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" EFFECT OF PRESERVATIVES ON STRENGTH OF WOOD "

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This Thesis is submitted to the President, Board of Trustees and Faculty of the Colorado School of Mines in partial fulfillment of the requirements for a Degree of Master of Science.

Respectfully,

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ACKNOWLEDGEMENT

The author wishes to express his appreciation to Professor J. Burns Read for presenting an opportunity to carry out these experiments and for his invaluable criticisms and suggestions during the course of the investigation.

FOREWORD

In the preparation of the descriptive part of this thesis, the author has made frequent use of Bulletins published by the American Wood Preservers' Association of Chicago, Illinois.

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INTRODUCTION

The desirability of employing some efficient process for the preservation of wood is now universally admitted, consequently the importance in the industrial world of such treatment is thoroughly recognized, and the use of preservative solutions is rapidly increasing. The advancing cost of timber has brought home to the consumer the fact that the only possible offset to this enhanced cost is the use of such preservative methods to prevent, or rather to retard, decay, and thus not only to lengthen the life of wood in all its forms, but also to widen the field of supply by bringing into use a number of less valuable species of timber.

In short, the advancing price of timber and the increasing scarcity of many kinds of wood render the use of some preservative treatment to protect it from decay, advisable in all situations where it is possible to use the timber so treated. The desirability of employing such preservative treatment will be more fully realized when it is considered that some 80 to 85 per cent of the wood used is stated to be lost by decay, the ravages of insects, fires, and mechanical destruction accounting for the balance.

In the United States, where a comparatively few years ago the supply of timber seemed all

but inexhaustible, and the amount of lumber now available hardly meets the ever increasing demand in a satisfactory manner. This is due to careless lumbering, failure to replant denuded areas, and to the enormous waste caused by forest fire. These remarks are also more or less applicable to other timbered countries.

As a general rule, it may be taken that preservative treatment should only be applied to such woods as are not in themselves resistant to decay, so as to render wood available which otherwise would be useless, and which can be obtained at a low price as compared with durable species. Wood to be treated should be of such a character as to receive impregnation at least through the sap-wood, and when the heart-wood cannot be impregnated it should be in itself resistant to decay. Only perfectly sound timber, free from defects, should be treated.

Object of Experiments

The object of these experiments was to determine the most suitable wood preservative to be used in underground mines, considered from the standpoints of relative strength, adaptability to the various underground conditions, fire hazard produced, costs, ease of handling and applying the preservative.

HISTORY OF WOOD PRESERVATION

The early history of the preservation of wood by the use of antiseptics is an exceedingly interesting one; unfortunately, however, the space available will only allow a very brief review of the principal outlines. The art is in all probability one of very great antiquity. It is supposed to have been practiced by the ancient Egyptians, and wooden coffins used by them, estimated to be at the very least 2,000 years old, have been found in a good state of preservation. Wooden dowel-pins, probably of tamarisk or shittim wood, are also employed in the stonework of the ancient Egyptians. These latter are in all probability the oldest pieces of wood existing in the world and are thought to have been treated with some preservative agent, probably bitumen.

Charred wood also has been found in excavations in perfect condition after lying in the ground for some 1,500 years. On the destruction of the Temple of Diana at Ephesus, it was discovered to have been built on charred piles, and at Herculaneum charred wood 2,000 years old was found in good preservation.

It is stated that the ancients employed garlic boiled in vinegar to preserve wood from the attacks of worms and they also recommended tar and linseed oil as preservatives. The wooden images of the

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goddess Diana at Ephesus and Jupiter at Rome were impregnated with olive oil and cedar oil, and the statues of Minerva and Bacchus with oil of Spikenard.

A table was shown at the 1851 exhibition in London made from the central portion of a charred beam found in an ancient Roman villa near Pompeii, overwhelmed by the eruption of Mount Vesuvius, which almost destroyed the city, A. D. 79. Allowing for the age of the tree when felled this beam, when found in 1835, would have been about 2,000 years old.

Among the pioneer investigators into the subject of preservative agents for wood was Hohann Glauber, of Carlsbad, Germany, a celebrated chemist in his day. Glauber's experiments were made about 1657, and his process consists in first carbonizing the wood under the action of fire, then coating the surface with tar, and subsequently immersing the wood so treated in pyroligneous acid, or crude acetic acid which is obtained by the dry distillation of wood.

In the year 1740, a Frenchman named Fagol is stated to have carried out experiments with solutions of alum, sulphate of iron, and various other substances, the wood being immersed in the solutions for several days. Haller, in 1756, proposed the use of vegetable oil as a preservative agent. Jackson, in 1767,

suggested a solution of sea salt, with the addition of sulphate of iron and magnesia, alum, lime and potash, at various times during the treatment. Pallas, 1779, experimented with a process, intended to mineralize the wood, which consisted in first immersing it in a solution of sulphate of iron or copperas (green vitriol) and afterwards in a bath of milk of lime. About the year 1784, Hales proposed steeping the wood to be preserved in a solution of sulphate of copper (blue vitriol) and afterwards coating with oil of tar. Fordyce substituted for the above sulphate of iron, and Congreve suggested the use of creosote as a preservative application.

A Norwegian chemist named Neils Nystrom, in 1800, suggested the use of a solution of sea salt and copperas. The application was to be made with the solution at as high temperature as possible.

In 1805, it was proposed by Maconochie to impregnate woods of inferior qualities with resinous substances to increase their durability, and to inject the distillation from chips of teak into fir woods.

In 1811, Lukin designed a special stove for impregnating timber with such preservatives, but little success attended the experiment. In the latter year also Cadet de Gassicourt saturated various

kinds of wood with different vegetable and mineral substances, unguents and metallic salts.

In 1813, Champy steeped wood in a bath of melted tallow, raised to a temperature of 168°C. for two to three hours.

It occurred to Wade, in 1815, to employ a solution of alum as a preservative. This, however, had been tried many years before and found worse than useless as it caused a rapid decay of the wood so treated. In the same year this experimenter recommended for the preservation of wood the use of resinous substances such as linseed oil and ordinary resin dissolved in lye, the impregnated wood to be subsequently immersed in a bath of water acidulated with some cheap acid or with alum in the solution. He also suggested the use of sulphate of copper, zinc or iron, objecting to deliquescent salts on account of their corroding action on metals. A. Boydon, also in the same year, very strongly advocated the boiling of wood, first in lime-water, to correct acidity, and afterwards in a weak solution of glue, to close the pores and render the growth of vegetation impossible. The glue he also thought might be used by itself or mixed with lime water.

In 1816, W. Champan tried experiments with yellow soap and in 1817 he conducted a number of further experiments with lime, soap, alkaline and mineral salts, as preservative agents. One preservative solution which was recommended by this inventor consists of one

pound of copper sulphate dissolved in four gallons of rain water and applied hot. Another solution is one ounce of corrosive sublimate to a gallon of rain water applied in a like condition.

In 1822 a patent was obtained by Oxford for what he claimed to be an improved method of preventing the decay of timber. The invention consisted in the extraction of the essential oil of tar by distillation and at the same time saturating it with chlorine gas. With the oil thus obtained suitable proportions of oxide of lead, carbonate of lime and carbon of purified coal tar in a finely disintegrated condition were mixed. This composition is to be applied in thick coatings to the wood to be preserved.

The above mentioned are a few of the processes [1] for the preservation of wood invented during the period that elapsed from the date of Glauber's experiments, many of which would doubtless be found to be more or less effective for the purpose, the chief question being the commercial one as to the possibility of economical application.

In 1831 hydraulic pressure for forcing the preservative agent into the wood was first patented and used by a Frenchman named Breant.

It was during the decade between the years 1830 and 1840 that the most satisfactory results

1 Preservation of Structural Timber - H. F. Weiss - McGraw-Hill Book Company, Incorporated.

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were obtained by the earlier investigators, and indeed several of these processes have survived to the present time and are in successful use in somewhat modified forms.

John Bethel, 1838, patented the process wherein the wood to be preserved is impregnated with dead oil of tar or creosote oil, and other bituminous matter containing creosote, also with pyrolignite or iron, which holds more creosote in solution than does any other watery menstruum. The inventor employed hydraulic pressure in closed iron tanks, from 100 to 150 pounds per square inch being maintained for six to seven hours.

A process largely used in France was invented in 1840. The preservative agent employed is sulphate of copper ($CuSO_4$), a solution of which is forced into the wood by gravity. The timber to be treated is set on end covered with a water tight cap and the solution consisting of one part of sulphate of copper to 100 parts of water, is delivered into this cap from a tank placed at a considerable height by means of a flexible pipe. The sap of the wood is forced out at the lower end, its place being taken by the solution.

The preliminary steaming of the wood was introduced in a process patented in 1841. The pro-

servative agent employed consists of sulphate of iron or ferrous sulphate ($FeSO_4$) and muriate of lime. The plant described and used by the inventor comprised a cylinder or retort which does not differ materially from those employed at the present day. Briefly the process consisted in arranging the timber to be treated on a sledge, on which it is kept in position by hoops and chains and the sledge being arranged to run on rails into a long, cylindrical iron vessel, the cover or door of which is then screwed on air tight. Steam is then admitted, through a valve, and the air driven out, after which a partial vacuum is formed by the introduction of a certain amount of cold solution of sulphate of iron, which is pumped into the retort by means of pumps worked from a steam engine, and the steam in the retort condensed. An air pump is then started to complete the vacuum, the antiseptic solution flowing in as the air is exhausted and pressure is subsequently applied by means of force pumps worked from the engine so as to fill the pores of the wood. After a few minutes the sulphate of iron solution is allowed to flow out of the retort, the air being readmitted, the retort is again heated with steam and is similarly filled with muriate of lime.

The entire process of preparing the timber, including the filling and emptying of the tank,

takes from one to three hours, according to the dimensions of the retort.

Wood subjected to this treatment becomes much heavier and is claimed to be not only less predisposed to decay but also less combustible, darker in color and proof against dry-rot and the ravages of insects.

In 1873, John Cullen patented a composition for the preservation of wood and the invention consists essentially in a composition of coal tar, lime, and charcoal, the latter two ingredients being reduced to an impalpable powder. The above materials having been well mixed and subjected to heat, the wood to be treated is immersed therein, and impregnation may be very materially assisted by the employment of exhaustion and pressure.

The beginning of wood preservation, at least on an extensive scale, in this country dates from the initiation and growth of the principal railway systems, which soon created a demand for some efficient process for the preservation of timber, primarily for a variety of uses but more especially for the treatment of railway ties, bridge timbers, mine ties and timbers. With respect to the latter, the value of an effectual method of preservation will be seen to be of greater value each succeeding year, as the prices of these

timbers have increased fully 70 per cent during the last 20 years.

Wood preservation on a commercial scale was begun in the United States in 1848, [2] in which year a non-pressure process or steeping plant was operated at Lowell, Massachusetts by Otis, Allen and Son, the preservative employed being chloride of mercury.

The preceding is a brief chronological outline of the early history of wood preservation by the use of antiseptics or germicides from 1657. Some of the various processes devised and used during recent years and the modern appliances for the preservative treatment of wood are given below.

WOOD PRESERVATIVES

Naturally some wood preservatives are more effective than others, and all possess certain disadvantages that limit their use, as well as advantages that make them especially suitable for specific purposes. These preservatives fall into three general classes: those of an oily nature, like creosote, which are relatively insoluble in water; the salts that are injected into wood in the form of water solutions; and those in which the toxic constituent is carried in some volatile solvent other than water.

2 American Wood Preservers' Association

Coal-Tar Creosote

Coal-tar creosote is a black or brownish oil made by distilling coal tar. The first fractions collected in tar distillation are the light oils, the residue is pitch, and in between comes the portion that is saved for wood preserving purposes. The character of the tar used, the method of distillation, the degree to which the distillation is carried, and the portion of the distillate that is included in the creosote fraction all govern the character of the creosote oil. The character of the various coal-tar creosotes available, therefore, may vary to a considerable extent. Small differences in character, however, do not prevent creosotes from giving good service, and satisfactory results in preventing decay may be expected from any reasonably good grade of coal-tar creosote.

Coal-tar creosote is the most important and most generally useful wood preservative. Its advantages are :

1. Its high toxicity, which makes it extremely poisonous to wood destroying fungi and insects.
2. Its relative insolubility in water and its low volatility, which impart to it a great degree of permanence under the most varied

use conditions.

3. Its ease of application.

4. The ease with which its depth of penetration can be determined.

5. Its general availability and relatively low cost.

Although for general outdoor service in structural timbers there is, as yet, no better preservative than coal-tar creosote, for some special purpose it has certain properties that are a disadvantage. Without question, freshly creosoted timber can be ignited easily and will burn readily, producing a dense smoke. After the timber has seasoned some months, however, the more volatile parts of the oil disappear from near the surface and the creosoted wood usually is but little if any easier to ignite than untreated wood. On the other hand, after untreated wood has started to decay, often within a few years, it is easier to ignite than timber that has been kept sound by creosote treatment.

The odor of creosoted wood is unpleasant to some persons and may be found objectionable in dwellings. Food-stuffs that are sensitive to odors should not be stored near creosoted wood. Workmen sometimes object to the use of creosoted wood because it soils their clothes and because it sometimes burns the skin, causing an injury similar to sunburn. There need be no fear, however, that creosoted timber has a

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serious effect on the health of workmen handling or working near it, or on the health of the occupants of buildings in which treated material has been used. Creosoted wood can undoubtedly be used in sills and foundation timbers, floor sleepers embedded in or resting on concrete, and even subflooring with little danger of the odor becoming noticeable.

The color of creosote and the fact that it usually can not be painted over satisfactorily make it unsuitable for finish lumber or other material where appearance and paint receptivity are of major importance.

Water-Gas-Tar Creosote

Water-gas-tar creosote is made from water-gas tar in much the same way that coal-tar creosote is made from coal tar, and the water-gas tar is the tarry residue remaining from the use of petroleum oils in the manufacture of water-gas. It is therefore a petroleum product and not a coal product, and the composition of both the water-gas tar and its creosote are different from the respective coal products. Although water-gas tar creosoted is not considered so toxic or so generally effective as coal-tar creosote, it is known to be a good preservative; wood that has been deeply penetrated with it will have satisfactory resistance to decay.

Aside from lower toxicity, the advantages and disadvantages of water-gas tar creosote are generally similar to those of the coal-tar product.

Zinc Chloride

Zinc chloride is the water soluble wood preservative most extensively used in the United States. The principal advantages of this salt are relative cheapness, general availability, uniformity of quality, cleanliness, lack of odor, ease of shipment, and lack of fire hazard. Its chief disadvantage is its solubility in water, which permits it in time to be leached out of the wood under outdoor exposure. The water that is injected with it temporarily adds considerably to the weight of the wood and in order to avoid shrinkage troubles must be dried out before the wood is used in buildings.

Zinc chloride treated wood, properly dried after treatment, is finding increasing use in the construction of buildings, especially in the roof planking of factory buildings where high relative humidity favors the rapid decay of the roofs. The facts that the net weight of the wood (after seasoning) is not greatly increased by the treatment and that the treated wood is clean and paintable and to some extent fire resistant favor its use in such places.

Zinc chloride is shipped either in the solid (fused) form or in concentrated solutions. When the freight haul is not too great, the concentrated solution, usually about 50 per cent strength, is shipped in drums or tank cars. For long freight hauls the salt is shipped in solid form in air tight drums. The air tight containers are necessary because zinc chloride attracts moisture from the air. For use in treating wood, water solutions of three to five per cent are prepared from the concentrated material.

The following zinc chloride specifications of the American Wood Preservers' Association is the one generally used in the purchase of zinc chloride for wood preserving purposes:

> "The zinc chloride shall be acid free and shall not contain more than 0.1 per cent iron. Fused or solid zinc chloride shall contain at least 94 per cent chloride of zinc. Concentrated zinc chloride solution shall contain at least 50 per cent chloride of zinc."

PRESERVATIVE TREATMENT OF WOOD

Brush Treatment and Spraying

The simplest treatment is to apply the preservative to the wood with a brush or a spray nozzle. Creosote and similar oils, preferably hot, are used in this method. Heating is sometimes inconvenient, however, and the oil is often applied cold. In such event creosote oil that is thoroughly liquid when cold should be selected. The oil should be flooded over the wood, rather than merely painted upon it, and care should be taken to see that every check and depression in the wood is thoroughly filled with the preservative, since any untreated wood left exposed provides ready access for fungi. At least two coats should be applied, the second one after the first has dried. This may require as much as 10 gallons of oil to 1,000 square feet of surface on rough lumber, although considerably less on surfaced lumber. The penetrations obtained will usually be less than one-sixteenth of an inch. Brush and spray treatments should be used only when more effective treatments can not be employed. The additional life obtained by such treatments over that of untreated wood will be affected greatly by the conditions of service, but it may be

from one to three years.

Brush treatment with water-soluble preservatives is not worth while for wood that is exposed to the weather or to water, and is less likely than creosote to be effective in protected situations.

The Dipping Process

The dipping process, which is used with creosote and similar preservatives, consists simply in submerging the wood in the hot preservative for a short time, usually from five to 15 minutes, and then removing it and allowing the excess oil to drain back into the tank. The treating temperature should be 90°C. or a little higher, and the wood should be thoroughly seasoned and dry on the surface. In cold weather a longer dipping period should be used. Wood that is covered with frost, snow or rain water should not be dipped, since the water on the surface will interfere with the absorption of oil.

The effectiveness of the dipping treatment is limited and the process should not be used unless better methods are out of the question. The amount of oil absorbed will depend upon the timber and upon the length of the treating period. Ordinarily, however, it will probably be about 10 to 15 gallons per

1,000 surface feet. The penetration obtained in exceptional instances may be from one-eight to one-fourth inch, but ordinarily it will be one-sixteenth inch or less. The dipping process gives greater assurance than brushing or spraying that all surfaces have been thoroughly coated with the oil and should result in slightly greater penetrations. The increase in life of the timber, therefore, should be slightly greater, on the average, than that which ordinarily results from brush treatment. The increase will usually be more than enough to pay for the cost of treatment, but it is only a partial solution of the problem of timber decay when a long life is desired under severe decay conditions.

Hot and Cold Bath Process

The hot and cold bath treatment is the most effective of the nonpressure processes and the thoroughness of the treatment obtainable most nearly approaches that of the pressure processes. The treatment consists in heating the wood in the preservative in an open tank for several hours, and then quickly submerging it in cold preservative and allowing it to remain several hours more. This may be accomplished by transferring the wood at the proper time from a hot tank to a cold one or by draining the hot preservative from a single tank and quickly filling it with cold. The same

result can also be accomplished, although more slowly, by shutting off the heat at the proper time and allowing the wood and the hot preservative to cool together.

The principle involved is the same in each case. During the hot bath the heating causes the air and moisture in the wood to expand and some to be forced out. When the cooling takes place, whether it is sudden or slow, the air and the moisture in the wood contract and a partial vacuum is thus created, drawing some of the preservative into the wood. Little absorption of preservative takes place during the hot bath, except in a few woods that are exceptionally easy to treat.

The chief use of the hot and cold bath process has been in treating the butts of fence posts and of poles for telegraph, telephone and power lines. The process is also useful for lumber or timbers for other purposes when circumstances do not permit the more effective pressure treatments. Coal-tar creosote is the preservative ordinarily chosen because it is the most suitable preservative for posts and poles, but water solutions, such as zinc chloride solution and the like, may also be employed if the solution is kept at uniform strength.

With coal-tar creosote, hot bath temperatures up to 110°C. may be employed but usually

100° to 105° C. is sufficient. In the commercial treatment of cedar poles temperatures of about 110° C. are specified. If the temperature is too high a considerable percentage of the oil may be lost by evaporation, especially if a creosote with a relatively low boiling range is used. In the cold bath a temperature of approximately 40° C. is usually about right. This temperature keeps the oil fluid but much cooler than the hot bath. If the oil is found not sufficiently fluid at 40° C., however, the temperature of the cold bath should be increased.

The length of both baths must be governed by the ease with which the timber takes treatment and the demand for speed. With well seasoned timber that is moderately easy to treat, a hot bath of two to three hours and a cold bath of like duration will probably be sufficient. In using coal-tar creosote the object is to obtain as deep a penetration as possible but with a minimum amount of oil. If the penetration is not sufficient, either the hot or the cold bath should be lengthened. If the penetration is satisfactory, but too much oil is absorbed, the cold bath should be shortened. The best combination in any instance will vary with the character and the condition of the timber, and must be learned by trial. The penetration can not always be

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controlled at will by manipulating the treating conditions, however, for some woods are highly resistant to treatment and at best may permit a depth of one-eighth inch or less, especially in heart-wood faces. The sap-wood of most species is less resistant to penetration than the heart-wood and hence penetrations of one-fourth to one inch are often obtained in sap-wood.

Pressure Processes

The most effective method of applying wood preservatives employs pressure. A number of pressure processes differ from one another in a few details but the general principle is the same in all. The wood, placed in steel cars, is run into a long steel cylinder, which is then closed and filled with preservative. Pressure then forces preservative into the wood until it has absorbed the desired amount. This amount is considerable and a relatively deep penetration is obtained. Two principal types of pressure treatment, the full-cell and the empty-cell, are in common use.

The full-cell creosoting process is widely used when the retention of a maximum quantity of preservative is desired. For timbers subject to severe exposure to decay, insects or marine borers it is standard. The steps in this process are essentially as given in the following description.

After the charge of timber has been placed in the treating cylinder a preliminary vacuum is applied for one half hour or more to remove the air from the cylinder and as much as possible from the wood. The preservative, previously heated to about the desired treating temperature, is admitted to the cylinder without the admission of air. After the cylinder has been filled, pressure is applied until the required absorption of oil is obtained. When the pressure period has been completed the preservative is withdrawn from the cylinder. A short final vacuum is usually applied immediately afterward to free the charge from dripping. When the timber is steamed before treatment the preservative is admitted at the end of the vacuum period that follows steaming.

The object of empty-cell treatment is to obtain deep penetration with a relatively low net retention of preservative.

The empty-cell process has been widely used for many years, both in Europe and in the United States. The following general procedure is employed.

Air under pressure is forced into the treating cylinder, which contains the charge of timber. The air penetrates some species easily, requiring but a few minutes application of pressure. In the treatment of

the more resistant species common practice is to maintain air pressure from one half hour to a full hour before admitting the preservative. The air pressures employed generally are between 25 and 100 pounds per square inch, depending on the net retention of preservative desired and the resistance of the wood.

Following the application of preliminary air pressure the preservative is admitted to the cylinder. During the filling process the air in the tank or treating cylinder interchanges with preservative at the same pressure in an equalizing tank, or it is gradually allowed to escape from the treating cylinder as the preservative enters, at a rate that keeps the pressure within the cylinder constant. When the treating cylinder has become filled with preservative the treating pressure is raised to a higher point and continued until the point of refusal is reached or until the gross absorption is sufficient for the required net retention of the preservative.

When green material is to be treated preliminary steaming should be included in the process. The following opinion is expressed in a report of the Committee on miscellaneous subjects to the American Wood Preservers' Association at an annual meeting held at New Orleans. The report is of considerable interest as it appears to settle the question as to the prevailing

American practice, and that, from ascertained facts, and not merely from theories. The following are the conclusions and recommendations arrived at:

1. All efficient plants should be equipped to steam material when occasion requires, and the best method of introducing and distributing steam in the retort by means of perforated pipes.
2. Steaming of ties, timber and lumber is apparently not injurious to the wood, if the work is conducted intelligently and within certain limits of temperature and duration.
3. It is difficult to inject any considerable quantity of preservative into green ties and timbers unless given a preliminary steaming or boiling in oil. One of the principal factors influencing the absorption of any kind of preservative is the moisture content of the wood, the dryer the wood the more it will absorb, consequently the more thorough the treatment.
4. The object of steaming is to put the wood in a condition to secure the maximum penetration with the desired amount of preservatives and admits of the immediate treatment of green or

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fresh cut material.

5. Theoretically, steaming of green material preliminary to air seasoning should materially reduce the period of air seasoning.

6. A maximum steam temperature of 138° C. should not be exceeded. The maximum steam temperature of 138° C. should not be maintained for a longer period than three hours. The maximum temperature of the steam should be reduced after a period of three hours to not more than 121° C. and maintained at this temperature, or less, for the remainder of the steaming period.

7. Under like conditions, chloride of zinc will penetrate the wood considerably more readily than creosote oil.

8. During the process of steaming a considerable amount of condensed steam remains in the wood, which to some extent resists the entrance of the fluid. The liberating of this condensation, after steaming, may be accomplished by subsequent drying in open air or in drying ovens.

To ensure success requires careful attention and skillful management, and of course, the provision of adequate and suitable appliances. The

attainment of a more or less perfect product demands the consideration of the following points: the wide divergence in the characteristics of timber; the varying amounts of sap due to the lapse of time since, and the season in which, the tree was felled; its possible subsequent immersion in water for a longer or shorter time; the character of the soil and the conditions under which the tree grew, whether in a dense forest or a comparatively open country; whether it is of a rapid even growth or of a slow intermittent one. To an experienced operator these conditions indicate in each case the proper course to be pursued, and failure to observe and to take them into consideration is to invite indifferent, uncertain, and in the end, unsatisfactory results.

Of almost equal importance is a proper understanding of the circumstances under which the finished product is to be used. Timber for piers, wharves and other structures in tropical waters demand processes and degrees of thoroughness of treatment that are unnecessary in the harbors of more temperate climates, which latter are in turn more exacting than land and fresh water constructions.

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EQUIPMENT USED IN EXPERIMENTS

The equipment used for the treating process was constructed, as shown in Figure No. I, from a section of six inch, seamless steel tubing, 16 inches in length. On one end of the tubing a solid plate was welded, on the other end a flange fitted with bolts, to which a blind flange could be bolted, with a woven asbestos gasket between the two flanges. Connections consisted of a one fourth inch pressure line, which could provide a maximum pressure of 60 pounds per square inch. The end connection provides an average of a ten inch vacuum.The thermometer well is a one quarter inch hole extending nearly to the center of the retort. A compound gage was connected at the top and from this the pressure or the vacuum could be read directly in pounds per square inch. The connection at the bottom of the retort leads from the storage tank and was placed at this point, in order that, at the completion of the operation, the excess or unabsorbed solution could be forced from the retort back into the storage tank by air pressure. The storage tank could also be drained at this point. The temperature in the retort was maintained with a gas burner (this practice could not be used in commercial plants because of the inflammability of the oily preservative).

PROCEDURE USED IN EXPERIMENTS

The procedure consisted essentially of drawing a short vacuum to open the cells in the timber. The vacuum was utilized to pull the preservative from the storage tank into the retort. Pressure and heat was then applied with the pressure varying from 40 to 60 pounds and the temperature from 120° to 160° C.

Mexican yellow pine blocks, 1½" x 1½" x 3" were used in the experiments. These timbers were free from knots or other defects and were in the most part composed of sap-wood.

Sample blocks, from each group of tests, were thoroughly dried and placed in water. The water was removed and fresh water added every three days. The first water taken from the creosote and water-gas creosote showed a thin layer of oil. After the first change of water this was not observed again. Those treated with zinc chloride showed traces of the preservative in four changes of water.

EXPLANATION OF TESTS

The group of experiments, shown in Table No. I, for which the green unseasoned timber was used, shows a considerable loss of strength compared to the natural wood, in all except those treated with the zinc chloride, which apparently does not decrease or increase the strength of the material.

The depth of penetration of the creosote oils vary an appreciable amount with the change in temperature at the time of the treatment. In the case of the water-gas creosote the penetration was less but this was probably due to the use of less pressure at the time of the treatment. The depth of penetration of the zinc chloride could not be determined because of the color of the salt. In commercial plants it is determined by mixing one per cent solution of potassium iodine and a five per cent solution of soluble starch and this mixture is sprayed on a freshly cut surface. The treated portion will turn dark blue.

Referring to Table No. II, the material treated here was seasoned and shows an average increase in strength in all of the tests. This increase was probably due to the cells of the wood being filled with the preservative solution, which acted as a cushion,

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and it is doubtful if the same effect would be noted on commercial sizes of material. It will be observed that the depth of penetration of the oily preservative, in this test, completely saturated the sample. This wood being seasoned and also sap-wood, a much deeper penetration would be expected, under the same conditions of temperature and pressure, than from the unseasoned or green material.

The material used in the experiments in Table No. III was green unseasoned timber and identical to that used for the tests shown in Figure No. I. However, the blocks were subjected to a preliminary steaming treatment before the preservative was added. The preliminary treatment consisted of placing the blocks on a wire stand, in the upper half of the retort, then one half of the retort was filled with water and the temperature kept approximately at 130° C. for one half hour. A one quarter hour vacuum was drawn and the water and liquid extracted from the wood drained. The retort was then filled with clear water the second time and the process repeated. This last vacuum was employed to draw the preservative solution into the retort. The pressure was applied and with different temperature variations, as shown in the Table. The preliminary steaming of the green material was done, as nearly as possible, to corre-

spond with the treatment at commercial plants.

The depth of the penetration of colored preservatives was noted to be slightly higher than the penetration of the oil on the unseasoned material. The average strength, in all cases, was considerably higher in the steam treated material.

5. Zinc chloride solutions could not be used in damp climates or in underground mines, where there is an appreciable amount of water, due to the solubility of the salt.

6. The strength of the material is not affected to the extent that different working stresses should be used in the design of wood structures. The timbers may be slightly weaker, but due to the longer life of the timbers, the same stresses may be used.

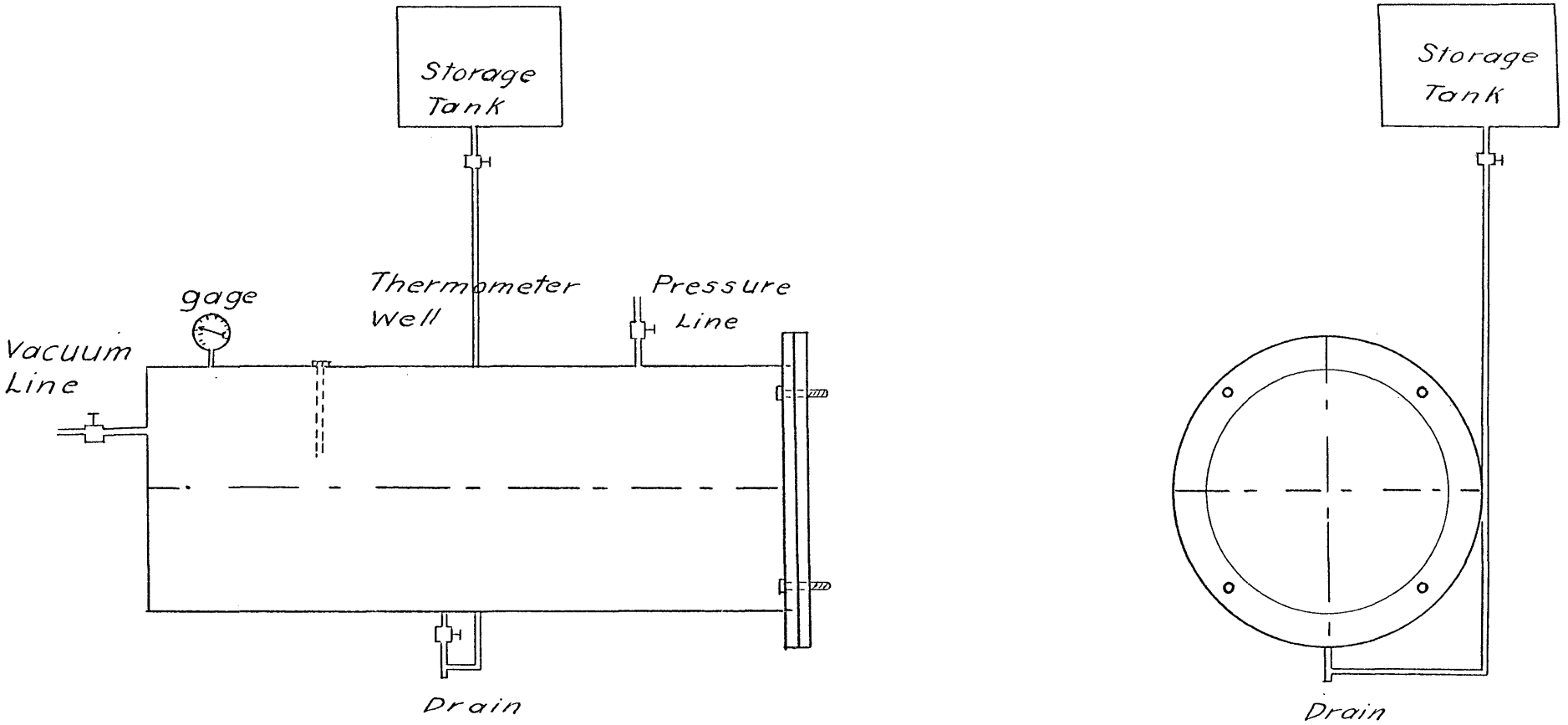
Storage Tank
gage
Thermometer Well
Pressure Line
Vacuum Line
Drain
Storage Tank
Drain

Fig. I

TABLE NO. 1-A

UNSEASONED TIMBER

CREOSOTE

Number Pieces	Vacuum Period	Average Temperature C.	Pressure Pound per Sq. In.	Time Pressure Treatment
3	30 min	120°	60	2 hour
3	30 min	130°	60	2 hour
2	30 min	140°	60	2 hour
3	30 min	150°	60	2 hour
3	30 min	160°	60	2 hour

Av. Strength Treated-Pound Per Sq. In	Av. Strength Untreated-Pound Per Sq.In.	% Treated Untreated	Depth of Penetration Inches
4,430	5,850	76.0	0.48
3,120	5,850	53.5	0.50
5,740	5,850	98.5	0.51
4,520	5,850	77.5	0.54
3,920	5,850	67.3	0.58

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TABLE NO. 1-B

UNSEASONED TIMBER

40% WATER-GAS CREOSOTE PLUS 60% CREOSOTE

Number Pieces	Vacuum Period	Average Temperature C.	Pressure Pound per Sq. In.	Time Pressure Treatment
2	30 min	120°	40	1½ hour
2	30 min	130°	40	1½ hour
2	30 min	140°	40	1½ hour
2	30 min	150°	40	1½ hour
2	30 min	160°	40	1½ hour

Av. Strength Treated-Pound Per Sq. In.	Av. Strength Untreated-Pound per Sq. In.	% Treated Untreated	Depth of Penetration Inches
5,750	5,830	98.8	0.40
5,260	5,830	90.5	0.43
4,530	5,830	77.7	0.45
4,730	5,830	81.1	0.46
4,510	5,830	62.9	0.49

TABLE NO. 1-C

UNSEASONED TIMBER

3 % ZINC CHLORIDE

Number Pieces	Vacuum Period	Average Temperature C.	Pressure Pound Per Sq. In.	Time Pressure Treatment
2	30 min	120°	60	1½ hour
3	30 min	130°	60	1½ hour
2	30 min	140°	60	1½ hour
2	30 min	150°	60	1½ hour
3	30 min	160°	60	1½ hour

Av. Strength Treated-Pound Per Sq. In.	Av. Strength Untreated-Pound per Sq.In.	% Treated Untreated
5,920	5,830	102.0
5,830	5,830	100.0
5,880	5,830	101.8
6,130	5,830	105.0
5,800	5,830	99.6

TABLE NO. II-A

SEASONED TIMBER

CREOSOTE

Number Pieces	Vacuum Period	Average Temperature C.	Pressure Pound Per Sq. In.	Time Pressure Treatment
2	30 min	120°	50	1½ hour
2	30 min	130°	50	1½ hour
2	30 min	140°	50	1½ hour
2	30 min	150°	50	1½ hour
2	30 min	160°	50	1½ hour

Av. Strength Treated-Pound Per Sq. In.	Av. Strength Untreated-Pound Per Sq.In.	% Treated Untreated	Depth of Penetration Inches
6,730	6,490	104.0	.0875
6,520	6,490	100.5	.0875
6,840	6,490	105.1	.0875
7,130	6,490	110.0	.0875
6,750	6,490	104.0	.0875

TABLE NO. II-B

SEASONED TIMBER

40% WATER-GAS CREOSOTE PLUS 60% CREOSOTE

Number Pieces	Vacuum Period	Average Temperature C.	Pressure Pound Per Sq. Inc.	Time Pressure Treatment
2	30 min	120°	50	1½ hour
2	30 min	130°	50	1½ hour
2	30 min	140°	50	1½ hour
2	30 min	150°	50	1½ hour
2	30 min	160°	50	1½ hour

Av. Strength Treated-Pound Per Sq. In.	Av. Strength Untreated-Pound Per Sq.In.	% Treated Untreated	Depth of Penetration Inches
6,570	6,490	101.3	.875
6,530	6,490	100.8	.875
7,000	6,490	108.0	.875
6,820	6,490	105.1	.875
6,730	6,490	103.8	.875

TABLE NO. II-C

SEASONED TIMBER

3% ZINC CHLORIDE

Number Pieces	Vacuum Period	Average Temperature C.	Pressure Pound Per Sq. Inch	Time Prossure Treatment
2	30 min	120°	50	1½ hour
2	30 min	130°	50	1½ hour
2	30 min	140°	50	1½ hour
2	30 min	150°	50	1½ hour
2	30 min	160°	50	1½ hour

Av. Strength Treated-Pound Per Sq. In.	Av. Strength Untreated-Pound Per Sq.In.	% Treated Untreated
6,230	6,490	96.0
6,430	6,490	99.1
6,930	6,490	106.8
7,100	6,490	109.7
6,740	6,490	103.9

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TABLE NO. III-A

UNSEASONED TIMBER STEAMED UNDER PRESSURE

CREOSOTE

Number Pieces	Vacuum Period	Average Temperature C.	Pressure Pound Per Sq. Inch	Time Pressure Treatment
2	30 min	120°	50	1½ hour
2	30 min	130°	50	1½ hour
2	30 min	140°	50	1½ hour
2	30 min	150°	50	1½ hour
2	30 min	160°	50	1½ hour

Av. Strength Treated-Pound Per Sq. In.	Av. Strength Steam Treated Pound Per Sq. Inch	% Treated Untreated	Depth of Penetration Inches
5,730	5,420	105.5	.51
5,400	5,420	99.5	.54
5,570	5,420	102.4	.57
5,220	5,420	96.3	.59
5,300	5,420	97.7	.60

TABLE NO. III-B

UNSEASONED TIMBER STEAMED UNDER PRESSURE

40% WATER-GAS CREOSOTE PLUS 60% CREOSOTE

Number Pieces	Vacuum Period	Average Temperature C.	Pressure Pound Per Sq. In.	Time Pressure Treatment
2	30 min	120°	50	1½ hour
2	30 min	130°	50	1½ hour
2	30 min	140°	50	1½ hour
2	30 min	150°	50	1½ hour
2	30 min	160°	50	1½ hour

Av. Strength Treated-Pound Per Sq. In.	Av. Strength Steam Treated Pound Per Sq.In.	% Treated Untreated	Depth of Penetration Inches
5,620	5,420	103.6	.53
5,350	5,420	98.2	.53
5,470	5,420	100.8	.55
5,400	5,420	99.8	.59
5,380	5,420	99.2	.61

TABLE NO. III-C

UNSEASONED TIMBER STEAMED UNDER PRESSURE

3% ZINC CHLORIDE

Number Pieces	Vacuum Period	Average Temperature C.	Pressure Pound Per Sq. In.	Time Pressure Treatment
2	30 min	120°	50	1½ hour
2	30 min	130°	50	1½ hour
2	30 min	140°	50	1½ hour
2	30 min	150°	50	1½ hour
2	30 min	160°	50	1½ hour

Av. Strength Treated-Pound Per Sq. In.	Av. Strength Steam Treated Pound Per Sq.In.	% Treated Untreated
5,510	5,420	102.0
5,400	5,420	99.8
5,320	5,420	98.1
5,210	5,420	96.0
5,200	5,420	96.0

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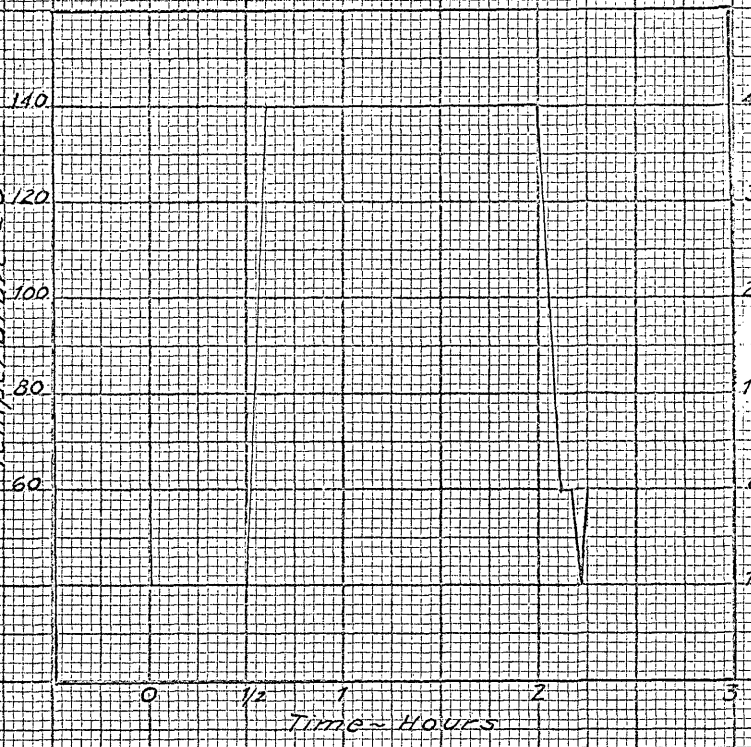
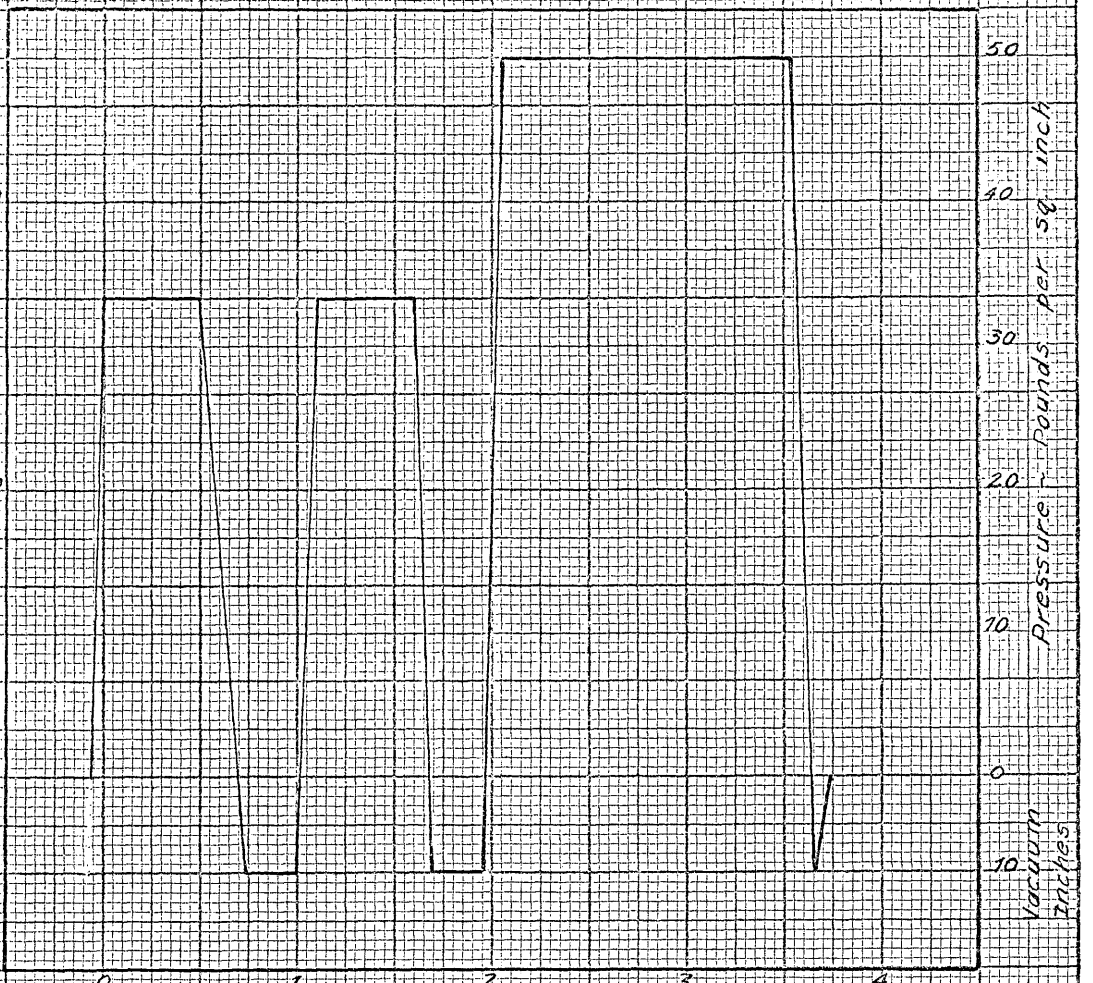
Chart No. I



Typical Treatment Chart for Experiments Shown in Tables Number I and II

Chart No. II

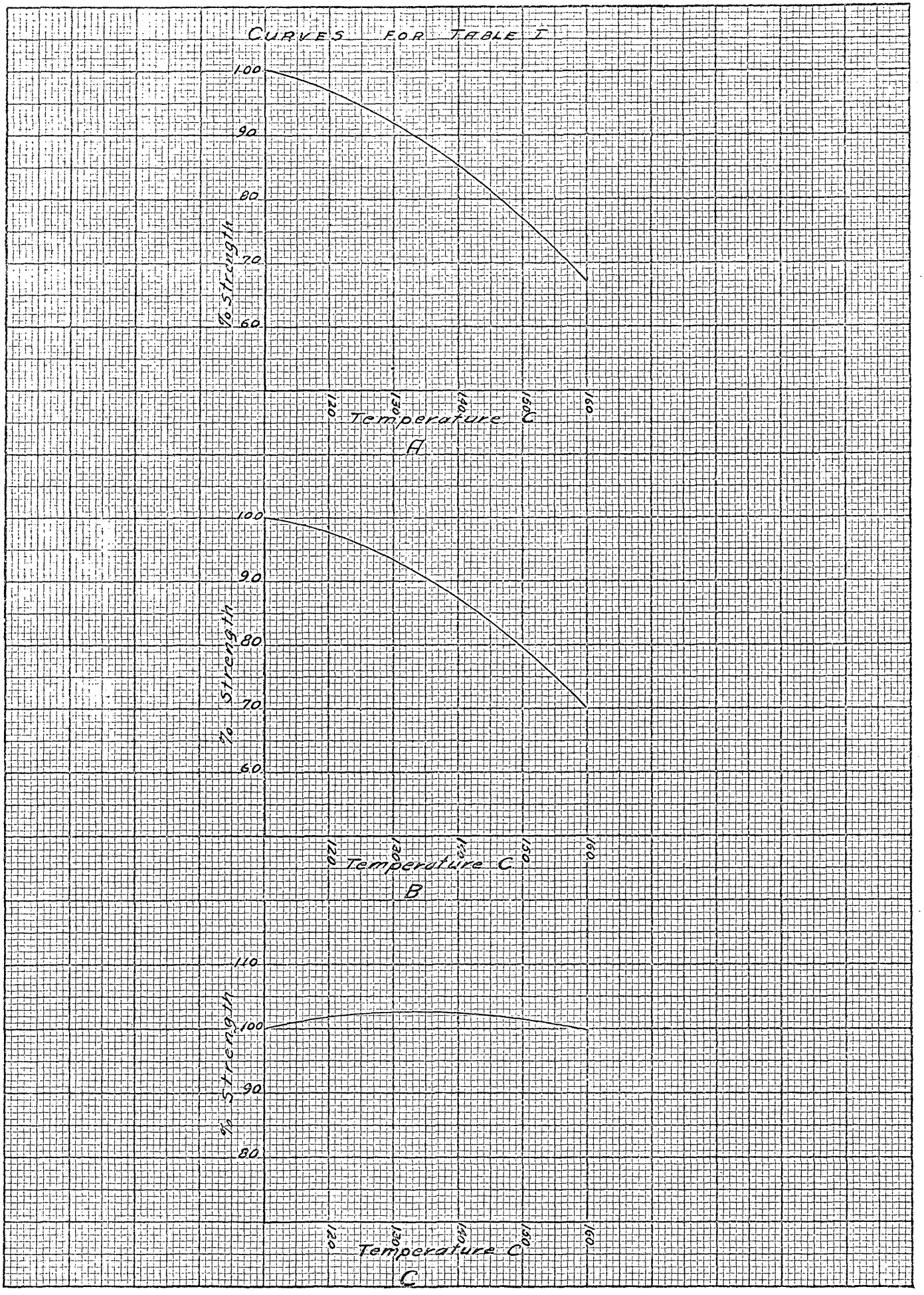


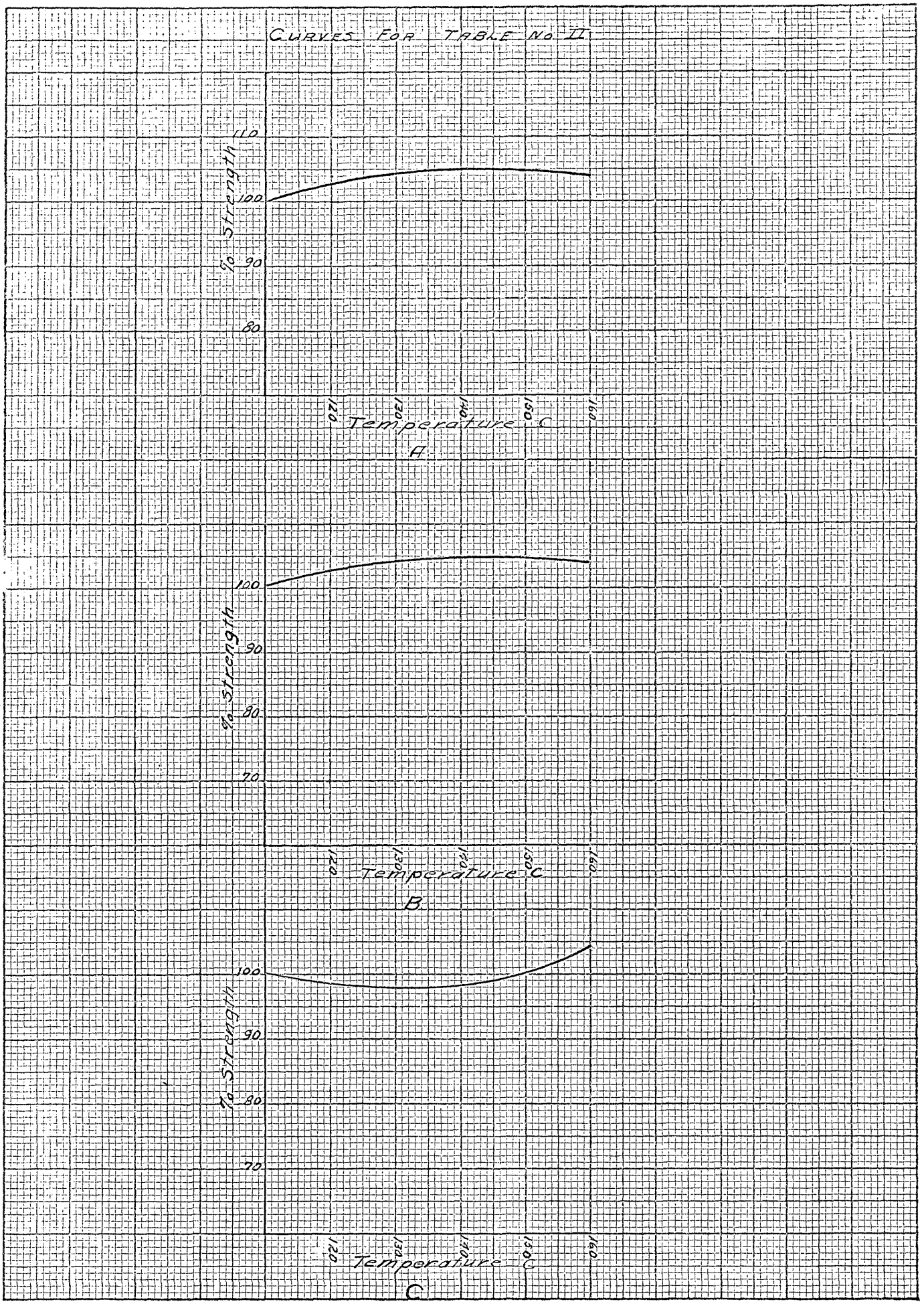
Typical Treatment Chart for Experiments Shown in Table III

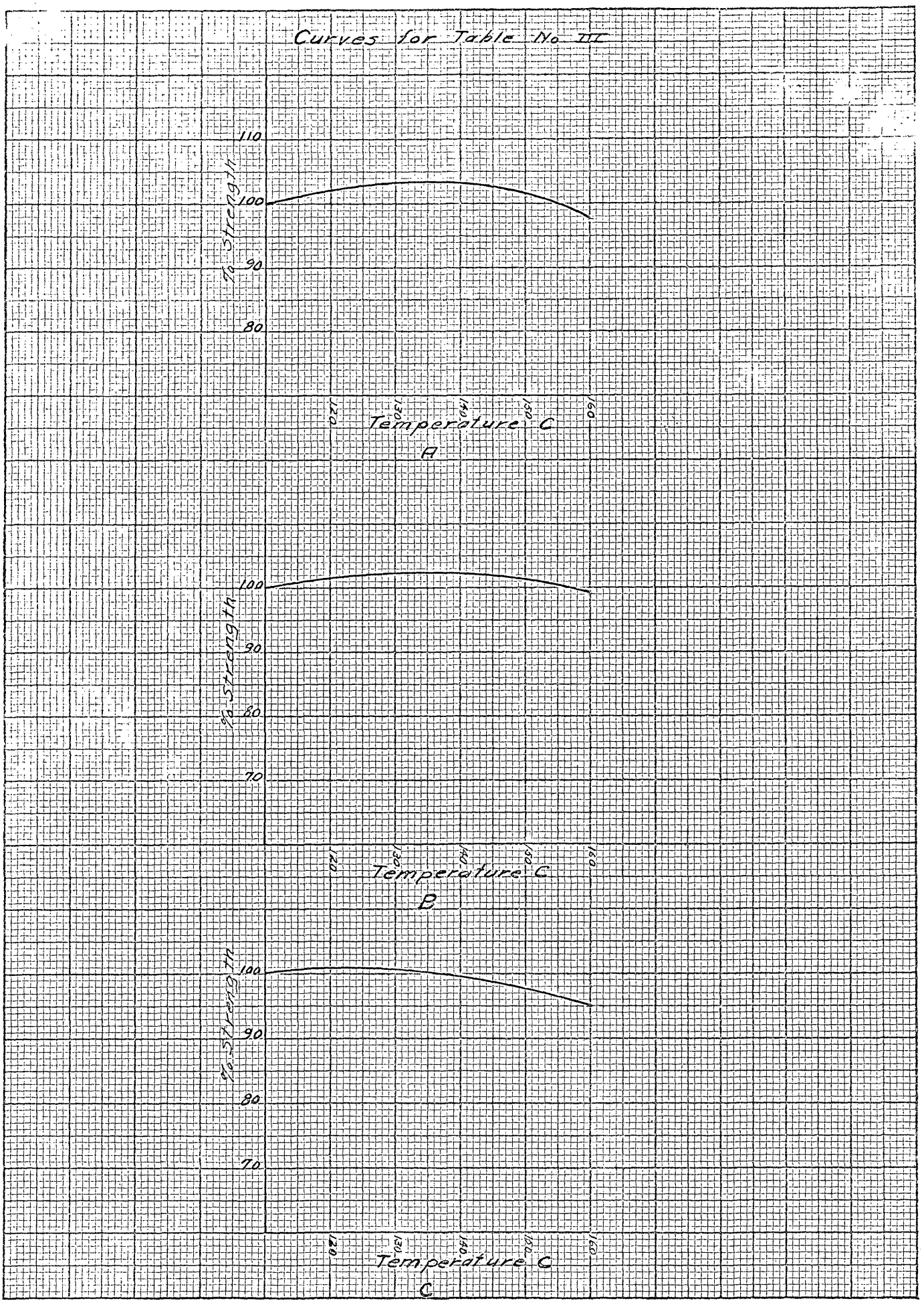
EXPLANATION OF TREATMENT CHARTS

Referring to Treatment Chart No. I, the process was started at a temperature of 60° C. and atmospheric pressure. A ten inch vacuum was employed for a one half hour period. The preservative was admitted and pressure was applied for two hours and at the end of the pressure period, the excess or unabsorbed solution was drawn from the wood by a short vacuum.

The preliminary treatment for the green unseasoned timber, Treatment Chart No. II, consisted of two preliminary, one half hour, steamings at 30 to 35 pounds pressure and 120° C. temperature. At the termination of each of these, the water and the liquid extracted from the wood by a vacuum was drained. The preservative was then admitted and pressure applied for a two hour period, drawing a short vacuum, at the completion of the pressure treatment, to remove the excess preservative.


CURVES FOR TABLE I
100
90
80
70
60
% Strength
120
130
140
150
160
Temperature C
A
100
90
80
70
60
% Strength
120
130
140
150
160
Temperature C
B
110
100
90
80
% Strength
120
130
140
150
160
Temperature C
C


Curves For Table No II
% Strength
110
100
90
80
120
130
140
150
160
Temperature C
A
% Strength
100
90
80
70
120
130
140
150
160
Temperature C
B
% Strength
100
90
80
70
120
130
140
150
160
Temperature C
C


Curves for Table No III
Tensile Strength
110
100
90
80
120
130
140
150
160
Temperature C
A
Tensile Strength
100
90
80
70
120
130
140
150
160
Temperature C
B
Tensile Strength
100
90
80
70
120
130
140
150
160
Temperature C
C