millimeters.

Summary of properties of the emulsion.

1. Density - .90

2. Viscosity - 2.09 centipoises

3. Rosin content - 15.8%

4. Average droplet diameter - 3.37 x 10^{-3} millimeters.

PART 2

IMPREGNATION

EXPERIMENTAL -

The wood used in these tests was slash pine sap wood.
It had been seasoned to the point that is called 'shipping
weight', being approximately seventy days from the stump
and containing from 38 to 40% moisture, on the dry basis.
No initial steaming treatment was given.

Both transverse and logitudinal absorption gradients
were determined for varying times of impregnation. For the
logitudinal tests two by fours four feet long were used.
In order to protect these from transverse penetration,
they were given two coats of automotive lacquer on the
sides. Only the two ends were left open to penetration.
For the transverse tests four by fours from eight to ten
inches long were used. These were given a double coat
of lacquer on the ends so that they were penetrable only
from the sides. To test the effectiveness of the lacquer
coating in preventing penetration, two blocks were coated on
all sides and treated. When tested, by a method to be
described later, they showed no greater rosin content than
that of the original wood.

Impregnation was carried out by what was essentially
a Bethell process with an added heat treatment. The wood

was charged into a pressure cylinder, which is described
later, and a vacuum of twenty seven inches of mercury was
pulled for thirty minutes. The cylinder was next filled
with emulsion at an average temperature of 75° F. and
7.5 pounds per square inch pressure was applied for from
five to thirty minutes. The emulsion was then drained
off and the wood left open to the atmosphere, through a
condenser, while its temperature was slowly raised to
200° F. This rise in temperature required two hours
and at the end of this time the treatment was complete.
This heat treatment at the end was found to be necessary
to prevent the leaching of emulsion from the wood by
water.

Experiments on small blocks showed that hot water
would extract emulsion from the wood a month after treatment
if the wood was not heated at the end of the treating process.
The heat treatment seemed to break the emulsion in the wood
and fix the rosin there so that water could not extract it.

A picture of the apparatus used for the impregnation
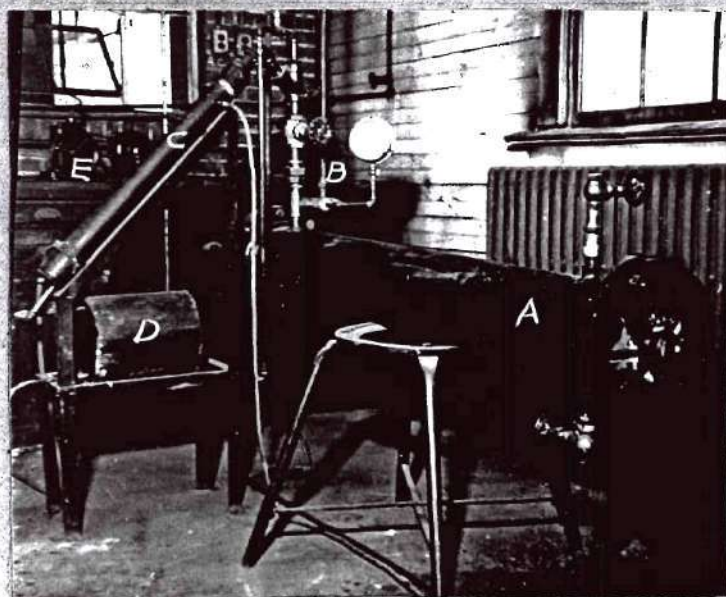is shown in Fig. 2.

Fig. 2.

A - Pressure cylinder. This is equipped with steam coils for heating.

B - Compressed air line.

C - Multi-tubular surface condenser. This condenses the naphtha and water that distills out of the wood during the heating period.

D - Receiver in which this condensed mixture is collected.

E - Vacuum pump used to evacuate the system.

In the transverse absorption test the corners of the treated blocks were cut out as shown in the Fig. 3. to eliminate the cumulative effect at the corners as far as possible. Samples were then taken from each quarter of an inch, marked 1 to 7 in the figure. The four by fours were
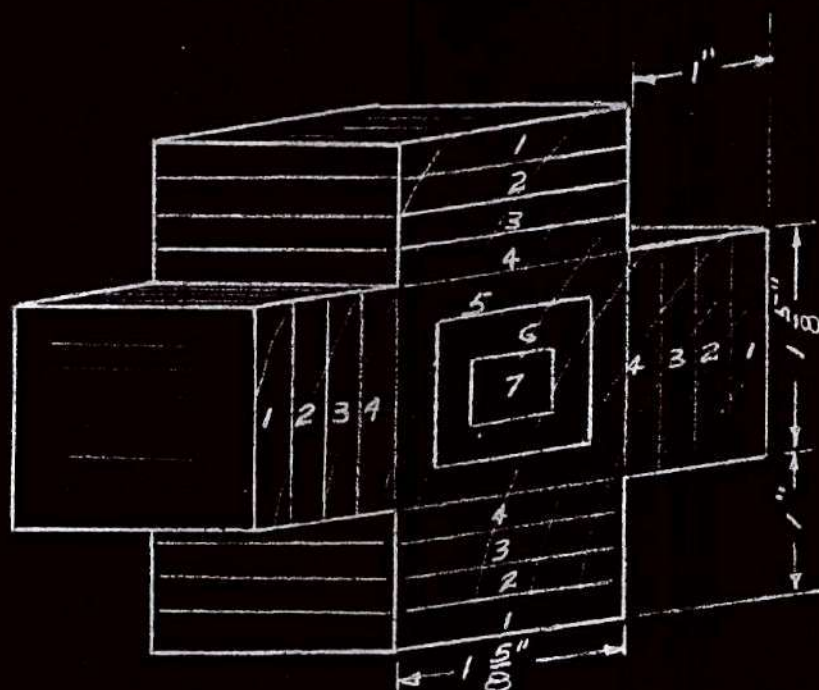
Transverse

Fig. 3   scale $\frac{3}{4}$

Longitudinal

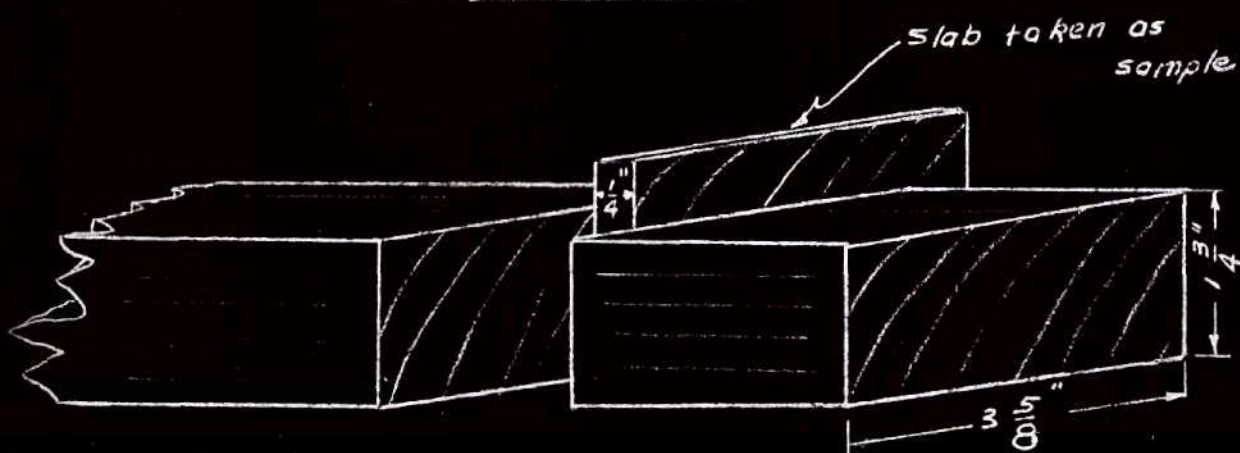slab taken as sample

Fig. 4   scale $\frac{1}{2}$

dressed when received and therefore measured only three and five eighths inches. All of the sections marked 1, from three blocks were combined and the rosin and moisture determined in a sample taken from this composite. The same procedure was followed with sections marked 2 through 7. The analysis of this series of samples of wood treated under a certain specified set of conditions constitutes a run. The depth of the number 1 sample was taken as the average depth or one eighth of an inch while that for number 2 was three eighths of an inch etc. A band saw was used to cut these samples as well as to further subdivide them to facilitate subsequent extration. For each run two composite samples were taken in which naphtha was determined.

In the longitudinal test, samples were taken in the form of thin slabs cut perpendicular to the length of the piece and at given distances from the end as shown in Fig. 4. The depth at which the samples were taken varied according to the penetration expected. Eight samples were taken for each run and as in the case of the transverse tests composites were taken from three pieces.

It was found more convenient to weigh the samples used for analysis than to measure their volume. Thirty gram samples were used. Since the rosin content should be stated in pounds per cubic foot to be consistent with the practice

of creosoters it was necessary to estimate the density of
the treated wood. To do this blocks one inch by one inch
by one half inch were cut, accurately measured with calipers
and weighed on a pan balance which was sensitive to a
hundredth of a gram. Two blocks were weighed for each
run made.

Both longitudinal and transverse runs were made for
five, ten, twenty and thirty minutes. The lengths of time
referred to here represent the pressure periods or the time
while the liquid is in contact with the wood.

Tests were made on treated wood both before and
after the heating period in order to determine the effect
of this heating on rosin distribution in the wood.

ANALYTICAL -

The samples of wood used for rosin, moisture or
naphtha determinations were subdivided to chips approximately
one quarter by one quarter by one eighth of an inch. The
smallest dimension is along the grain. The samples were
cut with a fine toothed band saw and broken to size. A
thirty gram sample was weighed and placed in stoppered
500 ml. erlenmeyer flask to prevent loss of water. Moisture
and rosin were determined on the same sample.

In the moisture and rosin determination the moisture
tube and condenser were arranged as shown in Fig. 5. The
moisture tubes C were made and calibrated. They are a
modification of the tubes used in the wood treating industry
for this purpose.

Naphtha was poured down the condenser until the
moisture tube was full and then 100 c.c. more were added
directly to the erlenmeyer flask which contained the sample.
The flask was then heated with a gas burner and kept
refluxing until no more water collected in C. This usually
required two hours. At the end of this time the moisture
was read directly from the tube C.

The flasks were now removed and the naphtha rosin

extract poured off thru a cloth filter into another
500 ml. erlenmeyer flask. This cloth filter was saved.
75 c.c. of fresh naphtha was now added to the chips, the
flask connected up as before and the sample refluxed for
an hour. At the end of this time the naphtha was poured
off again thru the same filter and into the same erlenmeyer
flask. The whole procedure was repeated with another 75 c.c.
of fresh naphtha and this extract combined with the other
two. The cloth filter was washed and the washings added
to the extracts.

The moisture tube was now replaced by a wide mouth
bottle which acted as a receiver. The condenser was tilted
and the erlenmeyer flask containing the combined extracts
and washing was connected to it's upper end as shown in
Fig. 6. Naphtha was evaporated off until only 30 c.c.
remained in the flask. This was transfered to a tared
100 ml. beaker which was placed on an electric hot plate
and the naphtha evaporated off leaving the rosin which
was weighed. During the evaporation a current of air was
kept moving over the beaker. The end point of the evaporation
was indicated by a distinct change in odor.

To test the effectiveness of the triple extraction
the spent chips from sixteen samples were combined, placed
in a three liter flask, covered with naphtha and refluxed
for three hours. The extract from this yielded .2 grams of

Naphtha
Determination Tube

safety tube

condenser

calibrated
C tube

Fig 5

A

calibrated
section K

scale $\frac{3}{4}$

Fig 8

safety tube
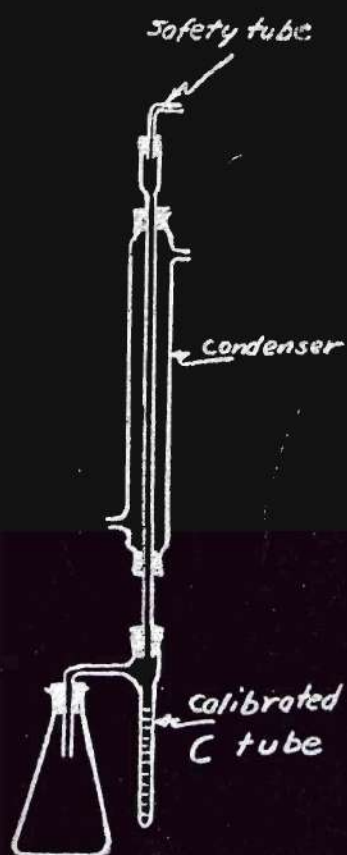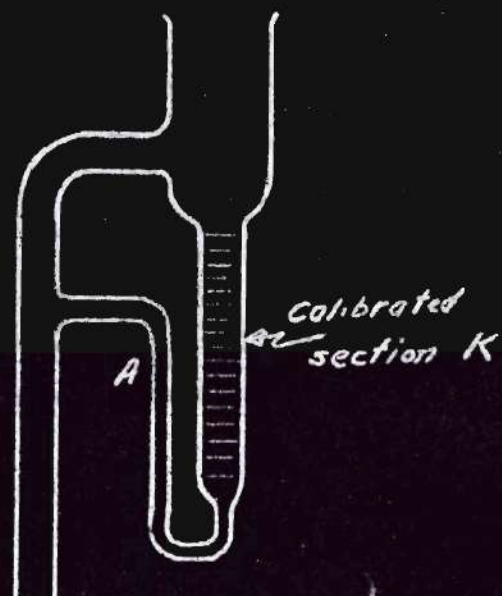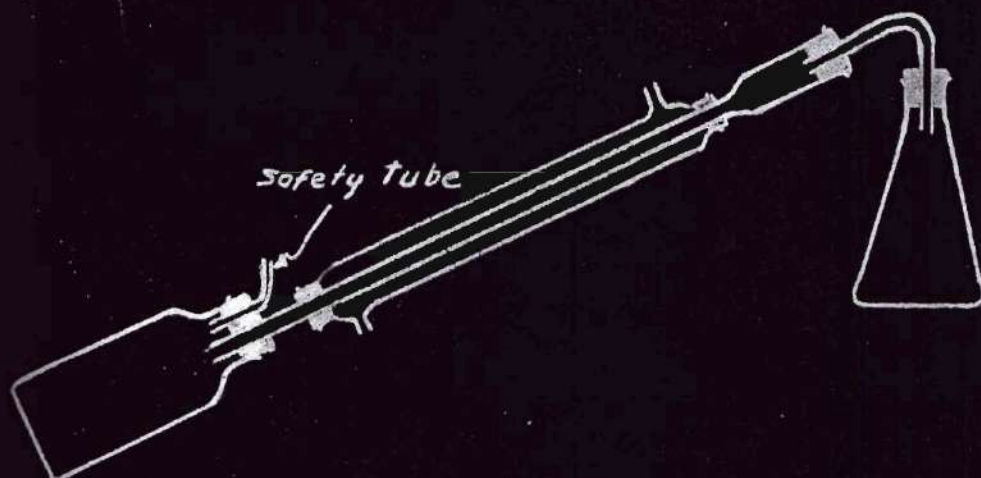
Fig. 6

Rosin. These same chips had given up approximately 50
grams of rosin in the first three extractions. Tests on
evaporation technique were made by dissolving known
weights of rosin in naphtha, evaporating down and
checking the weight of the residue.

Fig. 7 Shows a rack designed to accomodate
seventeen flasks and condensers. The piece that supports
the condensers is made so that it may be tilted back
placing the condenders in the position indicated by Fig. 6.
Metal shelves are provided in both the back and front to
support flasks and burners. Both the extraction and the
initial concentrating of the extracts may be carried out
without taking down the condensers.
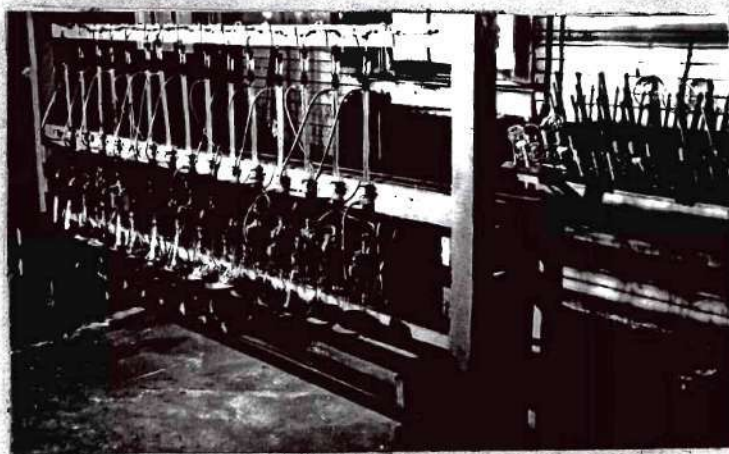
Fig. 7.

In the naphtha determination the tube shown in
Fig. 8 was connected up in the same manner as the moisture
tube was connected in Fig. 5. A fifty gram sample of
chips was placed in the flask and 150 c c. of water was
added. This was refluxed until no more naphtha collected
in the calibrated section of the tube marked K. The water
that returned from the condenser fell thru the naphtha
that had collected in K and returned to the flask thru
the tube A. A large number of known samples were made
up by adding given amounts of naphtha to dry chips. These
were run by the method given above as a check on the technique.
The error as indicated was sometimes as much as ten per
cent.

DATA -

Calculations necessary to make data interpretable

Analysis gives rosin as grams per thirty grams of
sample. To change to pounds per cubic foot -

$$\text{lbs/ cuft.} = \frac{\text{weight of rosin X density of wood X 62.42}}{30}$$

Water is given as cubic centimeters per thirty grams
of sample. To change to percentage on dry basis -

$$\text{\% moisture} = \frac{\text{c c. water X 1 X 100}}{30 - (\text{c c. water X 1})}$$

Naphtha is given as cubic centimeters per fifty
grams of sample. To change to percentage -

$$\text{\% naphtha} = \frac{\text{c c. naphtha X .72 X 100}}{50}$$

Density of naphtha is .72 at 80° F.

RUN A - Transverse absorption - Time 5 minutes

Before heating period

Sample No.	Depth "	Density	Moisture c c.	Moisture % dry basis	Rosin grams	Rosin lbs/cuft.
1.	1/8		11.0	59	3.02	4.52
2.	3/8		11.3	60	2.61	3.92
3.	5/8	.72	11.0	59	2.91	4.38
4.	7/8		11.0	59	1.43	2.15
5.	1 1/8		11.1	59	.61	.92
6.	1 3/8	.73	11.2	60	.41	.52
7.	1 5/8		11.4	61	.23	.35
Original wood	---	.53	8.7	41	.48	.53

Average naphtha content = 3.2%

Run B - Transverse absorption - Time 5 minutes

After heating period

Sample No.	Depth "	Density	Moisture c c.	Moisture % dry basis	Rosin grams	Rosin lbs/cuft.
1.	1/8		7.1	31	4.65	5.23
2.	3/8		6.9	30	3.30	3.71
3.	5/8	.54	7.2	31	2.69	3.02
4.	7/8		6.1	25	1.78	2.00
5.	1 1/8	.53	7.0	30	.77	.87
6.	1 3/8		6.9	30	.78	.88
7.	1 5/8		7.3	33	.47	.53

Average naphtha content = 1.8%

Transverse absorption – time 5 min.

Before the heating period.

RUN A

lbs/cuft of rosin

original rosin content

Distance from surface of wood in inches.

RUN B

After the heating period

lbs/cuft of rosin

original rosin content

Distance from surface of wood in inches.
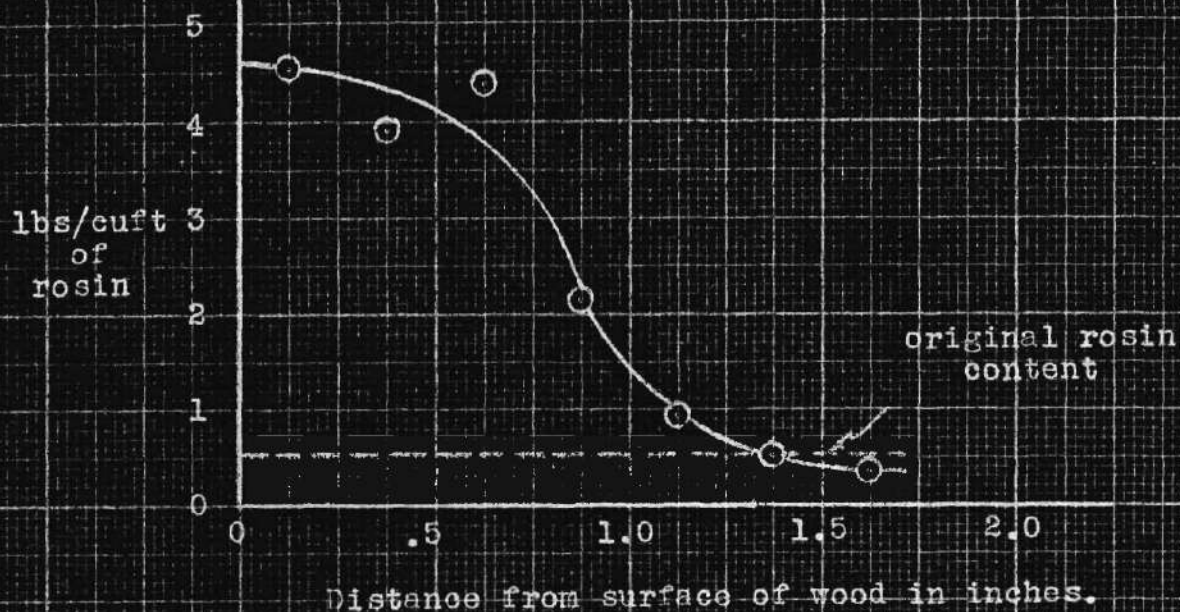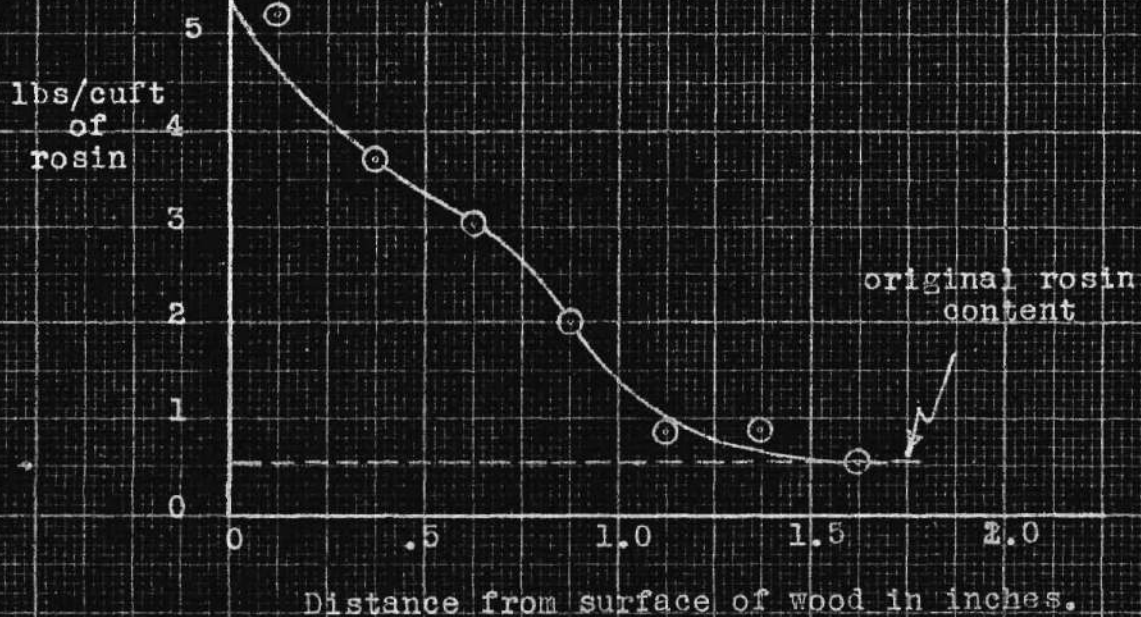
RUN C - Transverse absorption - Time 10 minutes

Before heating period

Sample No.	Depth "	Density	Moisture c c.	Moisture % dry basis	Rosin grams	Rosin lbs/cuft.
1.	1/8		10.0	50	2.86	4.35
2.	3/8		10.2	51	2.89	4.40
		.73				
3.	5/8		10.3	52	2.76	4.20
4.	7/8		10.2	51	2.04	3.10
		.72				
5.	1 1/8		10.1	51	.87	1.30
6.	1 3/8		10.5	54	.40	.61
7.	1 5/8		10.8	56	.23	.35
Original wood	----	.52	8.6	40	.44	.48

Average naphtha content = 3.1%

RUN D - Transverse absorption - Time 10 minutes

After heating period

Sample No.	Depth "	Density	Moisture c c.	Moisture % dry basis	Rosin grams	Rosin lb/cuft.
1.	1/8		6.4	27	4.00	4.60
2.	3/8		6.7	29	2.62	3.00
		.54				
3.	5/8		6.9	30	2.72	3.12
4.	7/8		7.2	32	2.45	2.81
		.53				
5.	1 1/8		7.3	33	2.05	2.35
6.	1 3/8		7.4	33	.81	.93
7.	1 5/8		7.4	33	.61	.70

Average naphtha contents = 2.5%

Transverse absorption – time 10 min.

RUN C

Beforenthe heating period

lbs/cuft of rosin

original rosin content

Distance from the surface of the wood in inches

RUN D

After the heating period

lbs/cuft of rosin

original rosin content

Distance from surface of wood in inches.
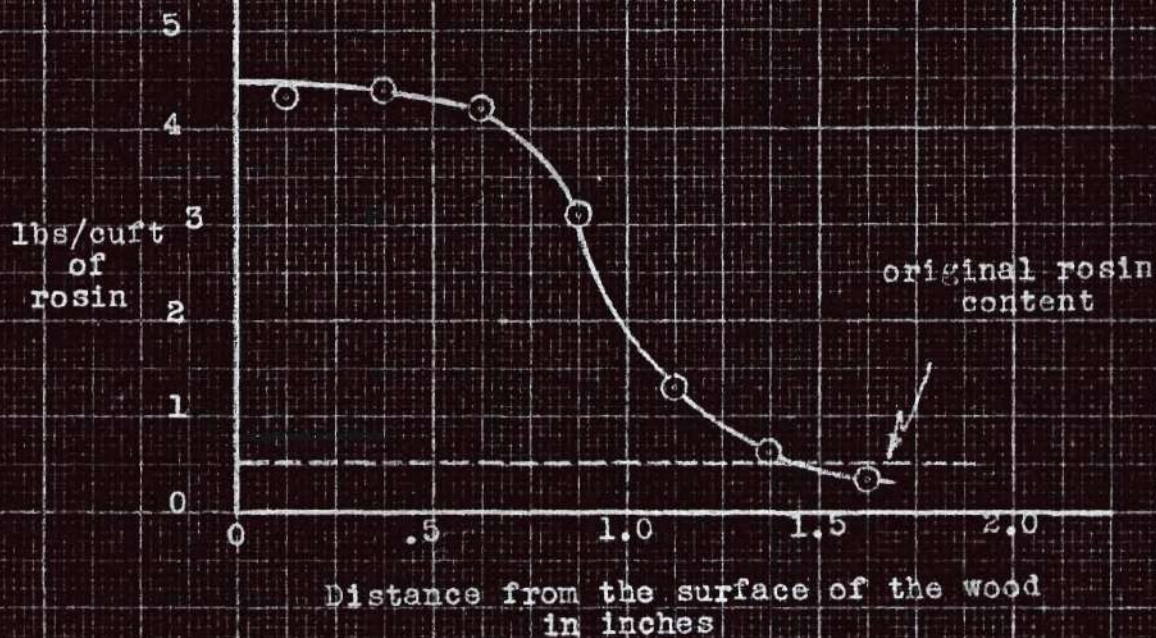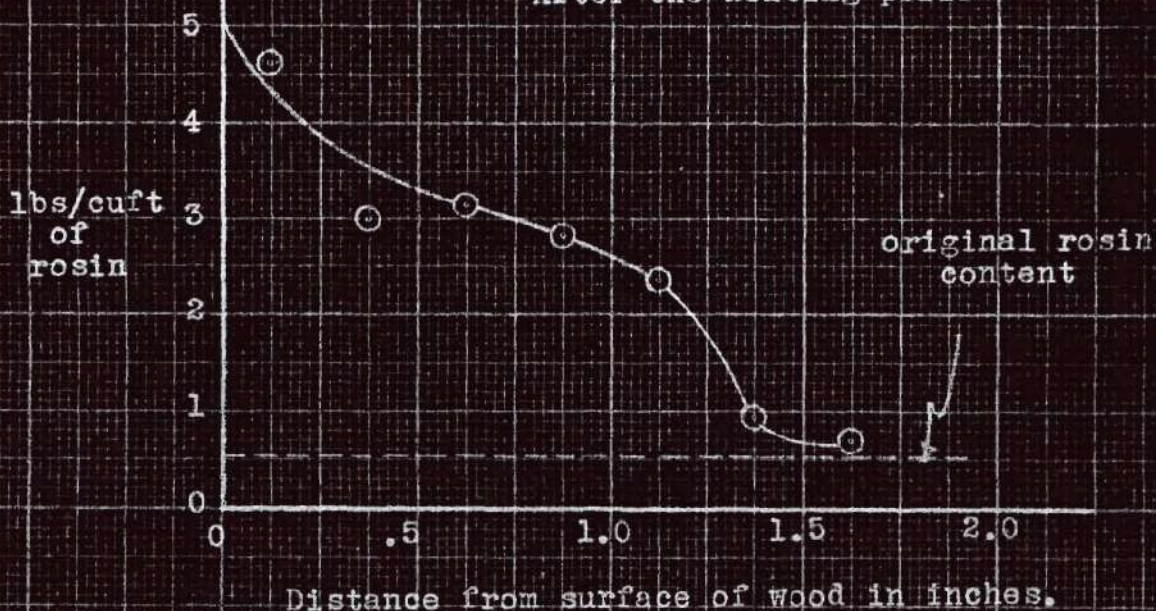
RUN E - Transverse absorption - Time 20 minutes

Before the heating period.

Sample No.	Depth "	Moisture c c.	Moisture % dry basis	Density	Rosin Grams	Rosin lb/cuft.
1.	1/8	10.1	51		2.81	4.21
2.	3/8	10.2	51		2.93	4.38
3.	5/8	10.1	51	.72	2.75	4.12
4.	7/8	10.0	50		2.61	3.91
5.	1 1/8	10.4	53	.72	1.74	2.61
6.	1 3/8	10.7	55		.95	1.42
7.	1 5/8	10.3	52		.50	.75
Original wood	--	8.1	37	.54	.51	.55

Average naphtha content = 3.1%

RUN F - Transverse absorption - Time 20 minutes

After the heating period.

Sample No.	Depth "	Moisture c c.	Moisture % dry basis	Density	Rosin grams	Rosin lbs/cuft.
1.	1/8	6.0	25		4.10	4.81
2.	3/8	6.0	25		2.65	3.10
3.	5/8	6.0	25	.53	2.92	3.42
4.	7/8	5.8	24		3.25	3.81
5.	1 1/8	7.2	32	.53	2.56	3.00
6.	1 3/8	6.8	30		2.58	3.02
7.	1 5.8	7.0	31		1.71	2.00

Average naphtha contents = 2.3%

Transverse absorption – time 20 min.

RUN E

Before the heating period

lbs/cuft of rosin

original rosin content

Distance from surface of wood in inches

RUN F

After the heating period

lbs/cuft of rosin

original rosin content

Distance from surface of wood in inches
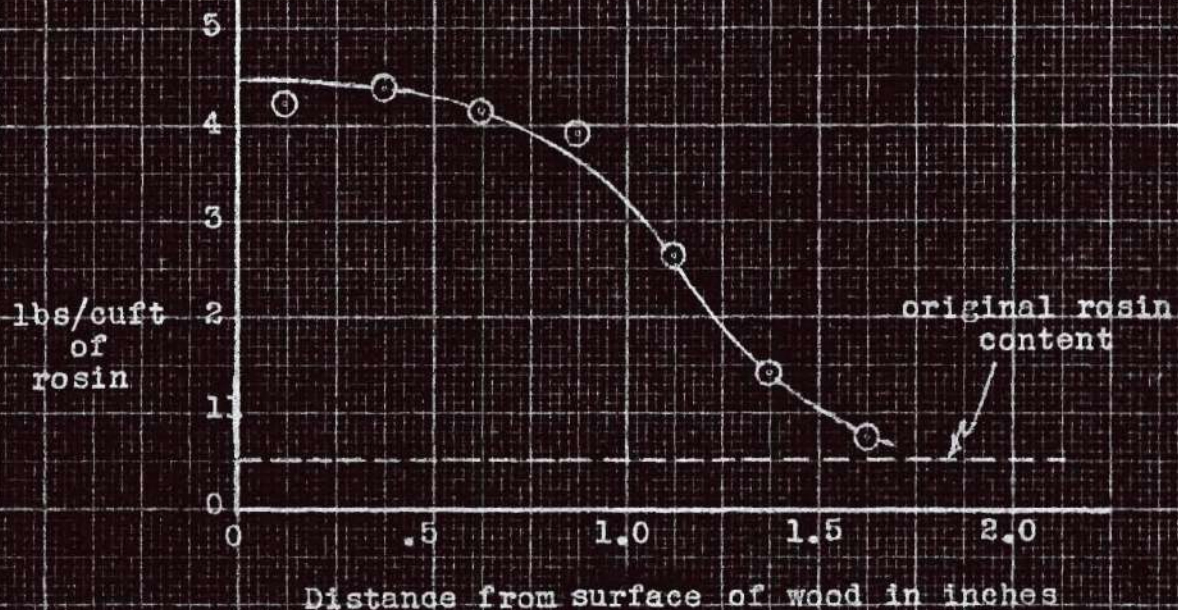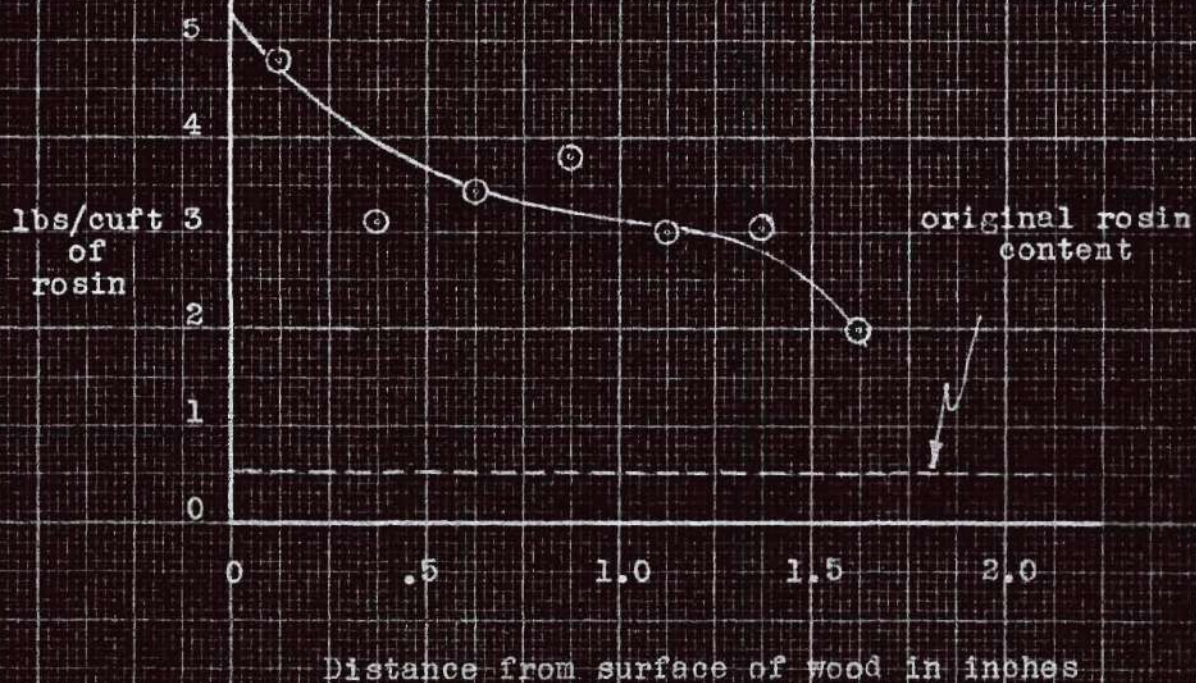
RUN G - Transverse absorption   - Time 30 minutes

Before the heating period.

Sample No.	Depth "	Density	Moisture c c.	Moisture % dry basis	Rosin grams	Rosin lbs/cuft.
1.	1/8		10.7	55	2.93	4.38
2.	3/8		10.1	51	2.89	4.32
3.	5/8	.72	10.2	51	2.97	4.45
4.	7/8		10.4	53	2.88	4.31
5.	1 1/8	.73	8.3	39	1.63	2.74
6.	1 3/8		9.6	47	2.00	3.00
7.	1 5/8		12.1	67	.47	.71
Original wood		.53	8.5	39	.47	.51

Average naphtha content = 2.9%

RUN H - Transverse absorption   - Time 30 minutes

After the heating period.

Sample No.	Depth "	Density	Moisture c c.	Moisture % dry basis	Rosin grams	Rosin lbs/cuft.
1.	1/8		5.2	21	4.04	4.71
2.	3/8		5.3	21	2.75	3.21
3.	5/8	.52	8.1	31	2.93	3.43
4.	7/8		6.2	26	2.49	2.91
5.	1 1/8	.55	7.1	31	2.66	3.10
6.	1 3/8		6.8	30	2.87	3.35
7.	1 5/8		7.4	33	2.41	2.81

Average naphtha content = 2.1%

Transverse absorption - time 30 min.
RUN G

Before the heating period

lbs/cuft
of
rosin

original rosin
content

Distance from surface of wood in inches

RUN H

After the heating period

lbs/cuft
of
rosin

original rosin
content

Distance from surface of wood in inches
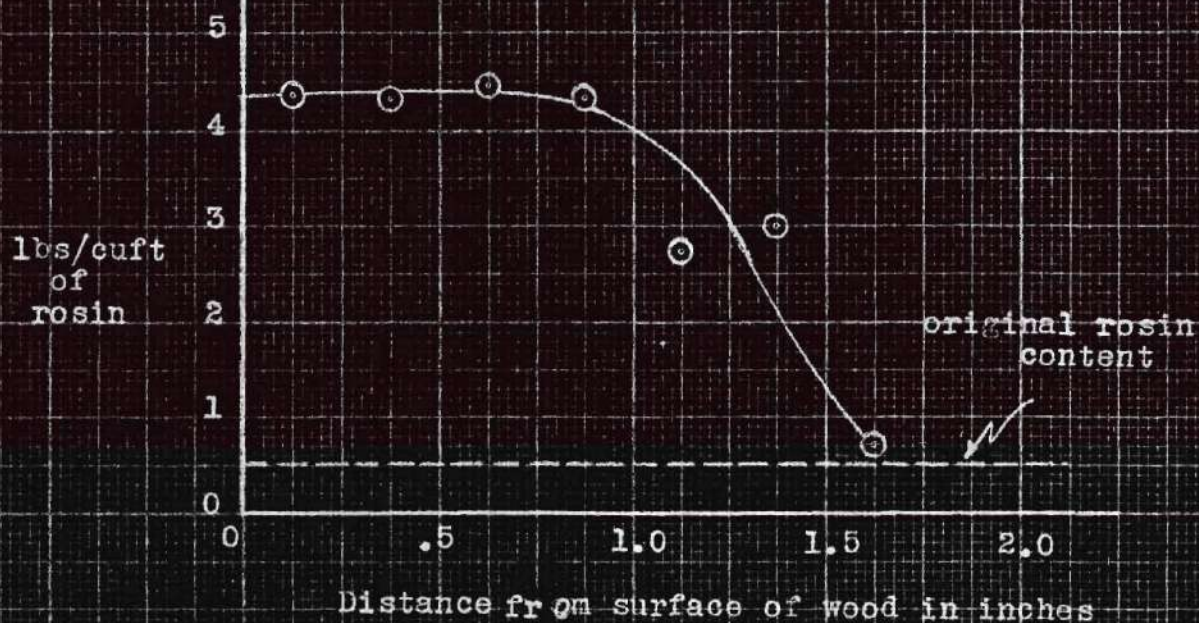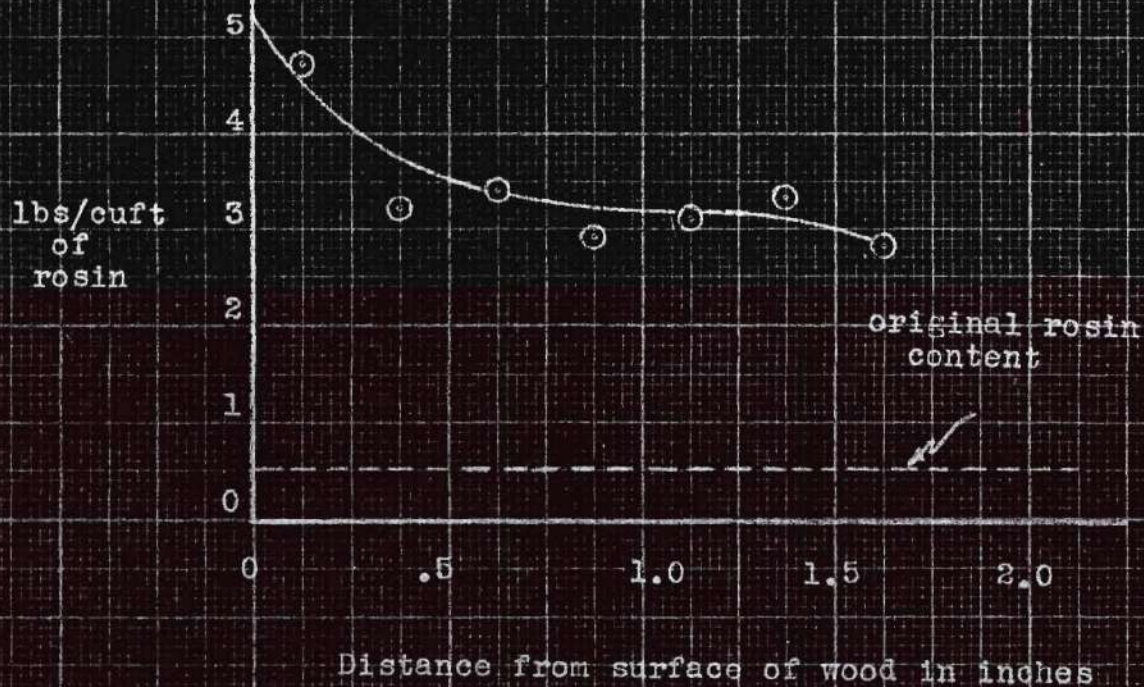
RUN I – Longitudinal absorption   – Time 5 minutes

Before the heating period.   Average naphtha content 3.0%

Sample no.	Depth "	Density	Moisture c c.	Moisture % dry basis	Rosin grams	Rosin lb/cuft.
1.	1		10.0	52	1.48	2.16
2.	3		11.3	60	.86	1.26
3.	5	.71	12.2	72	.87	1.27
4.	7		11.1	60	.56	.81
5.	9		11.4	60	.35	.50
6.	11	.70	11.8	68	.31	.47
7.	13		10.2	62	.42	.61
8.	15		11.4	66	.37	.54

RUN J – Longitudinal absorption   – Time 5 minutes

After the heating period.   Average naphtha content 1.7%

Sample No.	Depth "	Density	Moisture c c.	Moisture % dry basis	Rosin grams	Rosin lbs/cuft.
1.	1		5.3	21	3.27	3.54
2.	3		6.4	29	.80	.87
3.	5	.51	6.0	25	.65	.71
4.	7		7.1	31	.62	.67
5.	9		6.7	29	.85	.92
6.	11	.52	6.8	29	.50	.54
7.	13		6.2	26	.44	.48
8.	15		6.9	30	.51	.55

Longitudinal absorption - time 5 min.
RUN I
Before the heating period

original rosin content

Distance from end of piece in inches.

RUN J

After the heating period

original rosin content

Distance from end of piece in inches.

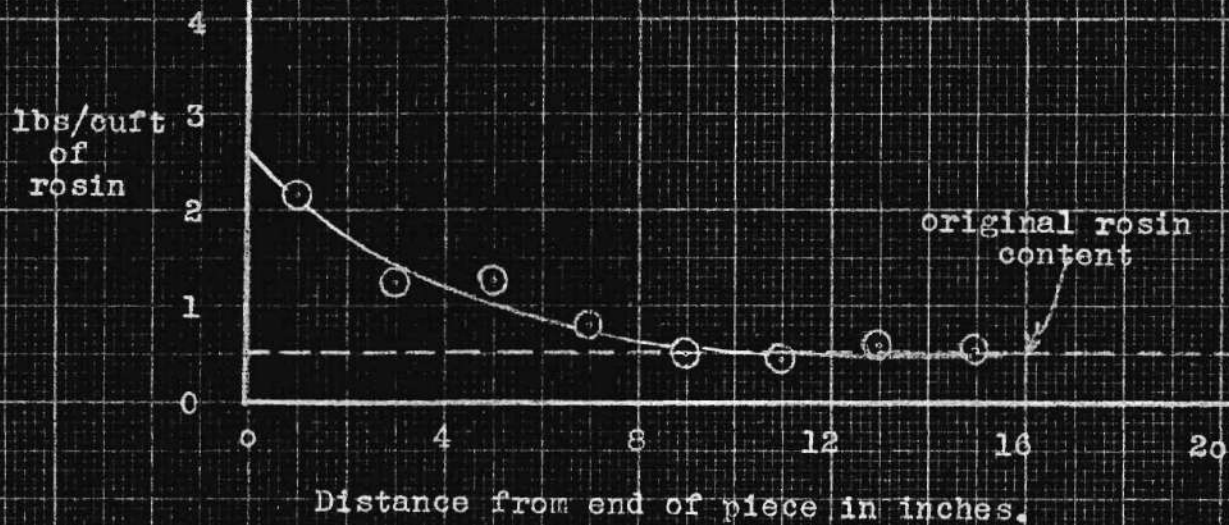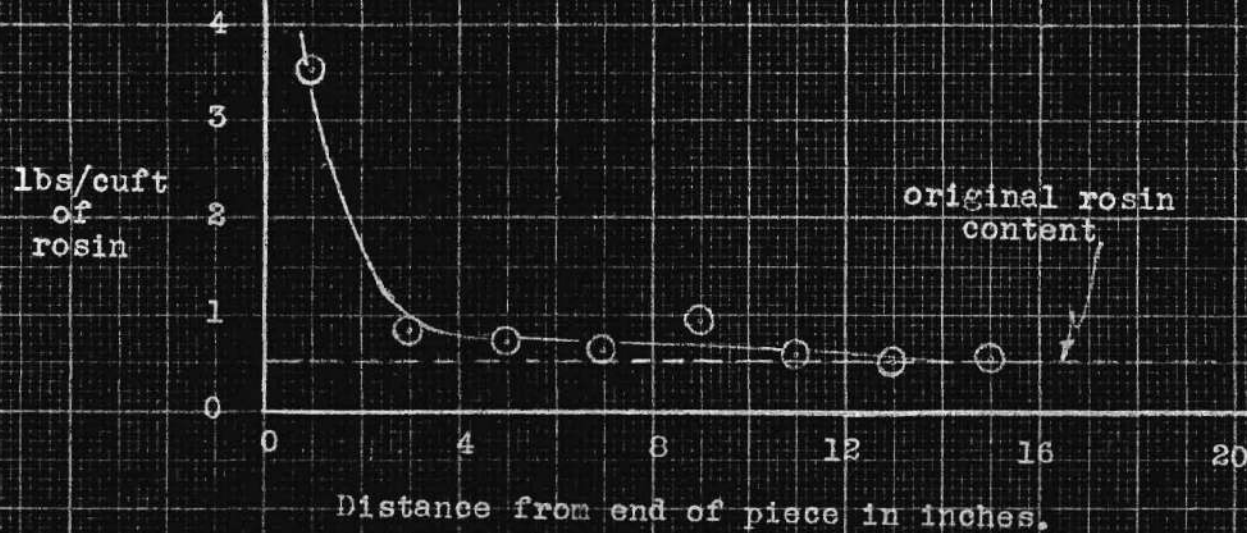RUN K - Longitudinal absorption - Time 10 minutes

Before the heating period.   Average naphtha content= 3.2%

Sample No.	Depth "	Density	Moisture c c.	Moisture % dry basis	Rosin gr ams	Rosin lbs/cuft.
1.	1		10.8	56	1.58	2.31
2.	3		10.8	56	.74	1.08
3.	5	.70	11.5	62	.42	.61
4.	7		11.2	60	.63	.92
5.	9	.71	11.3	60	.59	.86
6.	11		12.2	67	.66	.97
7.	13		12.0	67	.735	.51
8.	15		12.2	68	.44	.64

RUN L - Longitudinal Absorption - Time 10 minutes

Before the heating period.   Average naphtha content = 2.4%

Sample No.	Depth "	Density	Moisture c c.	Moisture % day Basis	Rosin grams	Rosin lbs/cuft.
1.	1		6.1	25	2.19	2.51
2.	3		6.0	25	.96	1.10
3.	5	.52	7.3	33	.64	.73
4.	7		7.4	33	.71	.81
5.	9	.52	7.4	33	.37	.42
6.	11		5.4	21	.84	.96
7.	13		7.6	34	.42	.48
8.	15		7.2	32	.66	.76

Longitudinal absorption - 10 min.

RUN K

Before the heating period

original rosin
content

lbs/cuft
of
rosin

Distance from end of piece in inches

RUN L

After the heating period

original rosin
content

lbs/cuft
of
rosin

Distance from end in inches

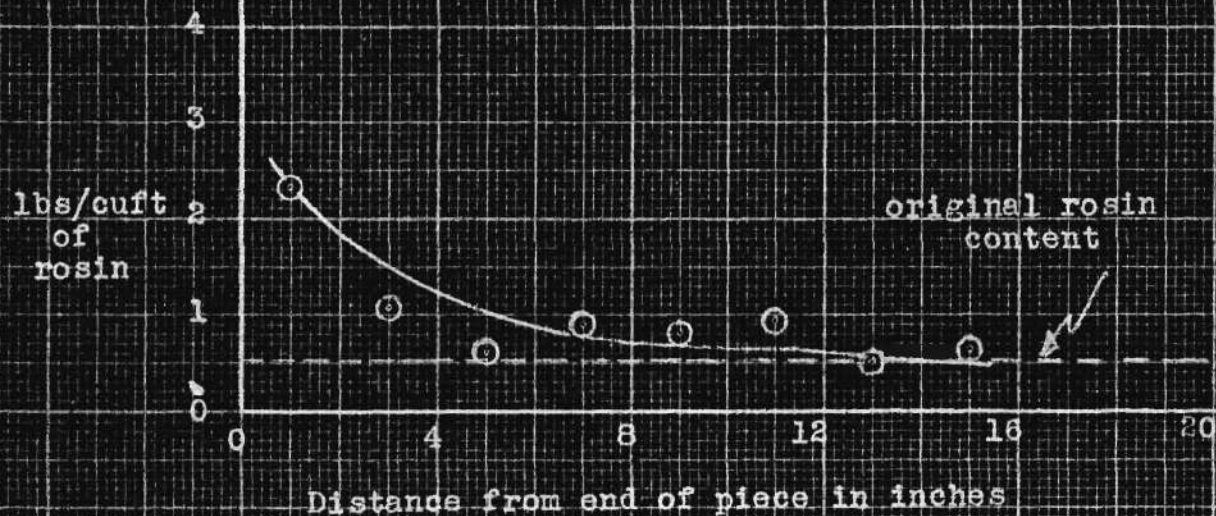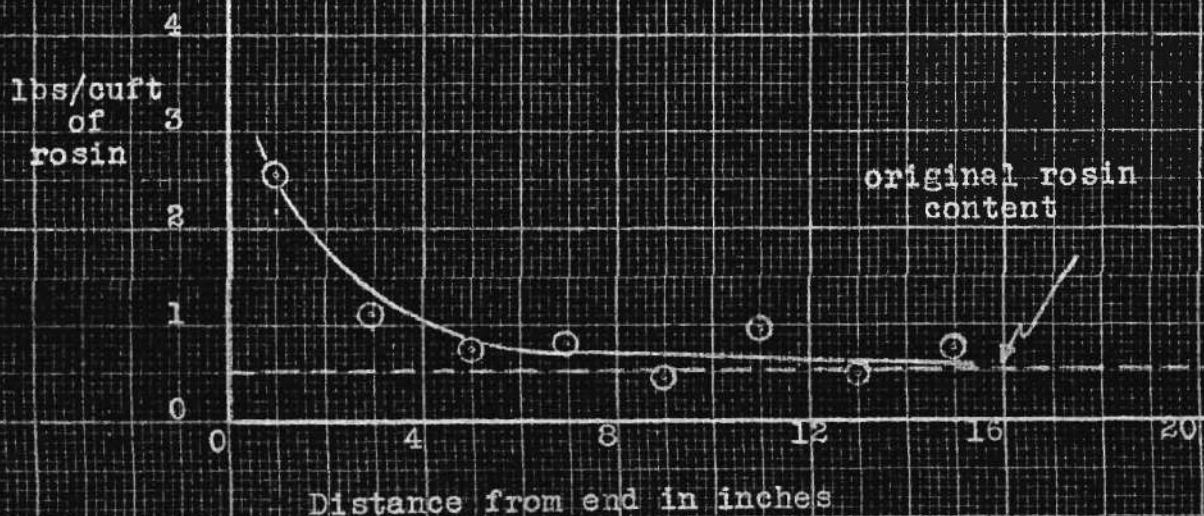RUN M - Longitudinal absorption   - Time 20 minutes

Before the heating period.   Average naphtha content = 3.1%

Sample no.	Depth "	Density	Moisture c c.	Moisture % dry basis	Rosin grams	Rosin lbs/cuft.
1.	1		10.3	52	1.63	2.43
2.	3		10.6	55	1.26	1.84
3.	5	.71	10.7	55	.74	1.10
4.	7		10.9	57	.49	.72
5.	9	.72	10.9	57	.64	.93
6.	11		11.1	59	.58	.84
7.	13		11.3	60	.49	.72
8.	15		11.6	63	.34	.50

RUN N - Longitudinal absorption   - Time 20 mintues

After the heating period.   Average naphtha content = 2.3%

Sample No.	Depth "	Density	Moisture c c.	Moisture % dry basis	Rosin grams	Rosin lbs/cuft.
1.	1		5.8	24	1.97	2.31
2.	3		5.7	23	1.68	1.97
3.	7	.52	5.9	25	.74	.87
4.	9		6.0	25	1.12	1.31
5.	13	.53	6.5	27	.61	.71
6.	15		6.4	27	.54	.63
7.	19		6.8	30	.40	.44
8.	23		7.1	31	.52	.61

Longitudinal absorption - time 20 min.

RUN M

Before the heating period

lbs/cuft
of
rosin

original rosin
content

Distance from end of piece in inches

RUN N

After the heating period

lbs/cuft
of
rosin

original rosin
content

Distance from end of piece in inches

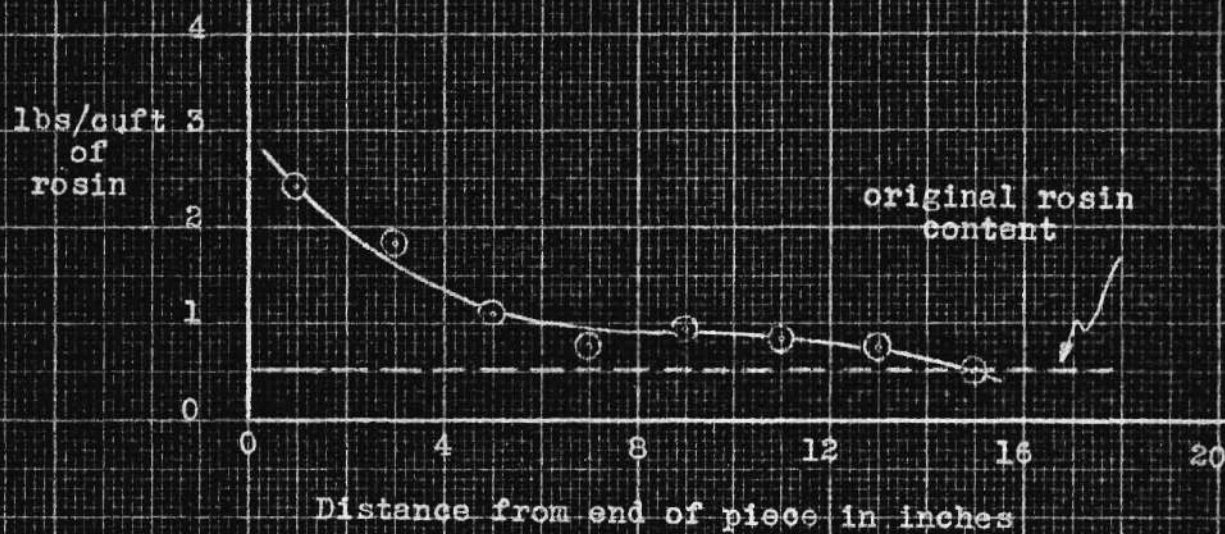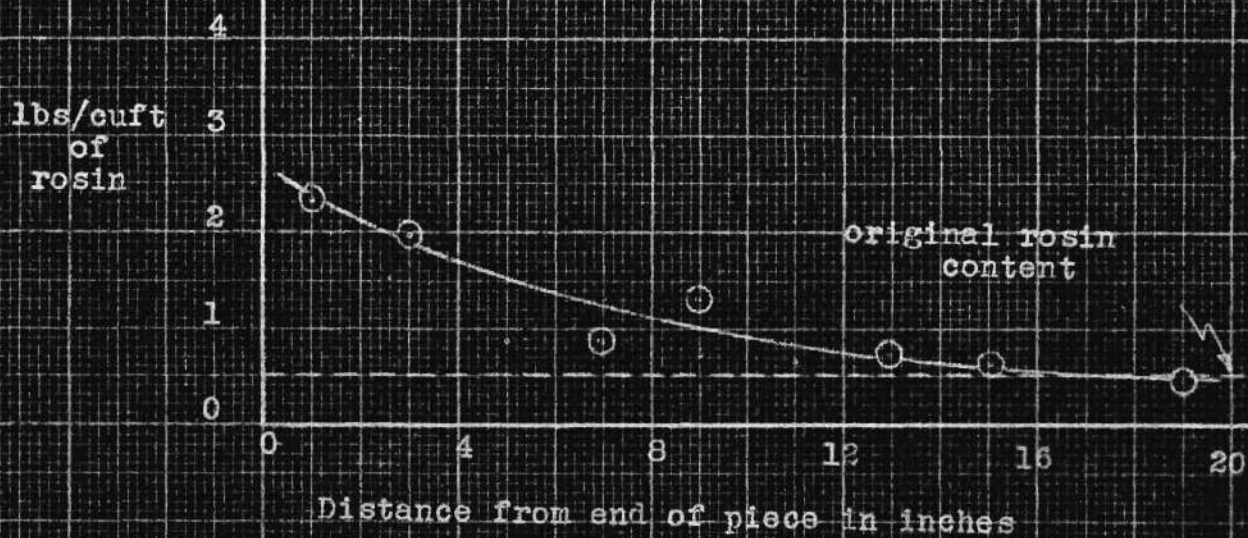RUN O - Longitudinal absorption   - Time 30 minutes

Before the heating period.   Average naphtha content = 3.3%

Sample No.	Depth "	Density	Moisture c c.	Moisture % dry basis	Rosin grams	Rosin lbs/cuft.
1.	1		10.3	52	1.80	2.63
2.	4		10.4	53	1.41	2.05
3.	7	.70	10.6	55	.82	1.20
4.	10	.71	11.1	59	.92	1.34
5.	13		11.2	59	.49	.71
6.	18		11.6	63	.33	.48
7.	21		11.1	59	.36	.53
8.	24		11.9	66	.37	.54

RUN P - Longitudinal absorption   - Time 30 minutes

After the heating period.   Average naphtha content = 2.2%

Sample No.	Depth "	Density	Moisture c c.	Moisture % dry basis	Rosin grams	Rosin lbs/cuft.
1.	1		5.5	22	2.67	3.10
2.	3		5.8	24	1.58	1.85
3.	7	.53	6.2	26	1.12	1.31
4.	9		6.7	29	.82	.97
5.	13	.51	5.9	25	.61	.71
6.	15		6.8	30	.51	.59
7.	19		6.9	30	.62	.72
8.	22		7.4	33	.37	.43

Longitudinal absorption - time 30 min.

RUN O

Before the heating period

lbs/cuft of rosin

original rosin content

Distance from end of piece in inches

RUN P

After the heating period

lbs/cuft of rosin

original rosin content

Distance from end of piece in inches
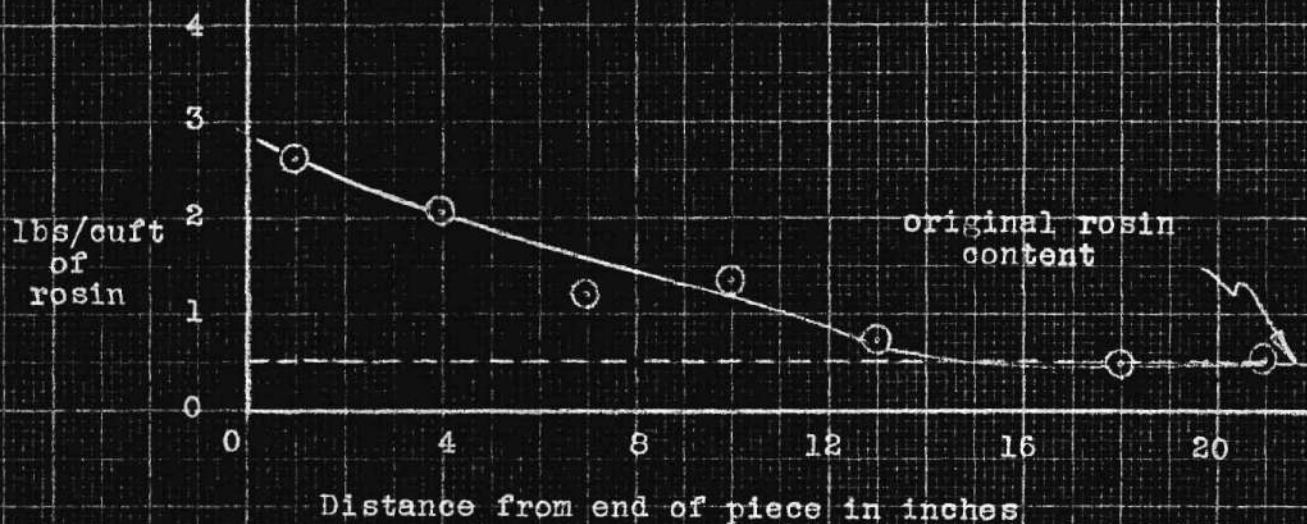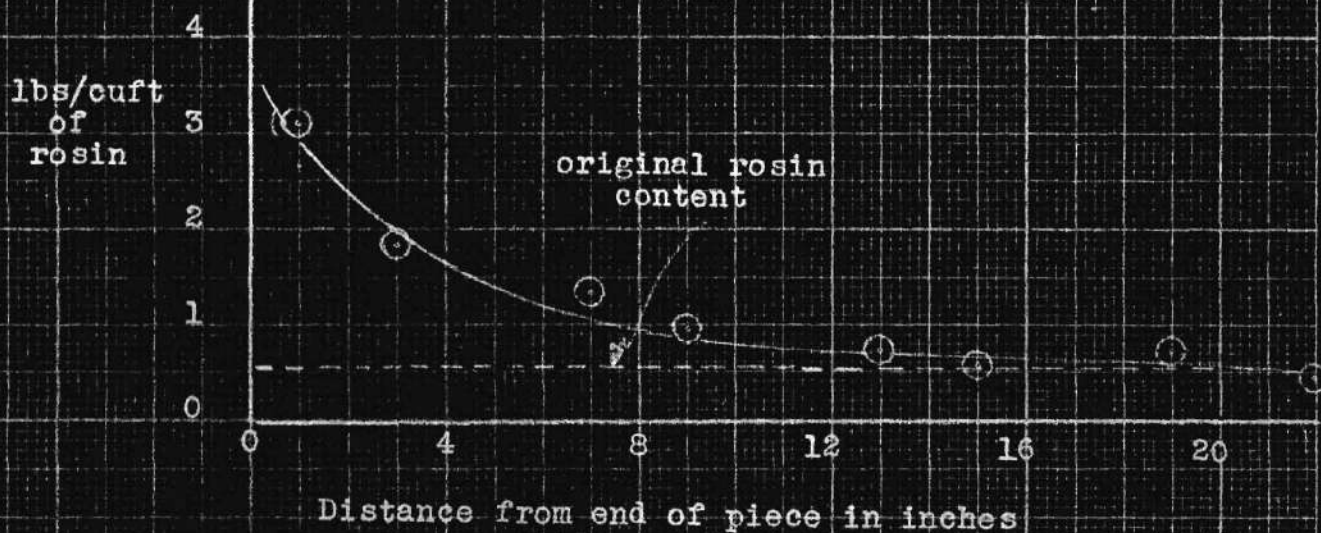
RUN Q   Both Transverse and Longitudinal Penetration.

Time one hour.

Sample No.	Density	Rosin grams	Rosin lbs/cuft.
1.		2.90	3.42
2.		3.00	3.52
3.	.53	2.96	3.48

DISCUSSION OF RESULTS

The absorbtion gradients were all run on one lot of wood and, therefore, show only tendencies for sap pine lumber in general. In order to difinitely determine average pentration and absorbtion rates in sap pine as a class, a large number of samples taken from different strains and from pieces that had experienced different growth conditions would have to be tested. The experiece of creosoters leads one to believe that the exact correlation of data thus obatined would be impossible. However, tests on one strain and lot should show tendencies of the whole class.

Penetration as indicated by absorbtion gradient curves is rapid. Runs A, C and D show one and three eights inches of transverse penetration in five minutes, nearly one and one half inches in ten minutes and complete penetration of the four by fours in twenty minutes. Longitudinal penetration in five, ten, twenty and thirty minutes as indicated by the curves for runs I,K,M and O were nine inches, thirteen inches, fifteen inches and fifteen inches. The heat treatment which further increased penetration was not used in the above mentioned runs.

Penetration is more rapid than that for creosote as indicated by Bateman's (9) data.

The average ratio of longitudinal to transverse penetration is 8:1. Values given by MacLean (29) for sap pine wood are 18:5 for penetration by coal tar creosote and 25:7 for zinc chloride solutions.

(9) Loc. Cit.
(29) Engineering News Record): 102,176 (1929)

In reference to penetration reported here, two facts should be noted. First, the use of composite samples tended to give the maximum penetration rather than the average and, second, penetration in small pieces, all sap wood, cannot be compared to that in large poles containing a heart wood center.

If the rosin, naphtha and moisture contents and the density of the treated wood is known, the density (d_o) of dry, naphtha free, rosin free wood may be calculated by -

$$d_o = \frac{100-\% \text{ water}-\% \text{ naphtha}-\% \text{ rosin X d}}{100}$$

Taking sample 1, run A as an example

$$\frac{100-36.7-3.2-10.0 \text{ X}.72}{100} = .36$$

The average value obtained from a number of such calculations is .36. Using Stamm's (6) value of 1.52 for fibre density the volume of the voids (V) in a cubic foot of dry wood may be calculated by -

$$V = \frac{1.52-.35}{1.32} = .77 \text{ cubic feet.}$$

Both weight and volume of the original rosin in the sap wood is negligible in these calculations.

The wood used for the tests contained an average of 40% moisture on the dry basis. This water occupied some of the above calcualted void volume. The void volume

(6) Loc. cit.

(V_1) in a cubic foot of the original wood is given by -

.77 - .35 x .40 ᠆ .63 cubic feet

Theoretically, the greatest amount of rosin that may be injected into the wood by the emulsion is -

.63 (90 x 62.4).158 ᠆ 5.59 pounds per cubic foot.

The original wood contained an average of .53 pounds of rosin per cubic foot. Therefore, the greatest possible rosin content in the treated wood is 6.12 pounds per cubic foot.

The maximum treatment theoretically possible, which would be had only when all of the void volume was filled with emulsion, corresponds, volume for volume, to a 40.4 pounds per cubic foot creosote treatment.

The greatest rosin content actually observed was 4.81 pounds per cubic foot. This was in run F. The extrapolation of both this curve and that of run H show a concentration of 5.3 pounds per cubic foot in the outer fibre.

Of this rosin content 4.77 pounds per cubic foot was injected with the emulsion. This is equivalent to the filling of 85.4% of the voids with emulsion and corresponds to a 34.2 pound creosote treatment.

In the runs marked 'before the heating period' no heat treatment was given and the treatment was essentially a straight Bethell process. These shall be referred to as the straight Bethell runs, hereafter. It was necessary, however, to give the heat treatment

to decrease leachability. It was given in the runs marked 'after the heating period' and these shall be referred to as the heat treated runs.

The affect of the heating period on transverse absorbtion gradients was very marked. No data have been published on absorbtion gradients in a Bethell process, so that there is nothing with which to compare the straight Bethell runs. The curves for these runs, A, C, E and G, indicate that absorbtion reaches a maximum of approximately 4.5 pounds per cubic foot and that this maximum moves in as time of penetration is increased. This maximum corresponds to the filling of 71% of the voids in the wood with emulsion. The curves probably show the distribution of emulsion that exists for the heat treated run just before the heating period is started.

It was observed during the heat treatment that some of the broken emulsion was forced out of the wood.

The curves for runs, B, D, F and H indicate that the heat treatment depresses the maximum plateau forming a lower and wider plateau at approximately 3.3 pounds per cubic foot and also increasing the concentration in the outer fibre. It should be noted that as time increases the lower plateau moves in. 3.3 pounds per cubic foot corresponds to the filling of 50% of the voids.

For the thirty minute run this 3.3 pound per cubic foot concentration seems to be that in the major portion

of the wood.   In order to determine if this was a limiting
value of absorbtion for the conditions imposed, run Q was
made in which four by fours were impregnated both transversely
and longitudinally for one hour.   Composite samples taken
indicated an average concentration of 3.47 pound per cubic
foot which would tend to show that a limiting value had
indeed been reached.

The effect of the heating period on longitudinal
absorption gradients was similar to that on the transverse
gradients though not so pronounced.   The general effect
was the depression of the central portion of the curve
and increasing the concentration at the outside end.

Combinations of the curves for absorption gradients
are given.   These show very well how the maximum plateaus
of transverse absorption move into the wood as time
increases.   The curves for longitudinal absorption show
an increase in rosin content with time but no maximum
plateaus.

While longitudinal penetration is great absorbtion
from that direction seems to be small except in the ends
of the pieces.

Little is to be learned from the moisture data that
are at hand.   Smooth moisture gradient curves which might
tell something about rates of drying can be obtained in
so few cases that their validity would be doubtful.

Transverse absorption - Time 5 to 30 min.
Without heating period.
Combination of curves for Runs A, C, E and G.
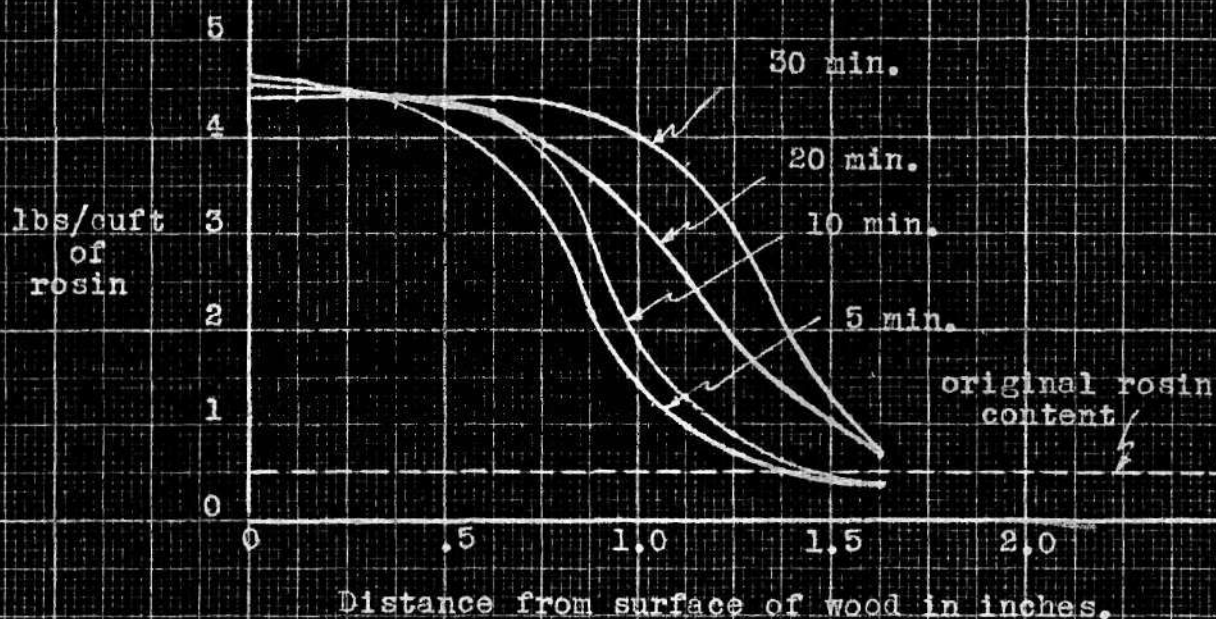
Combination of curves for Runs B, D, F and H.
With heating period.
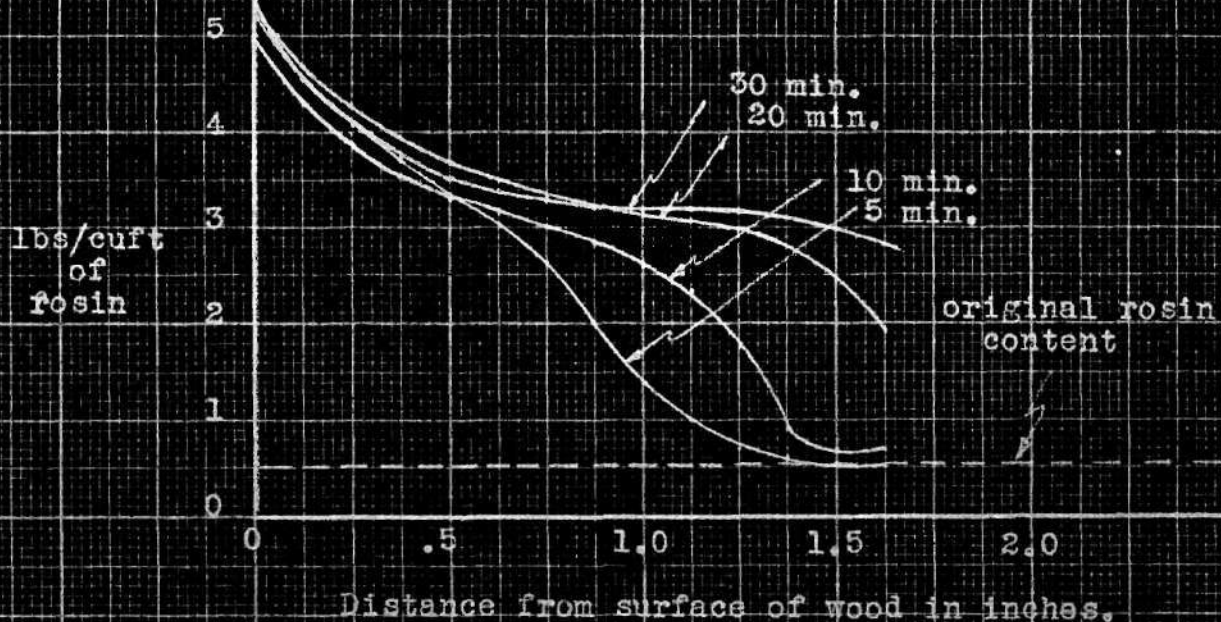
Longitudinal absorption - Time 5 to 30 min.

Combination of curves for Runs I, K, M and O.

Without heating period

lbs/cuft of rosin

30 min.
20 min.
10 min.
5 min.
original rosin content

Distance from end of piece in inches.
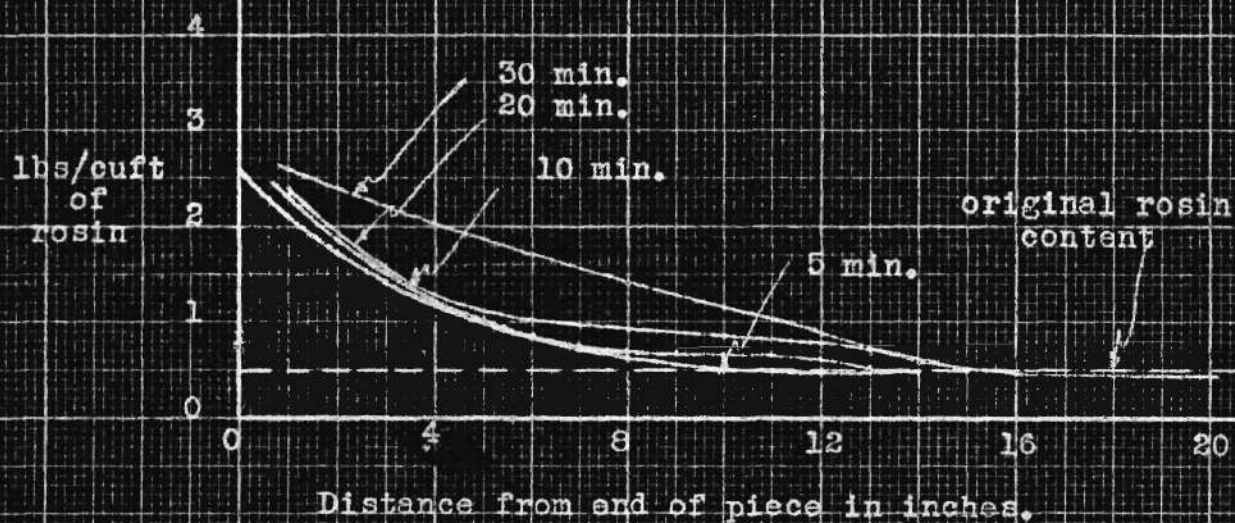
Combination of curves for Runs J, L, N and P.

With heating period

lbs/cuft of rosin

30 min.
20 min.
10 min.
5 min.
original rosin content

Distance from end of piece in inches.
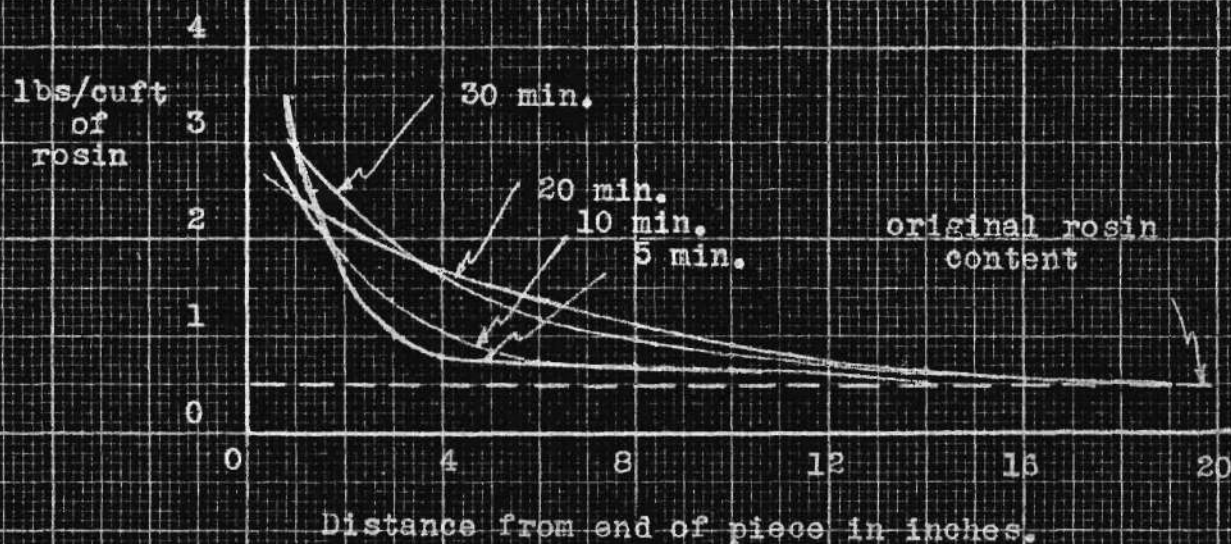
The effect of the heating period on moisture content is greater than is indicated by the data since it was necessary to air dry the pieces that were not given the heat treatment for a few days to facilitate the cutting of samples.

This explains the low value obtained for naphtha content in the straight Bethell runs. When the heating period was started the wood contained large quantities of water and naphtha that had served to carry the rosin in.

CONCLUSION

The heat treatment gave much the effect of a
Rueping treatment. The impregnating agent is forced
out of the wood in much the same manner as the air
forces the creosote out in the above mentioned treatment.

The depression of the absorbtion gradient curves
and the increase in concentration in the outer fibres
on heating might be explained by the creation of pressure
in the wood due to the vaporization of naphtha and water.
The pressure would be higher where there was the greatest
quantity of emulsion. This would be at the place indicated
by the maximum plateaus of the straight Bethell runs.
This pressure would tend to force the emulsion both in
and out. The curves indicate an increase in penetration
due to the heat treatment. It should be remembered that
the emulsion is now breaking down due to the heat. The
outside of the piece would be the easiest avenue of escape
so that more of the broken emulsion will be forced in that
direction. The heat is flowing in from the surface so
that the naphtha rosin solution is being concentrated
as it is forced out. Close to the surface the naphtha
solution of rosin is so concentrated that the rosin
begins to separate out increasing the concentration at
that point.

The resin ducts in the wood run along the grain
or longitudinally. These ducts are large and should
offer free passage to liquids penetrating in that
direction. Since the total void volume in the ducts is
relatively small no great concentration could be built
up by penetration through them.

The curves obtained for longitudinal absorbtion
gradients show deep penetration but low absorbtion
except close to the ends, from which the penetration
starts. These high concentrations in the ends might
be due to penetration through the fibre cavities while
the low concentrations deep in the wood might be due
to penetration through the resin ducts.

Regardless of the mechanism by which the rosin
enters and is distributed through the wood by the
heating period, the fact remains that the maximum
treatment that can be obtained is approximately 3.3
pounds per cubic foot. This treatment, however, may
be obtained in thirty minutes for four by fours.

PART 3

PHYSICAL PROPERTIES

Some of the physical properties of the treated wood
as compared to those of the original wood are listed below.

1. Color - The treated specimens were only slightly
darker than the original wood.

2. Milling - The treated pieces could be worked as
well as the original wood. No difficulty was experienced
in cutting samples.

3. Warping - In order to test for warping, both
during the process and in drying after treatment, samples
one quarter of an inch by three and five eighths inches,
four feet long, were cut, treated and air dried. These
were not warped after treatment and were only slightly
twisted after drying for two weeks.

4. Checking - Observations made during the drying
of both the original and treated wood indicated no
difference in the tendency to check.

5. Painting - Small paddles of the original and
the treated wood were painted with a lead oil white paint,
a flat white paint and a clear varnish. The treated and
original wood took the paints and varnish equally well.
This is a point worthy of consideration. A series of
tests made by H. A. Gardner(30) showed that creosote bled
through as many as three coats of red lead, white lead

(30) Paint Manufacturers Association Circular No. 286

and a lead free paint. Wood treated with rosin emulsions showed no tendency to bleed.

6. Strength - Transverse strength tests were made on clear samples of the original and treated wood. The treated samples were impregnated with emulsion that contained varying concentration of rosin in order to get uniform distribution of varying amounts of rosin in the wood.

The emulsions were simply diluted with the desired amount of water, placed in the emulsifier and agitated until homogeneous.

The rosin analysis was run on the samples of wood as soon as the treatment was finished but specimens were not tested for strength until they had air dried to practically equivalent moisture contents. Several moisture determinations had to be made on the samples as they dried to assure the following of this procedure. No difficulty was experienced in this as all the treated and original wood had dried to approximately the same moisture content in twenty three days.

The actual transverse breaking tests were run by a method used by the Experimental Engineering Laboratory of the Georgia School of Technology and on the equipment used by that Department. The method is an adaptation of the A.S.T.M. method for small clear timbers.

Samples were approximately one and five eighths inches by five eighths inches by twenty inches. Each one was accurately measured when tested. These were of course, clear of knots and blemishes and all had been taken originally from the same piece of timber.

The samples were placed on two supports eighteen inches apart and the load was applied at the center of the span thus formed. This load was increased until the specimen broke. As one of the supports was resting on a platform scale with an indicating dial the increase in load could be followed. The maximum scale reading was recorded and this was doubled to give the breaking load. At least four specimens were broken for each of the treatments and five were taken for the original wood.

Ultimate strength (S) was calculated from

$$S = \frac{Mc}{I}$$ where M = maximum bending moment
c = distance from the outermost fibre to the neutral center.
I = moment of inertia of the section.

For a simple beam loaded at the center

$$M = \frac{Pl}{4}$$ where P = breaking load in pounds
l = length of span in inches

For a rectangular section

$I = 1/12\ bd^3$ where d = thickness of piece in the
direction in which the load
is applied
b = width of piece normal to the
direction of the applied load.

$$c = \frac{d}{2} \qquad (30)$$

Results obtained on short samples of a different lot
of wood are also reported. These were given a straight
Bethell treatment.

(30) Mechanics of Materials, Merriman, John Wiley and Sons

DATA -

Transverse Strength Test   - Length of span 18".

Samples heat treated.

Sample	Rosin in wood lbs/cuft.	b	d	P	S	Moisture % dry basis
Original						
1.		1.62	.78	448	12250	
2.		1.69	.62	376	15320	
	.53					12
3,		1.56	.75	398	12220	
4.		1.62	.69	346	12110	
5.		1.75	.78	294	7500	
				Average	11840	
Run R.						
1.		1.62	.69	402	14200	
2.		1.75	.62	415	16480	
	3.35					11
3.		1.75	.62	466	18400	
4.		1.62	.62	468	21400	
5.		1.62	.62	458	19410	
				Average	17980	
Run S.						
1.		1.62	.62	422	17800	
2.		1.50	.62	332	14600	
	2.97					11
3.		1.50	.62	404	17600	
4.		1.50	.69	388	14900	
				Average	16220	

Transverse Strength Test - Length of Span 18".

Samples heat treated.

Sample	Rosin in wood lbs/cuft.	b	d	P	S	Moisture % dry basis
Run T						
1.		1.75	.75	292	8050	
2.		1.75	.75	240	6630	
3		1.69	.75	408	11680	
	1.43					11
4.		1.62	.75	360	10760	
5.		1.62	.75	328	9740	
			average		9370	
Run U						
1.		1.75	.75	302	8300	
2.		1.62	.75	264	7850	
	1.30					11
3.		1.75	.75	366	10080	
4.		1.75	.75	292	8060	
			average		8570	

Transverse Strength Test - Length of span 7.25"*

Samples not heat treated.**

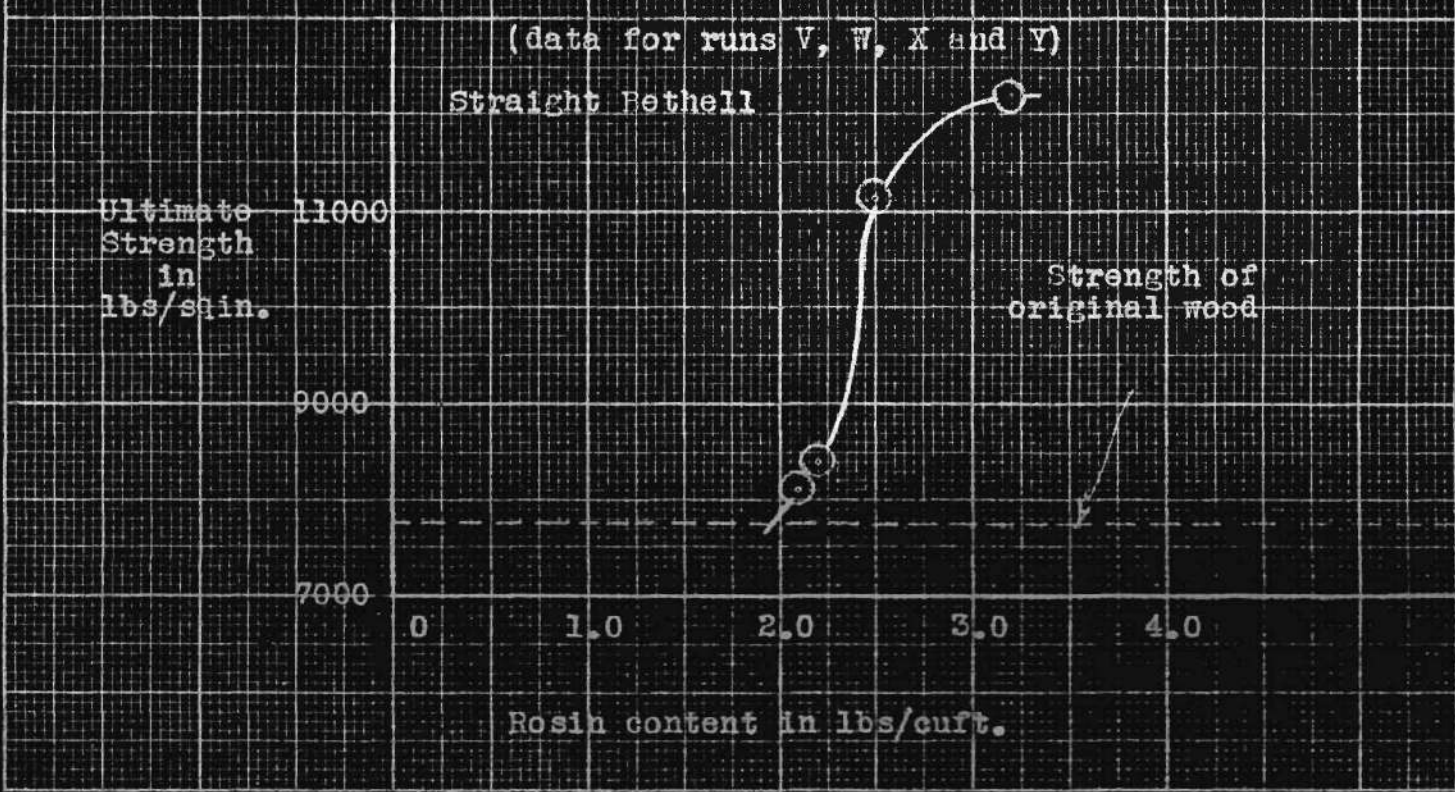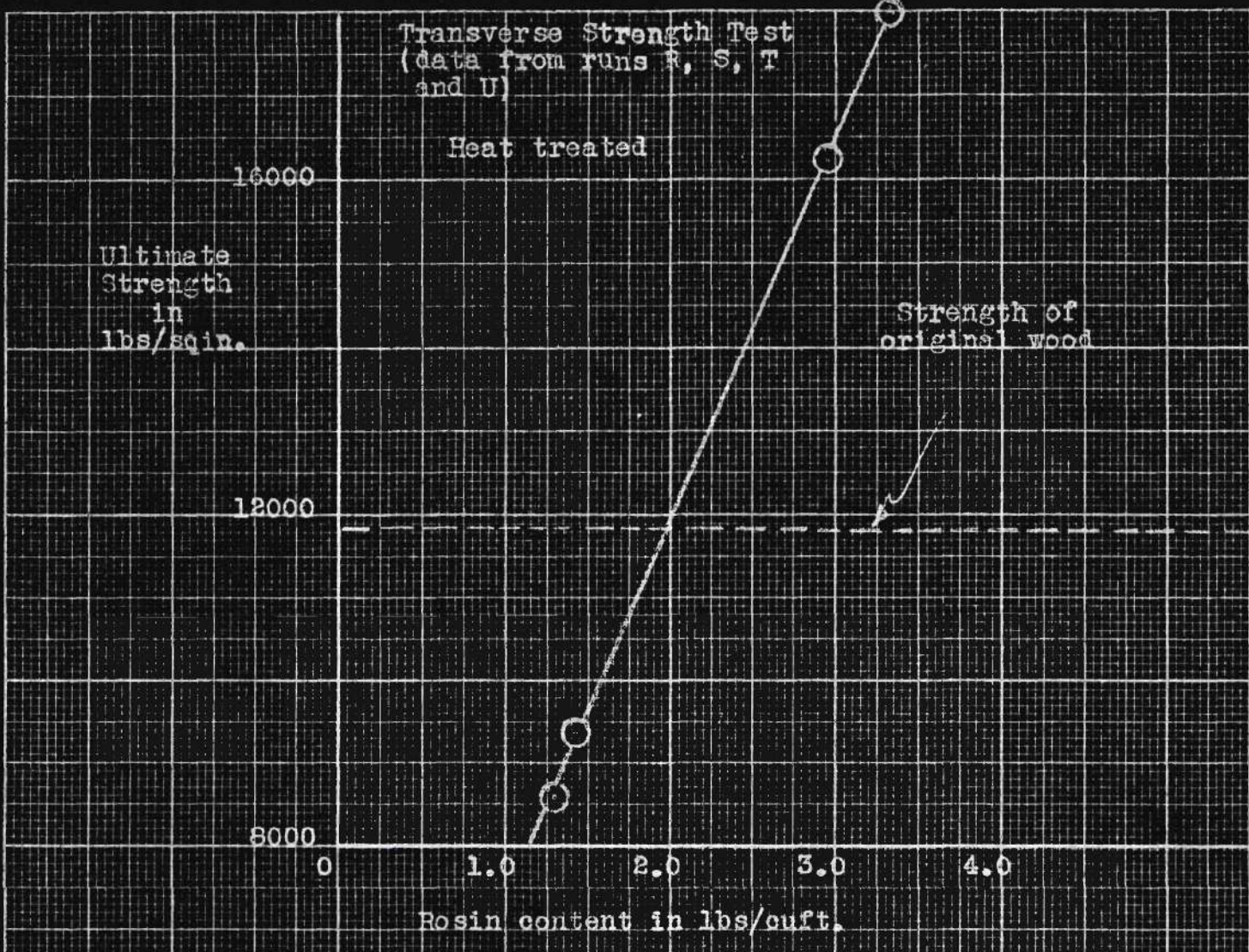| Sample	Rosin in wood lbs/cuft.	b	d	P	S	Moisture% dry basis
Original						
1.		1.76	.94	1165	8250	
2.		1.87	.94	1100	7330	
3.	.37	1.81	.94	1110	7670	12
4.		1.81	.81	900	8100	
5.		1.81	1.00	1250	7530	
				average	7780	
Run V						
1.		1.87	.87	1100	8420	
2.		1.81	.87	1010	8000	
3.	2.12	1.87	.87	1040	8000	12
4.		2.00	.81	975	7980	
				average	8100	
Run W						
1.		1.87	.94	1150	7680	
2.		1.94	.81	950	8110	
3.	2.20	2.00	.81	1120	9140	12
4.		1.81	.87	1010	8010	
				average	8230	

* Span could not be made longer since the treating vessel used
  in these runs was small.

**The wood used in these runs was not from the same lot as
that used for other tests reported in this thesis.

Transverse Strength Test - Length of span 7.25"

Samples not heat treated.

Sample	Rosin in wood lbs/cuft.	b	d	P	S	Moisture% dry basis
Run X						
1.		1.06	.87	855	11500	
	2.50					11
2.		1.06	.81	680	10450	
3.		1.06	.87	855	11500	
			average		11150	
Run Y						
1.		1.94	.81	1290	10900	
2.		1.75	.81	1410	13120	
	3.20					11
3.		1.75	.75	1115	11780	
4.		1.81	.87	1435	12950	
			average		12190	

Transverse Strength Test
(data from runs R, S, T
and U)

Heat treated

Ultimate
Strength
in
lbs/sqin.

Strength of
original wood

16000

12000

8000

0   1.0   2.0   3.0   4.0

Rosin content in lbs/cuft.

(data for runs V, W, X and Y)

Straight Bethell

Ultimate   11000
Strength
in
lbs/sqin.

Strength of
original wood

9000

7000

0   1.0   2.0   3.0   4.0

Rosin content in lbs/cuft.

Both sets of data show an increase in strength of approximately fifty per cent for a 3.2 pound rosin treatment. The curve for runs R, S, T and U show that for concentrations below 2 pounds per cubic foot the strength is decreased. In the straight Bethell runs no samples were tested that contained less than this amount but the curve, when extrapolated, crosses the original strength line at 1.95 pounds per cubic foot. This would tend to indicate that with lower concentrations a straight Bethell process would lower the strength in much the same manner as the process that included a heat treatment did.

J. Compredon(3) has found that the strength of wood impregnated with resins, such as bakelite, is increased from one and a half to three times that of the original wood.

(3) Loc. cit.

PART 4

TOXICITY TESTS

Comparative toxicity tests were run on rosin and a commercial creosote using the procedure of Henry Schmitz and others of the Department of Agriculture of the University of Minnesota(17).

This procedure requires the use of malt extract agar as a culture medium and suggests Fomes annosus as a test organism. Varying quantities of the inhibitor to be tested are added to the medium and the whole is placed in a nine centimeter petri dish. A one centimeter circular inoculum of a fourteen day old culture is then placed on the hardened medium at the center of the dish. Controls to which no inhibitor is added are also inoculated. After the cultures have been incubated at 28° C. for fourteen days the amount of radial growth is measured. Percentage retardation is reported for each concentration of inhibitor.

$$\text{Per cent Retardation} = \frac{G_c - G_s}{G_c} \times 100$$

Where G_c = radial growth on controls

G_s = radial growth on sample

Sterile technique must be used throughout.

When volatile agent, such as creosote, are tested stoppered flasks replace the petri dishes.

(17) Loc. cit.

In those samples in which complete retardation is obtained a test must be made to determine if the organism is still alive. To do this a bit of the inoculum is placed on a fresh malt agar slant and incubated for two weeks. If there is no growth in this time the organism is considered dead.

It was found that creosote emulsified very well with the agar medium. Therefore, no difficulty was experienced in conducting tests with this agent. This, however, was not the case with rosin.

The material that was left in the wood after impregnating and heating was probably not simply rosin. There might have been some ammonium resinate left that was not decomposed by the heating. It is also possible that the rosin itself might have decomposed to a certain extent. The extract taken from the wood was much darker than the original rosin. In order to introduce the same material into the medium, varying quantities of the emulsion were added and the dishes thus prepared were placed in an autoclave and subjected to fifteen pounds per square inch steam pressure for one hour. The naphtha was all distilled off by this time, being replaced by condensed steam. It was necessary to remove the naphtha as the paraffin hydrocarbons are, themselves, very effective inhibitors. The naphtha content

of the treated wood averages two per cent but this was, no doubt, lost in a short time. All of the naphtha was therefore removed from the medium. The time required to do this was determined in preliminary experiments in which the method used for the determination of naphtha in wood was employed. One hour was found to be sufficient. When the naphtha had distilled off the rosin was left suspended in the agar.

In order to determine whether the naphtha formed any toxic material by reacting with the agar or malt controls were made up by adding pure naphtha to the malt extract agar and removing the naphtha in the autoclave. Growth was the same in these controls as it was in those controls to which no naphtha had been added.

The incubation period had to be cut to six days as by that time growth had reached the edges of the plates in the controls.

The organism used in the tests was the No. 517 of the Forest Products Laboratories. This is the strain that has been used in practically all of the toxicity tests made in this country though there is some doubt as to whether it is Fomes annosus.

DATE ON TOXICITY TESTS

Creosote

Concentration of Creosote, in per cent	Retardation in per cent	Concentration of Creosote in per cent	Retardation in per cent
9	dead	.1	100
5	dead	.05	95
3	dead	.03	80
2	dead	.01	55
1	dead	.005	60
.5	100	.003	20
.3	100	.001	0

Rosin

Concentration of Rosin in per cent	Retardation in per cent	Concentration of Rosin in per cent	Retardation in per cent
9	35	.2	0
7	38	.1	0
5	50	.05	0
3	16	.03	0
2	0	.01	0
1	0	.005	0
.5	0	.003	0
.3	0	.001	0

In the rosin series the samples containing seven per cent and nine per cent are of no value since uniform distribution of rosin could not be obtained in these high concentrations. The data indicate that .005 per cent of creosote is as effective as 5 per cent of rosin. This would tend to indicate that the use of rosin in wood would be impractical.

Hoxie and Smith(24) expressed the opinion that the protective power of rosin was largely mechanical since the rosin is hard and is therefore, penetrated with difficulty and since it water-proofs the fibres. The toxicity tests made above these protective mechanisms were not brought into play.

As has been mentioned before in this thesis, the only reliable method by which the effectiveness of an impregnating agent made by determined is by actual use in exposed timber. To this end a'garden' of stakes impregnated with rosin is being planted.

GENERAL CONCLUSION

The result obtained in absorption tests show that sap wood may be easily penetrated with the rosin emulsion. As far as the actual mechanics for impregnation is concerned the treatment is therefore, commercially feasible. Optimum conditions of treatment were not determined but those as stated in the experimental part of this thesis should serve satisfactorily.

The fact that strength is increased and other physical properties, such as color and general appearance, are unchanged by the treatment, should materially increase the value of the treated wood.

Toxicity tests give discouraging results. It should be remembered however, that any mechanical protection offered by the rosin is not brought into play in these tests. Any future work on this problem should include experiments in which a small amount of a metallic resinate is added to increase toxicity.