Fig. 1. Loblolly pine pile, from southern Texas, showing decay after 12 months.

Fig. 2. White oak tie, showing growth of destructive fungus.

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN No. 14.

B. T. GALLOWAY, Chief.

THE DECAY OF TIMBER

AND

METHODS OF PREVENTING IT.

BY

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., January 8, 1902.

Sir: I have the honor to transmit herewith a paper on The Decay of Timber and Methods of Preventing It, and respectfully recommend that it be published as No. 14 of the Bureau series of bulletins. The paper was prepared by Dr. Hermann von Schrenk, special agent, in charge of Mississippi Valley laboratory, Vegetable Pathological and Physiological Investigations, and was submitted by the Pathologist and Physiologist.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

PREFACE.

The annual destruction by decay of forest timber and of timber used for construction purposes, such as railroad ties, fence posts, telegraph poles, bridge timber, etc., is almost beyond computation, and is one of the greatest drains on the timber resources of the country. Several years ago this Office undertook an investigation of the causes of such destruction, and the general awakening of interest in forestry has called special attention to the importance and necessity of our work in this line. For a number of years the railroads have been investigating methods of preserving ties, and early in our work we were led to examine the progress made by them as a basis for the general investigation of the subject of preservation of construction timber.

Dr. Hermann von Schrenk, instructor in the Henry Shaw School of Botany, and special agent in charge of the Mississippi Valley laboratory of Vegetable Pathological and Physiological Investigations, has been actively engaged in the work for several years, and has collected much valuable information in connection with it both in this country and in Europe. The present report, which is a basis for much more extensive investigations planned for the coming year, embraces a discussion of the factors which cause the decay of wood, an account of the various methods used in this country and abroad for preserving timber, and also an account of original work conducted to test various methods.

The Department is under obligations to the railroads for furnishing Dr. von Schrenk facilities for conducting his investigations, and also to many others who have aided him in his work.

The work is being pushed vigorously, in cooperation with the Bureau of Forestry, which is actively aiding us in our investigations in this line, and it is believed it will appeal to the country as a whole, as all interests and classes are affected, directly or indirectly, by the losses occasioned by the decay of construction timber.

It is to be hoped also that as a result of the experiments planned much standing timber of varieties now worthless for construction purposes, owing to its rapid decay, may be made commercially valuable by preservative processes.

ALBERT F. WOODS,
Pathologist and Physiologist.

OFFICE OF THE PATHOLOGIST AND PHYSIOLOGIST,
Washington, D. C., January 9, 1902.

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THE DECAY OF TIMBER AND METHODS OF PREVENTING IT.

INTRODUCTION.

The various uses to which wood is put at this time are so numerous that an enormous amount of timber is required annually to fill the demand. Building materials, railway ties, fence posts, telegraph poles, etc., make up the larger part of the wood cut. Figures as to the actual amount of timber cut are difficult to obtain, and after all they give the average reader very little intelligent information. The individual is interested in so far as he wishes to be assured that there is enough timber for him now and that there will be some in the future, both at a reasonable price. One can, however, give an approximate idea of the amount used by considering that the railroads alone renew over 110,000,000 ties every year, and that one telephone company (the Bell Telephone Company) has now in use some 6,000,000 poles, varying from 20 to 90 feet in length, of which some 500,000 were added during the past year. In 1887 the number of tie renewals was estimated as about 70,000,000.

It is very evident that the amount of timber removed from our forests every year is enormous, and with the extension of the arts and industries it is easy to foresee that the future will show a very marked increase over the present consumption. Although it is not probable that we are to face a timber famine in the near future, it can hardly be denied that the removal of such quantities of timber as are now coming from the forests every year can not fail to make a deep impression on the forest resources of any country, no matter how large the reserve may be.

During the last thirty years there has been a constant appreciation in the prices of timber in many sections of the country. This appreciation has not occurred uniformly; in fact, some classes of timber are cheaper to-day than they were thirty years ago.

It is perhaps hazardous to explain why, with the constantly decreasing supply, such timbers are cheaper to-day. It is presumably more a matter of transportation than anything else. With increased railroad construction, sections of timber land have become readily accessible which years ago were distant from centers of distribution. The great supply of the past was drawn chiefly from sources along lines of railway or contiguous to them. As these became exhausted the sections back from the roads were tapped. The timber brought out cost more than that immediately on the line, until a branch was built into this new section, and then the cost fell again.

It is not fair, therefore, to judge of any future supply by a mere comparison of prices. This is obvious when one remembers that the source of white oak, for instance, in the early period of railway construction was chiefly in Pennsylvanina, Ohio, Indiana, and Wisconsin. These States furnish a very small amount of the supply at present. It now comes from southern Missouri, Arkansas, Kentucky, and Tennessee. Even the most sanguine lumber contractor will not admit of more than fifteen years' supply from southern Missouri, and ten years will probably be more nearly correct. The price of oak timber is not so very much greater than it was ten years ago, and yet the visible supply is very small at this time. Many other sections of the country once well timbered are now bare, to wit sections of Pennsylvania, Wisconsin, Michigan, and Minnesota.

Those who say, therefore, that there is no need of considering the question of future supply because timber is still cheap are simply voluntarily ignoring what to most observers is a very obvious situation.

Looking for a moment at the tie situation, we find that the railroads of the Eastern States are drawing a large part of their supply from the pine forests of the South and from Canadian points, the lines of the north-central West are beginning to bring timber from the Pacific coast, while those of the Central States are drawing on the recently tapped forests of the lower Mississippi Valley. The changes which occur in the sources of timber supply are slow, and it is impossible to state at this time what the situation is likely to be twenty years hence. Our knowledge of the timber now standing is very inexact, and it is to be hoped that ere long some steps may be taken to obtain more reliable data on this subject. The sources of supply will within an appreciable time be shifted without doubt from the Northern and Central States to those of the far South and of the Pacific coast.

There is now no longer any question as to the desirability of a rational discussion as to where the great volume of timber is to come from in the future. We must find out how we can best take measures to insure an adequate supply for all time, and at the same time at reasonable cost. The discussion and study of this problem is the province of the forester of to-day. One phase of this subject leads toward establishing methods of cutting timber along lines which will insure a regular supply. Another phase will occupy itself with establishing new centers of supply by caring for or planting denuded or treeless areas. A third phase will be devoted toward finding out how we may increase the length of service of the material now at hand.

Timber, when it is removed from the forests, decays sooner or later, and has to be replaced. The replacing involves the cost of new timber, the cost of replacing, and in many instances the cost engendered by the disturbance. By increasing the length of service of timber, we not only make it cheaper, but we use less of it. Increasing the length of life of timber is, therefore, one way of conserving the existing timber supply and of lessening the cost of the timber actually used. This has been realized for a long time, as instanced by the first forestry bulletin published by this Department. In this Mr. Kern points out very clearly the advantage to be derived by securing a longer life for structural timber. This increase in the length of life applies to timber used for ties, for buildings, greenhouse and other construction, for fence posts, in fact wherever wood is used. Longer life may be attained in two ways—by placing wood under such natural conditions that decay becomes impossible, or by preserving the wood in one way or another.

During the past hundred years or more the highest grade timbers have been used at all times wherever they could be obtained. In the North the white pine was used exclusively, while the spruce was left standing. Now that the pine is almost gone, the spruce is in demand, although it is in most respects a very much inferior timber.

There are in many parts of the United States many kinds of timber which are for one reason or another not being used at the present time. We find, for instance, that the so-called high-grade timbers have always been cut out first, leaving the less valuable kinds standing. In the central West the inferior oaks were left and only the white oak was cut; in the North the tamarack and balsam fir remained after the removal of the white oak and spruce; while on the Pacific coast the hemlock and lodgepole pines are ignored because of the red fir and bull pine. Where the strength requirements form secondary features, as in ties, the resistance to decay has often kept these woods in the lower class. One of the problems of the future will be how to make use of these timbers. They can be bought at a low price, for many large tracts are within easy reach of transportation lines. If some method can be found by which tamarack, the swamp oak, and the loblolly and lodgepole pines can be used for ties, leaving the white oak and other expensive timbers for higher grade structural material, a great forward step will have been taken in the utilization of our forest resources and in their more economical handling.

In the following pages some brief considerations will be presented, calling attention to the knowledge which we have concerning the problem of timber preservation at this date. Much of the matter presented has been referred to before, both in reports of this Department and elsewhere, but so little headway has been made in the practical application of the older reports that it has been thought advisable to go over the whole problem again at this time, when the problem is becoming so much more vital. The writer wishes to refer to the papers by Dudley, Flad, Chanute, Curtis, and others mentioned below, which may be read at this time with profit.

It will be noted that much attention has been paid to railway ties in this report. The reason for this is that the railway companies have been and still are among the largest consumers of timber in the United States. But, aside from that, they have been most active in the study of preservative processes in all countries. The position of a tie in the roadbed is one most unfavorable to the long life of wood. It presents, on that account, one of the best means for studying the changes which take place in wood, and how these may best be prevented. That which applies to wood in the form of a tie is, as a rule, applicable to all forms of structural timber, telegraph and telephone poles, mine timbers, fence posts, bridge and building timbers, greenhouse material, etc.

SCOPE OF THIS REPORT.

The subject will be considered under the following heads:

(1) Structure of timber (wood cells, heartwood, and sapwood) and its mechanical and chemical nature.

(2) Factors which cause decay of wood.

(3) Timber preservation.

(4) Account of an experiment to test the value of preservative processes.

(5) Report of an inspection trip to Europe for the purpose of investigating the results of timber impregnation.

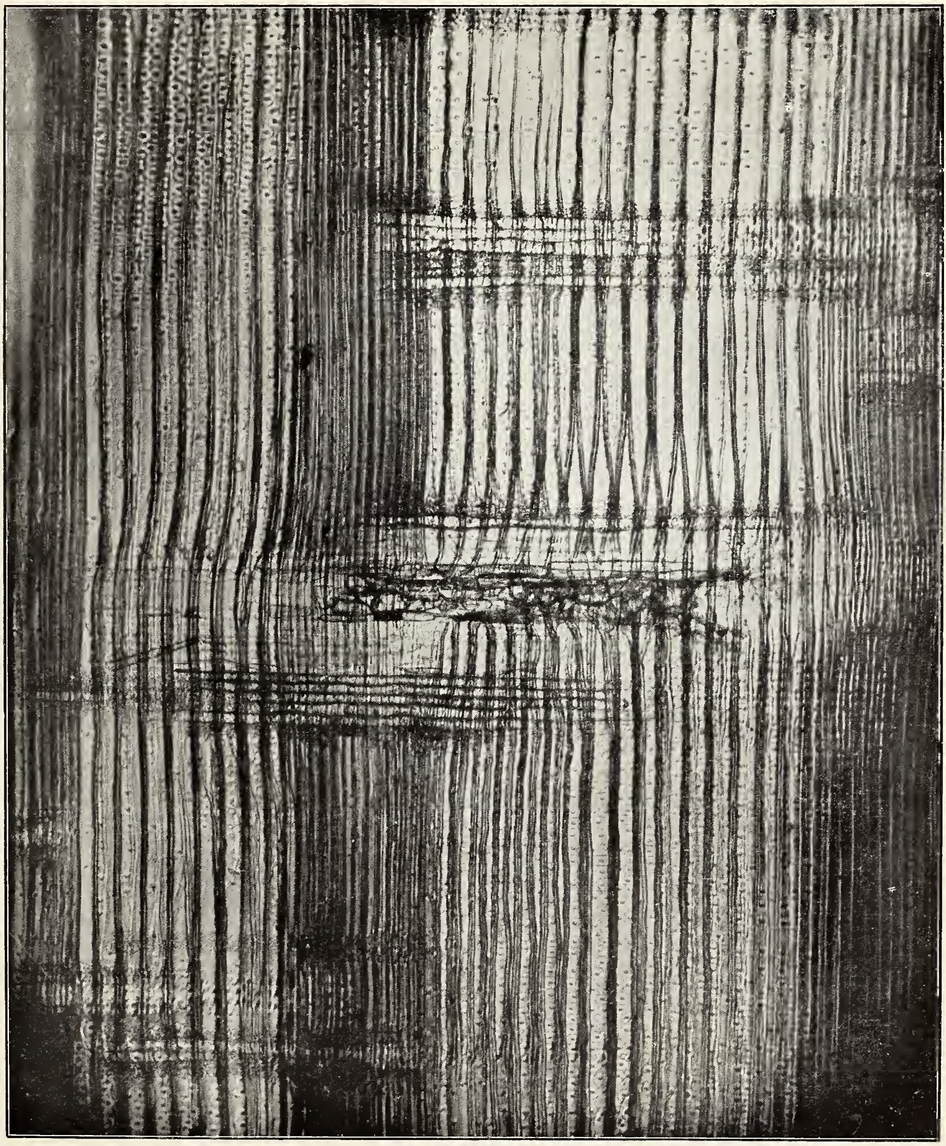
(6) Conclusions and recommendations.

STRUCTURE OF TIMBER.

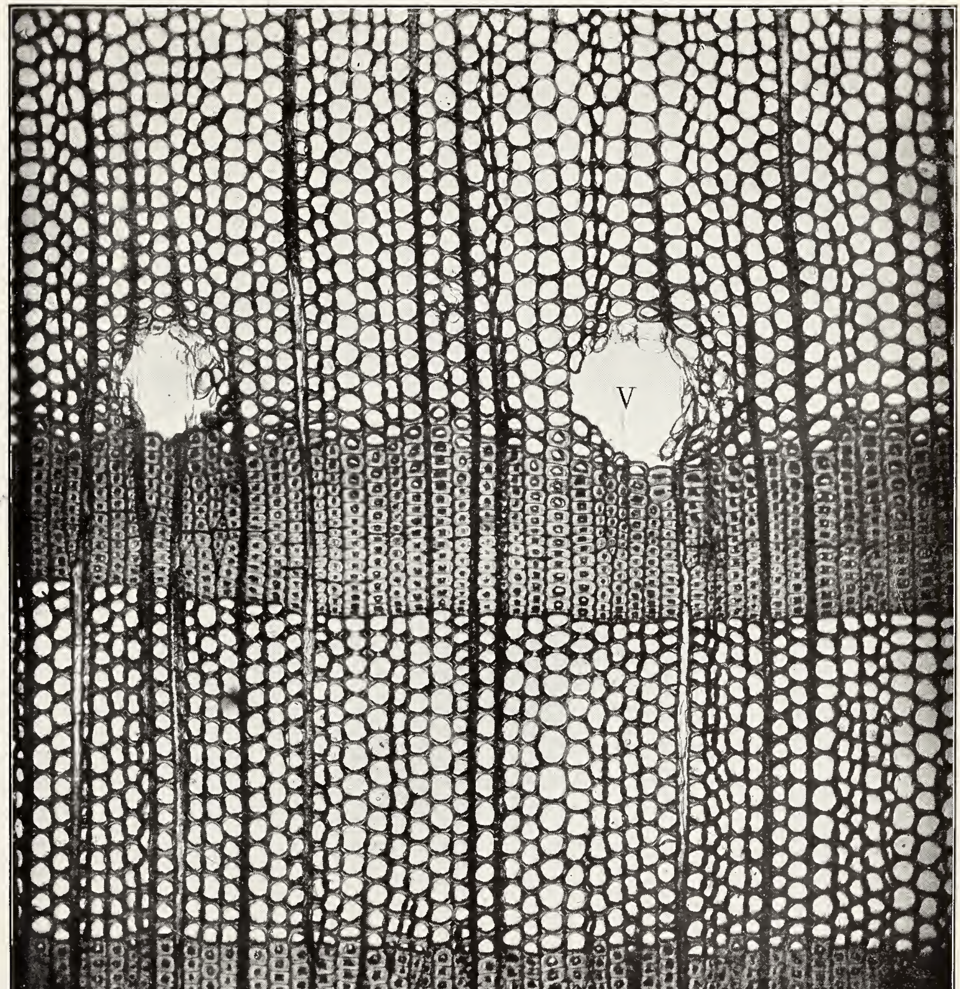
Before describing the various agents which destroy wood fiber, it may be well to consider briefly the character, structural and chemical, of wood. It will be found that a good understanding of the impregnating problems can be obtained only after a clear comprehension of the various chemical and physical features of woody matter itself, and woody matter as a part of a piece of timber.

WOOD CELLS, WOOD FIBERS, ETC.

Wood is composed of a series of closed tubes extending parallel to the long axis of a tree trunk (Pl. II). These tubes are firmly united laterally, and are so arranged as to fit into one another endwise, so as to form a splice. This will be comprehended by a study of the figure on the accompanying plate (Pl. II), which represents a longitudinal section of a piece of yellow pine. It will be noted that the tubes are of varying sizes, some with large diameters, others smaller, and that there is a regular succession of larger and smaller ones. (See also Pl. III, which represents a cross section of the same wood.) The larger tubes are found in the spring wood, when growth is most active. With the approach of summer, the tubes of smaller diameter and thicker walls are formed. A group of the spring tubes, together with the adjoining summer tubes, represents the growth of one year,



RADIAL SECTION OF WOOD OF LONGLEAF PINE (PINUS PALUSTRIS).



CROSS SECTION OF WOOD OF LONGLEAF PINE (PINUS PALUSTRIS).

and is termed an annual ring. One of these rings is usually formed every year, and only under most exceptional circumstances are two produced in one year.

The tubes, called by various names (wood elements, vessels, tracheids), are of various kinds. They differ in their diameter, in the thickness of their walls, and in the marking of the walls. Some are perfectly smooth, slender fibers (fig. 1); others are marked in a peculiar way (fig. 2). All wood cells are formed by a series of thin-walled cells lying immediately under the bark—the cambium layer. These cells divide and form wood cells toward the inner side and form bark toward the outer side. The young wood cell is filled with a semi-liquid mass called protoplasm. Very soon after its formation there is deposited on the thin wall of the new cell from the protoplasm a second layer called the thickening layer. In some cells this is deposited evenly; in others in a manner so as to leave spaces or surfaces. When this thickening has gone on for some time it ceases, and we have then a mature wood cell. The spaces and surfaces left unthickened appear as markings on the wall. A brief study of the accompanying figures will make this clear. Figure 3 shows the most complex form, found in the wood of pines and all other coniferous woods. It will be noted that in none of these cases is an absolute hole formed between two adjoining cells. There is always a thin membrane between the cells, and only when the cells have been dead for a very long period do these fine membranes ever break. In the pines, spruces, etc., the small plates in the pits effectively close the opening, even in old cells.

FIG. 1.—Wood fiber.

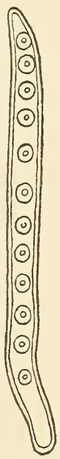


FIG. 2.—Wood fiber (tracheid) with pitted walls.

The wood tubes differ very much in size and their method of arrangement. In the hardwoods one finds some very large tubes, called ducts, which are sometimes arranged in rows at the beginning of a year's growth, as in the ash; in other cases they are scattered through the entire wood ring, as in the oaks (Pls. V, VI, and VII), birches, chestnuts, etc. They are entirely absent in all coniferous woods. The length of the wood fibers differs. In the pines, etc., they are usually comparatively short, while in those of the oak they are much longer. As the cells grow older they lose their content of protoplasm, and become filled with air and various infiltrating substances (resins, gums, etc.), which will be referred to again.

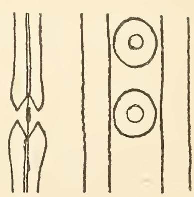


FIG. 3.—Showing nature of the thin places in cells of coniferous wood.

In most woods a series of plates extends radially outward from the pith, known as pith rays or medullary rays. These rays are composed of short, thin-walled cells, which serve to conduct water and food substances. The rays vary in diameter and height, as may be seen from Plate IV, where the lens-shaped cell groups represent cross sections of pith rays.

On Plate VII the very large group of cells in the middle of the figure, marked "M," is one of the large rays which are very characteristic of oak wood.

Besides the large ducts mentioned above found in hardwood trees, one meets with large ducts in some of the conifers, which secrete resin and conduct it from place to place. They are known as resin ducts. (v, Pls. III and IV.)

CHEMICAL NATURE OF WOOD.

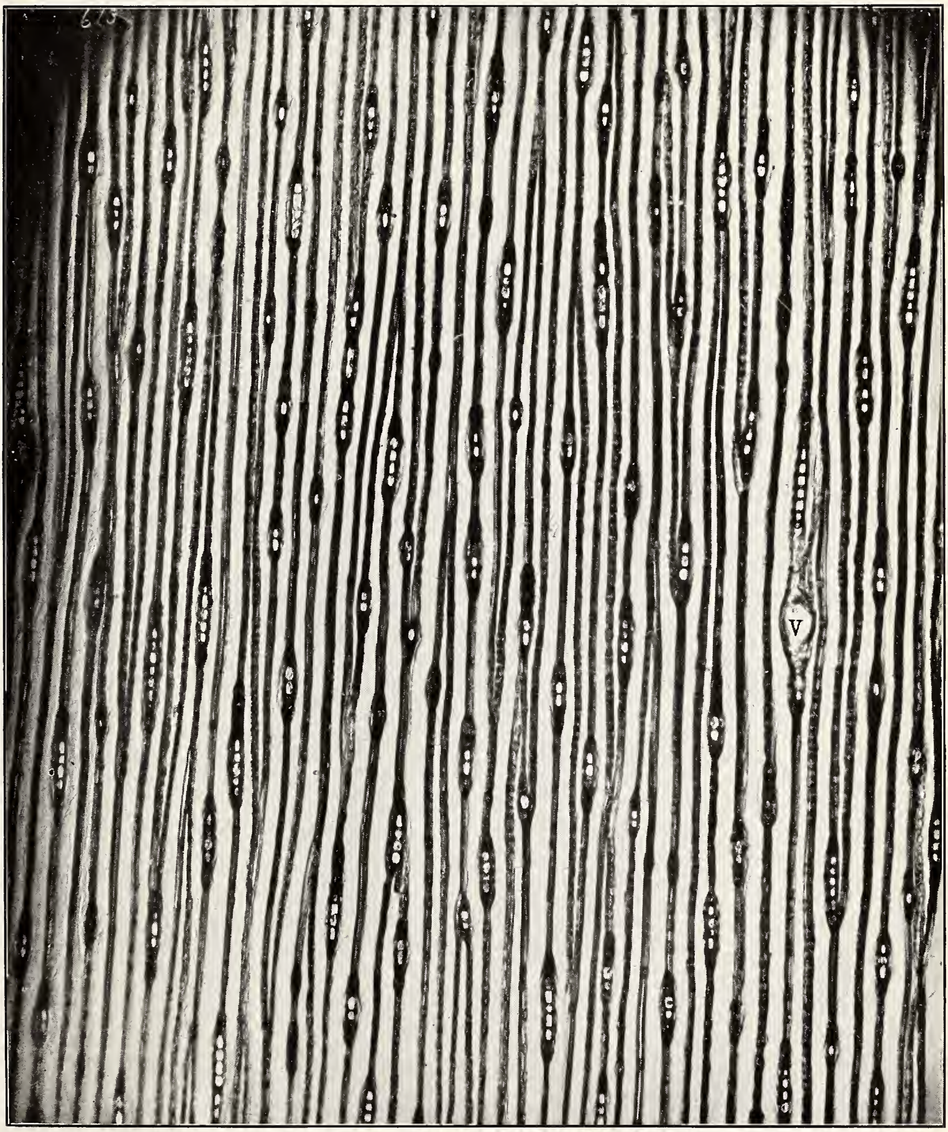
The chemical composition of wood is little understood. It will be sufficient for the present purpose to say that the fine, original membrane of the cell and the groundwork of the thickening is composed of cellulose. This cellulose is infiltrated with various materials, collectively known as lignin. This lignin is dissolved out by various fungi, leaving the cellulose skeleton, and vice versa, as can be seen from figures 10 and 11.

MECHANICAL NATURE OF WOOD.

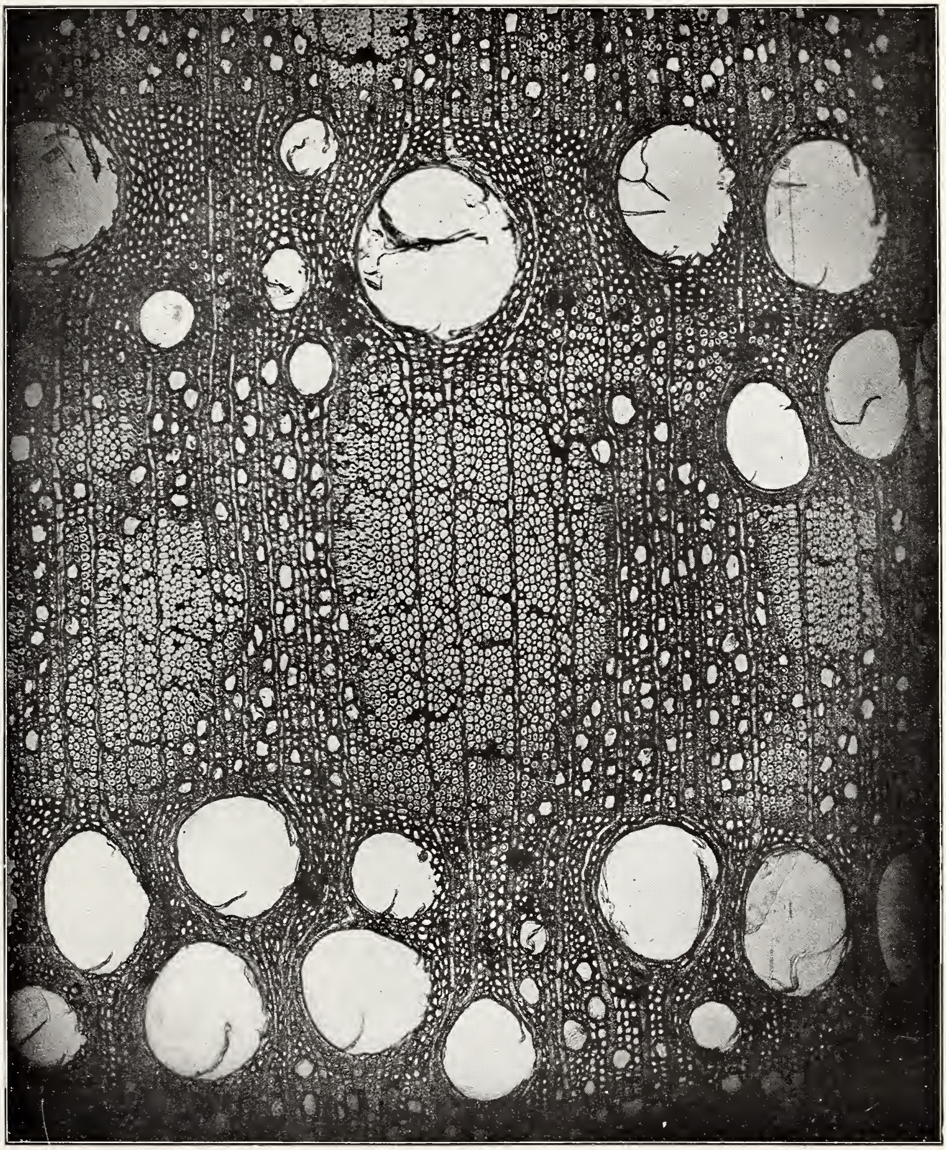
The mechanical properties of wood fibers must be mentioned in this place. There has been much discussion as to the effect upon wood cells of high pressures, such as are applied in forcing preservatives into wood. In the living condition the internal pressure exerted upon the walls because of osmotic forces often reaches 5 atmospheres and more. It is therefore highly improbable that any pressure brought to bear on wood fiber by forcing a liquid into it would be sufficient to injure the same in any way. Wood fiber of pine is capable of withstanding a crushing load of 4,000 pounds per square inch, applied endwise.

LIFE OF THE WOOD CELLS.

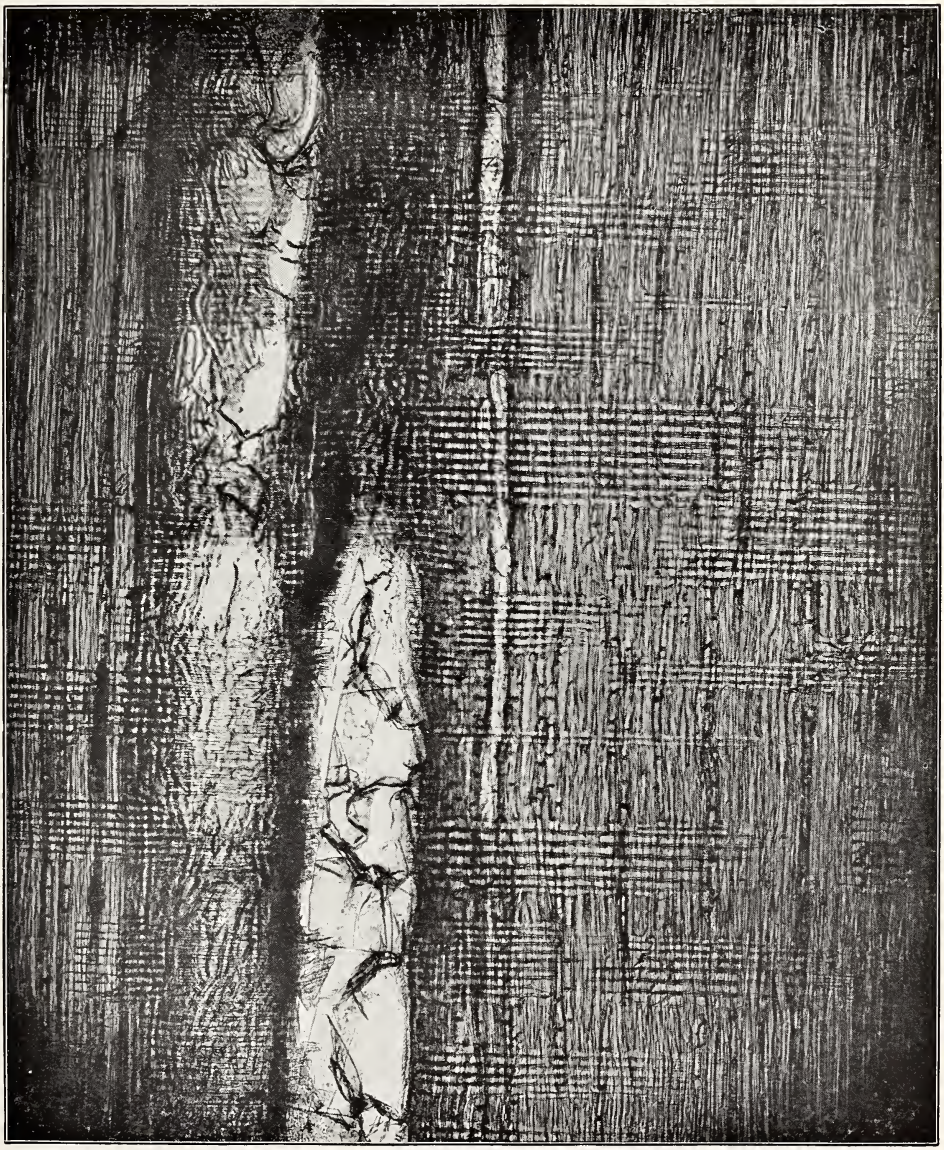
Reference has been made above to the manner in which wood cells are formed by the cambium layer. It is very essential that the relation of the cells to one another be considered, particularly in relation to the circulation of water and the so-called life of the tree. The outermost rings of wood in a tree trunk usually constitute the living elements. It is in them that the circulation of water takes place, particularly the transfer of the same from the roots to the crown above. The wood cells are filled with protoplasm and with various food substances, such as sugars, starches, and oils. The medullary rays are particularly rich in these substances. As one goes toward the center of the trunk one will find that the wood cells gradually lose their con-



TANGENTIAL SECTION OF WOOD OF LONGLEAF PINE (PINUS PALUSTRIS).



CROSS SECTION OF WOOD OF WHITE OAK.



RADIAL SECTION OF WOOD OF WHITE OAK.

M

Tangential Section of Wood of White Oak.

tents and become filled with air. They are then mature; their walls have attained their maximum thickness and strength. They begin to make reservoirs for the deposition of various substances—gums, resins, aromatic substances of various kinds—which remain in the cells, but take no part in the life of the tree. These cells are then, to all intents and purposes, dead. The medullary-ray cells remain alive much longer. Going inward, one finds that they at first lose their sugars, then the starch reserve, and lastly the oil products. It will appear from this that the boundary line between the living wood and the dead elements is no very sharp one.

The water passes through the walls of the newer wood cells readily, and continues to do so for a considerable period after the cell contents have disappeared. It is only when the walls of the cells become thoroughly infiltrated with the resins, gums, etc., that the water transmission comes to a stop. The depth to which the living elements in a tree trunk go depends entirely on the kind of tree. In some trees, for instance the maple and the beech, the living elements extend through many rings, as many as 30, counting from the bark inward, while with trees like the locust or red cedar the number of rings with living cells is very small, not exceeding 14 in the locust, for instance.

HEART AND SAP WOOD.

It appears from the preceding, therefore, that the outer living part of the tree differs materially from the inner dead parts in the presence of large quantities of food materials, oils, starches, sugars, and nitrogenous substances, and in its readiness to transmit water, while the inner parts have larger quantities of infiltrated substances in the walls of the wood cells. These considerations bring one to the question of heart and sap wood. Much has been written on this subject, but we have as yet no very clear conception of what makes heart or sap wood. Broadly stated, the sapwood is composed of the living parts, or, better still, of those outer parts of a tree which allow of free passage of water, while the heartwood consists of the dead inner parts, which serve mainly as a support to hold the crown and in which, because of profound changes in the walls of the wood cells, water no longer travels with ease. The heartwood of most trees is easily distinguished from the sapwood by its darker color and by the presence of various coloring substances. The appearance of these in the wood often indicates which wood is heartwood, which sapwood. The change from sapwood to heartwood is apparently a sudden one. It does not take place in one ring every year, but skips many years frequently, so that 8 to 10 rings or more may become heartwood in one year. Then, again, one side of a tree may change to heartwood, including more annual rings than another—that is, one ring may be heartwood at one point and sapwood at another.

For practical purposes, however, the differences between heart and sap wood are sufficiently well marked. Heartwood lasts longer than sapwood, and it is stronger. In some trees the heartwood resists decay for hundreds of years during the life of the tree, as in the giant trees, while in others, willow and maple, for example, it offers no resistance, apparently, to decay.

The varying resistance of woods to bacteria and fungi will be discussed below at greater length. Having described the structure of wood, one now comes to a consideration of decay.

FACTORS WHICH CAUSE THE DECAY OF WOOD.

GENERAL REMARKS.

By decay one understands at this time the gradual change which any substance undergoes in breaking up into simpler substances. The decaying body changes in its physical and chemical nature, and when it is entirely decayed, the remaining materials bear no resemblance to the original. The breaking-down changes were formerly supposed to be due to some spontaneous process working within the changing substance. The great German chemist, Liebig, was the author of a theory which dominated all others during the middle of the nineteenth century. He maintained that the change in organic matter was a form of slow combustion, which he called "eremacausis." The processes of change were induced by oxygen, much as iron changes to rust. He stoutly denied that bacteria, fungi, or other living agencies had anything to do with decay. Not until the epoch-making researches of Pasteur and his school was it understood that the changes which accompany decay were due to the activity of lower animals and plants. These low organisms, living on or within the substances, use a portion of the same for food, and by removing some of the elements from the substratum they break up the complex chemical compounds. This results in the liberation of various gases and in the phenomena which are known collectively as rotting or decay. It is probable that with the majority of organic substances, that is, substances of plant or animal origin, no change takes place in their chemical nature without the active working of some living organism.

AGENTS WHICH CAUSE DECAY.

The living organisms which cause decay of timber may be insects, bacteria, or fungi. Insects bore holes into sound timber, and in many cases they may riddle a stick completely, so that it falls to pieces. The work of the white ants or termites, which is so destructive to all timbers in warmer climates, is of this character. Then there is a class of beetles, the larvæ and adults of which bore in wood as soon as the same is dry enough to allow them to enter. The decay of structural timber is, however, brought about most frequently by either bacteria or fungi.

Bacteria are low plants which multiply with great rapidity. A single individual divides into two, and these two each divide again. As their method of action on wood is, so far as known, about the same as with the fungi, the two will be considered together.

FIG. 4.—*a*, Fungus spores; *b*, the same, germinating.

Fungi are low plants, consisting of colorless, fine threads, called hyphæ, many hyphæ making up the mycelium. All fungi grow on either dead or living organic matter, from which they remove certain parts.

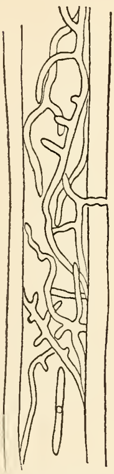


FIG. 5.—Mycelium of a fungus attacking a cell wall.

The mycelium starts from a single spore (fig. 4*a*). The spore, when brought under favorable conditions, sprouts or germinates, sending forth a single thread or hypha (fig. 4*b*). This thread branches and rebranches quickly. The various hyphæ creep through the tissues of the substratum upon which they are growing and absorb the materials necessary for their growth. In living cells they attack the protoplasmic contents—the starches, sugars, and oils. In dead cells they attack the cell walls (fig. 5). After sufficient food has been absorbed some hyphæ form the fruiting body, which bears a crop of spores (fig. 6). The fruiting bodies of the fungi which destroy timber are elaborate structures, which may be formed once every year, or when once started may continue to grow in size from year to year. They form the familiar punk knots, punks, conchs, toadstools, frog stools, or mushrooms found on live and dead timber in the forest. Many of these fungi attack wood. They are readily distinguished by their fruiting bodies, but since the manner in which these fungi work is, so far as we know, approximately the same for all, it is hardly necessary to attend much to the form. Figure 6 shows the cross section of one of these punks discharging spores. On the under side one finds a series of tubes (fig. 7), along the edges of which long rows of threads are arranged. A small part of one of these walls is shown in figure 8. Some of these threads extend out into the tube, and on each one finds four spores. When ripe these fall off and come out of the tubes in clouds (fig. 6). The wind carries them in all directions, and when they fall on wood they sprout, as shown in figure 4*b*.

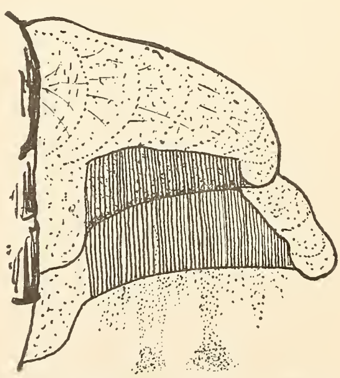


FIG. 6.—Fruiting body of a wood-destroying fungus.

HOW FUNGI AND BACTERIA GROW.

The fungi and bacteria that destroy wood obtain their food by breaking up the complex chemical compounds of which wood is composed into simpler substances, utilizing some of these and leaving some either as gases or solids. A crude idea of the working of a fungus may be obtained by comparing it to a wheat plant. The wheat plant takes something from the soil and something from the air. After it has taken these substances from the soil and air they are changed. When the wheat plant has accumulated enough food it forms seeds. Just so the fungus. It takes all of its food from the wood, and leaves a different substance, rotted wood, behind. When ready it forms a seed plant, the punk or toadstool. It obtains its food by giving off peculiar liquids, known as ferments or enzymes, which have the power of transforming wood fiber into substances which the fungus uses for food. Their action usually results in whole or partial solution of the substance attacked. Sugars and starches are attacked by different ferments; the sugars may be absorbed by the fungus directly, or changed to some more easily digested sugar. The starches are changed to sugar and are then absorbed. The nitrogenous substances undergo similar changes. Wood fiber may be dissolved entirely by the ferments, or only the cellulose or lignin elements. Some mycelia excrete ferments which attack only cellulose, others only the lignin, while others attack starches and sugars. When one part of the wood substance is removed it is no longer wood. The chemical changes have brought about profound physical changes. The hard, elastic wood fibers have become a soft mushy mass, or a dry, brittle substance which falls to pieces at the slightest touch. Figures 9–11 show a number of structural changes in the cell walls. At first the hyphæ simply puncture the cell walls here and there (fig. 9). As they grow more numerous more holes are made, and often enough so that the tensile strength vanishes

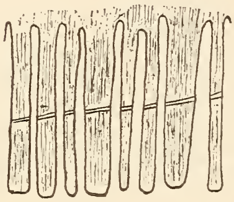


FIG. 7.—Enlarged section of lower (spore-bearing) part of fig. 6.

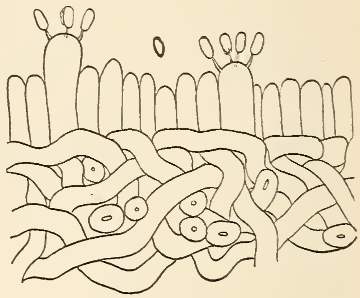


FIG. 8.—Highly magnified spore-bearing surface of fungus shown in fig. 6.

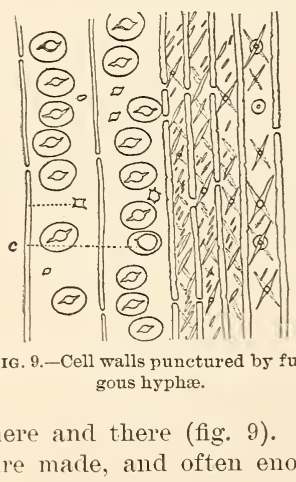


FIG. 9.—Cell walls punctured by fungous hyphæ.

almost entirely. Then again, by the solution of the cellulose or lignin, cracks may form (fig. 10). Some fungi dissolve out the middle lamella (fig. 11), so that the various wood cells fall apart. It will be evident that wood when attacked in this manner very soon loses its properties, and before long changes into a mass of unconnected pieces. Figure 12 shows how even the hardest wood is gradually dissolved. It is this change which one terms decay.

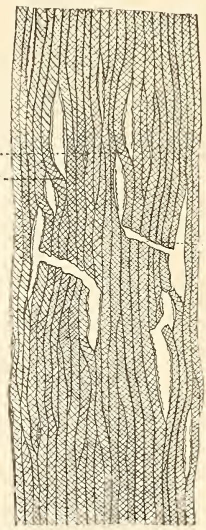


FIG. 10.—Cracks in wood due to the solvent action of fungi.

RATE OF GROWTH AND DECAY.

The best conditions for growth of fungi and bacteria are an abundant food supply and a certain amount of heat and moisture. One point requires particular attention. Fungi are living organisms, which, in common with other living things, grow and develop at a certain rate, which has its limit. Beyond a certain point at which optimum conditions have been reached, it will not be possible to increase the rate of development. It ought to be said that there is considerable range between ordinary and optimum conditions. To use a simile, it is not possible to make a child of 5 grow to be as large as a man of 30 years in two years. Just so is it impossible to force the development of a fungus which takes two years for its development into a period of two months.

Optimum conditions vary with the different fungi and bacteria. Some grow best with a large supply of oxygen; others grow best without it. Some require sugars and starches, others do not. All, however, require water. Where there is no water, there will be no fungous or bacterial growth. The so-called "dry rot" fungi require a certain amount of moisture. It is a very erroneous, though widespread idea, that they grow in perfectly dry situations.

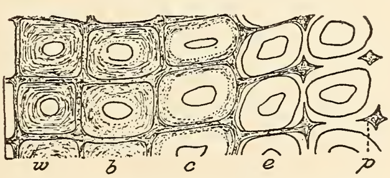


FIG. 11.—Cross section of wood, highly magnified, showing solvent action of fungi.

Much of the rotting of timber could be prevented by heeding this simple fact—that without water there will be no rot. For this reason a tie in a well-drained roadbed will last ever so much longer than its neighbor in a badly drained ballast, in spite of the absence of treatment, the presence of fungi, and ignoring the variability in the timber itself. Wherever organic food is stored, there the bacteria and fungi are sure to grow with great rapidity if moisture is present. This is one of the reasons why sapwood rots so much faster than heartwood. The medullary rays and wood elements of the sapwood have been described as full of protoplasm and reserve sugars, starches, oils, etc. After the death of a tree these cells are rapidly invaded by hyphæ, which flourish in the sapwood, and soon bring about its entire dissolution. The heartwood offers no such basis for the beginning of fungus growth. It is furthermore protected by antiseptic bodies, such as various resins, the tannins, etc. The sapwood admits of the more ready circulation of water, and in that way favors the rapid

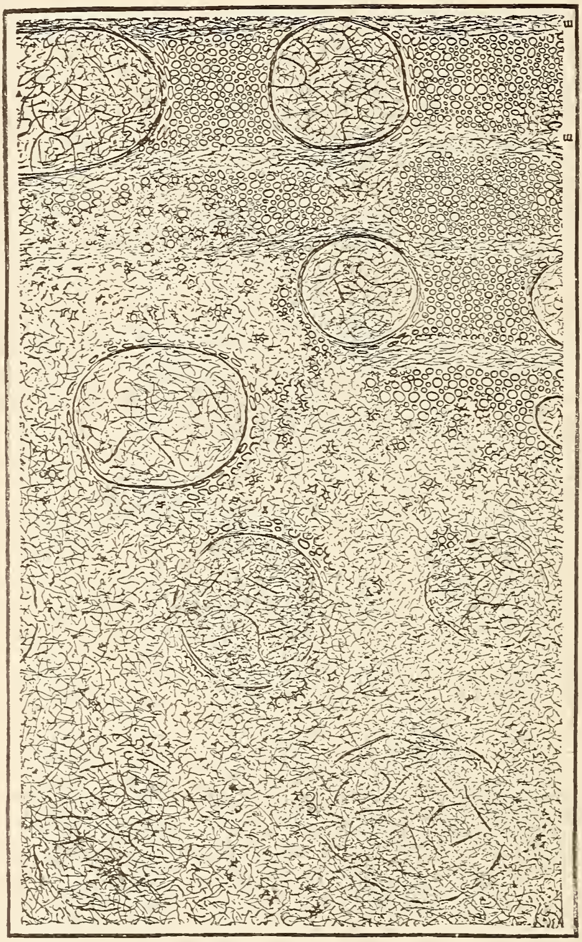


FIG. 12.—Advanced stage of decay of locust timber due to fungi.

development of the fungus threads. What has been said of fungi is also true for bacteria. So far as we know they also produce ferments which destroy the starches and oils in the wood, also the wood fiber. Very little is as yet known about the bacteria which destroy wood. For the present purpose it is sufficient to know that they do so in a manner similar to the fungi.

Attention is here called to a rather surprising statement made by

Mr. Herzenstein in reply to Dr. Dudley's discussion of the manner in which fungi destroy timber. He says[a] that the fungi (by which he appears to mean the "punks") appear only on ties which have come out of the track; and, again, that "the vibrations caused by trains prevent, if not the formation of filaments, at least the growth of the fungus itself." Such statements are so obviously false and misleading that no attention would have been paid to them here if they had not come from one whose words might be taken seriously. At this time we know absolutely that fungi cause decay of wood; furthermore, that the "punks" which Mr. Herzenstein seems to lay so much stress on are simply the fruiting bodies of these fungi; and, again, everyone knows to their own regret that "vibrations caused by trains" do not stop the rot of ties in the track. It would be a pertinent question to ask Mr. Herzenstein, if he is so sure that the vibrations stop the growth of the fungi, why he thinks any injection of salts necessary.

NATURAL RESISTANCE OF TIMBER.

Dry wood will resist the attacks of destructive agents, such as fungi and bacteria, for indefinite periods of time. The timbers in many old buildings have been in position for hundreds of years. The writer examined some larch wood obtained from an old chapel in Switzerland which was supposed to be about 500 years old. It was hard and sound and showed no signs of deterioration.

Engineers have made use of this principle now and then by employing several timbers instead of one large one. It was found that a timber 12 by 12 inches would not last nearly as long as one composed of four timbers 12 by 3 inches. When more widely appreciated, this principle will no doubt be applied still more. In general, all conditions which favor drying and keeping wood dry will tend to prolong its life.

Wood completely immersed in water will not decay. The supply of oxygen necessary for the development of fungi is cut off. Decay in piles, for instance, takes place near the point where the pile emerges from the water. In fence posts and telegraph poles the decay usually starts just below the surface of the soil. Above the ground the wood remains dry, while at the extreme base there is only a limited supply of oxygen. Where there is some oxygen and some moisture, i. e., near the surface of the ground, there the rot sets in.

SAWN VERSUS HEWN TIMBER.

A word may be said here concerning a question which is as yet but imperfectly understood, but which has already caused much discussion. There appears to be a well-defined opinion that so-called

[a] Bulletin of the International Railway Congress (English edition), 15: No. 10, October, 1901, p. 2429.

hewn timber will last longer than sawn timber. Many railroad companies specify that their ties shall be hewn from young trees, i. e., be pole ties. Because of this practice millions of young trees are cut annually from forests where the older timber remains standing.

The reasons why hewn timber should last longer are difficult to define. It may be that the sawing, passing as it does in one line, irrespective of the "grain," cuts across many fibers, thus presenting many openings where the water can pass in readily. The sawing exposes the more resistant and less resistant parts of annual rings in an irregular manner. Then, again, the sawn surface is rough; many fibers are torn away partially. This gives the wood a felty surface, which holds water readily. The hewn timber, on the other hand, has no fibers exposed, for the ax causes the chips to split off "along the lines of the grain." It shows a smooth surface of either spring or summer wood, generally the latter.

The objection sometimes made that the hewn ties cut from a young tree are firmer and naturally more resistant because the wood is younger appears to have no good foundation.

Whatever the relative value of sawn and hewn timber may be—a point which needs careful investigation—it becomes a matter of small importance when timber is impregnated. The impregnated wood would be influenced only to a very small extent by such differences as are spoken of above. The results of many years' practice are not easily laid by, and it will probably require a practical demonstration to convince many of the correctness of the contention that, when properly treated, a sawn timber is just as good as a hewn one. Hewing is a very wasteful process. It is slow and not economic and, above all, it requires the use of young timber, to the exclusion of that which is older and often more durable.

SEASONED VERSUS GREEN TIMBER.

As the presence of a certain amount of moisture is indispensable for the growth of the destructive agents, it follows readily that seasoned timber will last longer than green timber. Although this is so simple a matter and one generally appreciated, it is surprising how rarely it is heeded by those who use timber. The chief excuse made is that it takes time to season timber. Many say that they are in doubt as to whether the expense involved in keeping timber is warranted by increased length of life. Some practical experiments on a large scale ought to be made to convince those who still doubt the advisability of long seasoning. The writer ventures to assert that few realize how much longer a piece of seasoned wood will resist the action of decaying agents than a similar piece of green wood.

The Russian railway authorities have found that their seasoned oak ties last practically as long as the same timber impregnated with zinc chloride and laid shortly after treatment, and on that account do not treat their oak. A good deal depends upon the manner in which wood is piled. The Europeans pile ties so as to give the maximum amount of air space around each tie. They make piles with several hundred and often several thousand ties in one pile (Pl. VIII, fig. 2). (Compare with this Pl. IX, showing an American pile.) The ties are hoisted into position with a donkey engine, and when seasoned are either treated or in some cases laid directly. The piles are located so as to give the greatest exposure to the sun's rays and with reference to prevailing winds. The length of time allowed for seasoning will vary much with the climate and must be determined separately for each locality. The present practice of exposing timbers to decay very soon after cutting is extremely wasteful and could with ease be modified. Of course that means an accumulation of material for a year or more in advance, but this ought to be no serious objection when one takes into account the great amount saved by such a step.

RACES OF WOOD.

Susceptibility to decay and comparative resistance to decay vary with the different kinds of timber. The qualities which determine the greater resistance to fungus attack are as yet almost unknown. Hardness, density, specific gravity, tensile strength, are factors which seem to have no influence one way or the other. Some of the tropical timbers which are extremely hard and heavy decay in exceedingly short periods of time, while equally hard woods last very long. The teak wood of India is a notable example of endurance, and is highly esteemed on this account. Among the timbers of the United States the hard, strong white oak decays far more rapidly than the light, porous cypress. The resistance is, furthermore, not confined to broad-leaved trees or conifers. The tamarack and hemlock decay rapidly, while the cypress and cedar are lasting timbers; just so we find elm and birch short lived, the locust long lived. There are certain groups of timber which resemble one another in being highly resistant to decay. Some of these are the red cedar (*Juniperus virginiana* and *Juniperus barbadensis*), the cypress (*Taxodium distichum*), the incense cedar (*Libocedrus decurrens*), the big trees and redwoods (*Sequoia sempervirens* and *Sequoia washingtoniana*), and the arbor vitæ (*Thuja occidentalis* and *Thuja plicata*). The lasting powers of these woods, as is well known, exceed those of any other of our native woods. All of them are usually classed as soft woods. The reason for their resistance is probably to be sought for in the presence of some substances in the wood which give it protection against fungi. All of these timbers come from trees of ancient lineage which have persisted down to the present time and are able to grow in our forests with more recent trees.

VARIABILITY IN TIMBER.

A striking feature which must be mentioned at this point is the great variability in all respects of timber of the same kind taken from different trees. Those who have impregnated timber are constantly confronted with this fact, for they find "that very rarely are two pieces of wood alike." This variability is one of the attributes, as now viewed, of all living matter. There are hardly two trees which grow under exactly the same conditions. We have learned to regard the influence of the external conditions on the growth of a living animal or plant (in this case the tree) as a most profound one; in fact, this influence seems to determine, with plants even more than with animals, the size and form and vigor of any or all parts. It is probably owing to the different conditions under which different trees grow that such variable wood is formed. The differences in the wood are largely in the size of the wood cells, the thickness of their walls, and the extent of infiltration of these walls in the heartwood. This variability extends to the natural resisting power of the timber to decay. Some oak ties decay in three years, while others cut and laid at the same time last ten to fifteen years. It is well to bear in mind that the time of cutting and the subsequent care given to cut timber may have something to do with its behavior when it comes to the impregnating stage.

SUMMARY.

The facts set forth in the foregoing may be summed up as follows:

Wood is composed of many tubes, having a complicated structure. These tubes are invaded by low plants, called fungi, which bring about changes in the fibers, which changes are called decay. There is a marked difference in heart and sap wood, and in different woods, with reference to their susceptibility to decay.

TIMBER PRESERVATION.

INTRODUCTION.

The first attempts made to preserve timber from decay date back many centuries, when wood was charred to make it more resistant. Later on came a period when wood was coated with preservative paints, and then attempts were made to inject preservatives into the wood. The literature dealing with this subject is bewildering, for as soon as the prices of timber began to rise, owing to scarcity of material, all sorts of processes were devised to increase the life of the wood.

It is not the present intention to add to this already voluminous literature, and anyone who is interested in the historical development of this question is referred to the works of Paulet, Bruesch, Boulton, Chanute, Curtis and others, likewise to Bulletins 1, 3, and 9,

FIG. 1.—PILE OF NEW OAK TIES AT GHENT, BELGIUM. (NOTE "S" IN ENDS.)

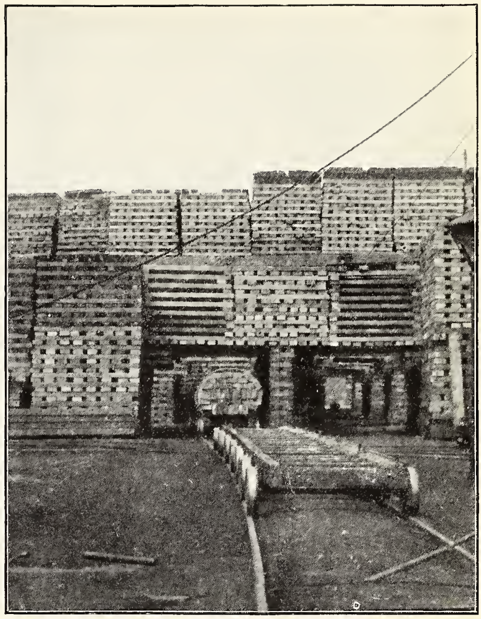
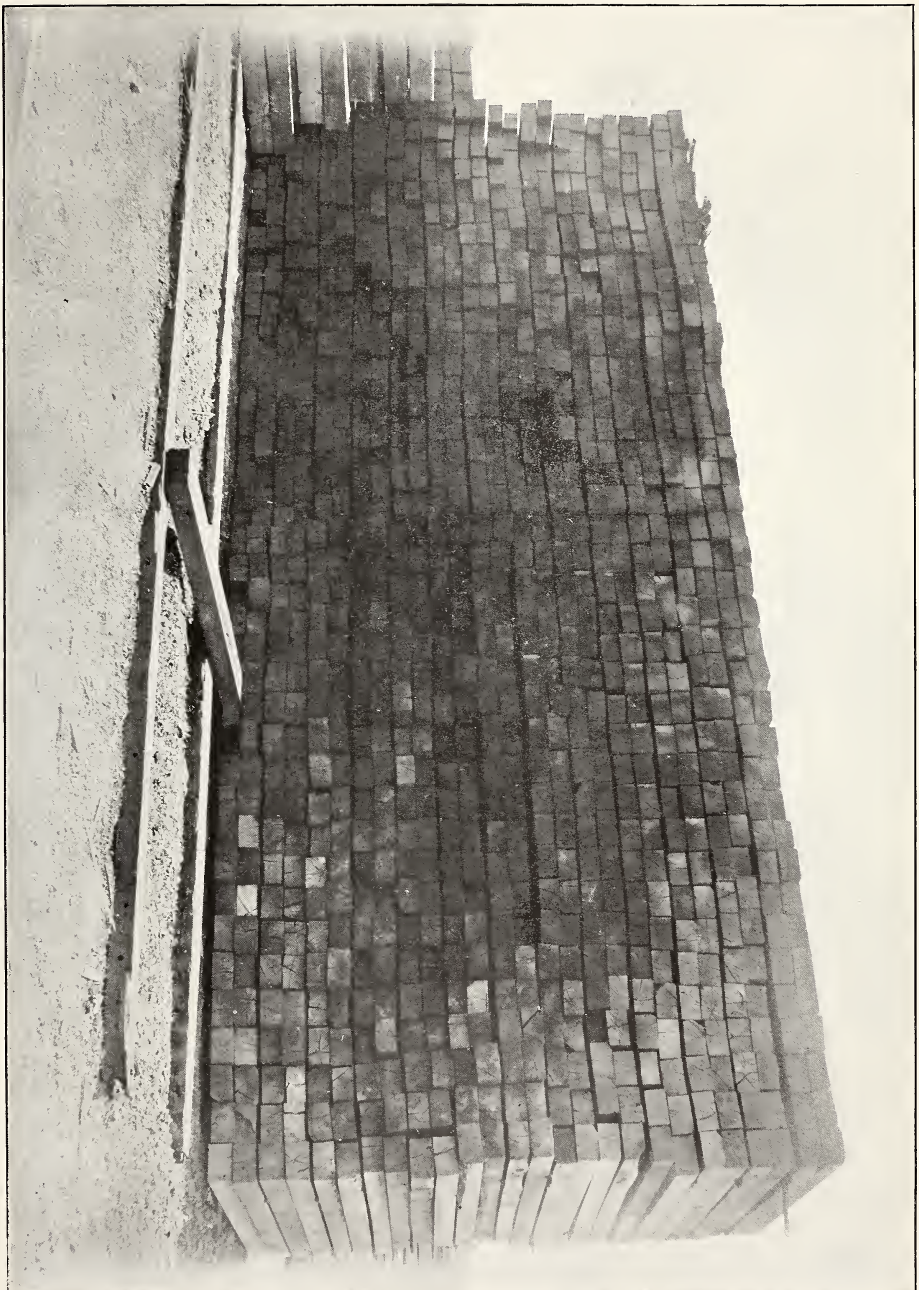


FIG. 2.—SCOTCH PINE TIES SEASONING, GREAT WESTERN RAILWAY, ENGLAND.

FIG. 3.—OAK TIES READY TO ENTER CYLINDER, GHENT, BELGIUM.

FIG. 4.—TIES ARRIVING IN CANAL BOATS GREAT WESTERN RAILWAY, ENGLAND.



AMERICAN TIMBER RECENTLY CUT, SHOWING POOR METHOD OF PILING.

Forestry Division, United States Department of Agriculture, mentioned in the annexed bibliography. Suffice it to say that the processes advocated consisted in either external applications of preservatives or in forcing the preservatives into the wood. The trials were attended with varying degrees of success, and of the large number advocated (Paulet mentions 174 in all) only a few have survived. The painting processes, for wet exposures, have gradually fallen into disuse, because it was found that by covering the outside of a timber with an impervious coating the evaporation of water was prevented. This gave any chance fungus spore, which may have been on the wood before coating, an opportunity for rapid growth, thus destroying the wood rapidly. Some of these processes are still being advocated, but it is hardly necessary to say that in most cases they do more harm than good.

The processes which depended upon getting preservatives into timber encountered from the first great difficulties because of the peculiar structure of wood. It was not realized, and it is not realized by many even at this day, that the wood fibers are not like so many open pipes. The sapwood is more easily injected and absorbs more preservative because it allows of a greater water penetration than the heartwood, where cell walls are made more or less impermeable because of the wall infiltrations. Pressure was resorted to to drive the solutions employed into the wood. These solutions were usually heated, in order to increase the amount pressed in, as hot solutions penetrate porous matter more readily than cold material. The materials used for impregnation differed. They were and now are chiefly copper sulphate ($CuSO_4$), zinc sulphate ($ZnSO_4$), zinc chloride ($ZnCl_2$), mercuric chloride ($HgCl_2$), aluminum sulphate ($Al_2(SO_4)_3$), and the products of coal-tar distillation. The various methods now in use will be referred to below.

THEORY OF IMPREGNATION.

The theory upon which the injection of salts into wood is based is that the salts act as poisons, killing the fungi or bacteria which grow in wood and destroy it. The amount of salt of one kind or another necessary to kill the fungi varies, but is usually very small. In order to protect the wood it is necessary to have a certain amount of salt so distributed that it will suffice to prevent the growth of the destroying agents. As soon as the amount of salt present falls below that definite quantity, growth of the fungi will be possible. Most of the salts injected are soluble in water. The solutions are made of varying strength, but usually very much stronger than is necessary to prevent growth of the fungi, for a simple reason. Timber impregnated with a salt soluble in water will have part of that salt removed every time the timber comes into contact with water. The object of preservative processes of to-day is therefore to inject as much salt as will go in, so that the time in which all the salt will be leached out may be made as long as possible. Experience has given us a long series of figures as to the amounts of salts of various kinds injected into various timbers necessary to insure their lasting for some time. These figures vary considerably, as was to have been expected. The reader is referred to extensive reports on this subject by Chanute, Curtis and others.

One must not forget that it is the presence of the injected salt which prevents decay. A piece of wood may be in a locality excessively favorable to the growth of fungi, but as long as the amount of salt necessary to destroy the fungus is present, just so long will the wood remain sound. It is of no use, therefore, to accelerate the growth of fungi in newly injected wood, as has been suggested, in order to test the efficiency of a preservative. Only when the amount of salt in the wood is decreased below a certain per cent can the fungus begin to grow.

Theoretically, in order to obtain perfect protection, the preservative ought to penetrate every part of the wood. With the impregnating methods which depend on pressure this is practically impossible, because of the structure of wood, as already pointed out.

To sum up, an ideal preservative ought to conform to the following conditions:

(1) It must be poisonous to bacterial and other destroying agents.

(2) It must be capable of easy injection, and when once in the wood it ought to stay there.

(3) It must penetrate all parts of a piece of timber; to which a fourth condition must be added because of present economic conditions.

(4) It must be cheap.

RETROGRESSIVE CHANGES WHICH TAKE PLACE IN IMPREGNATED WOOD.

Wood impregnated with salts soluble in water undergoes changes as soon as it is exposed to weathering influences. The rate with which the injected salts are leached out differs with the timber. In general, they leach out most rapidly from those timbers into which they were injected with the greatest ease. The leaching out is, however, dependent on several circumstances. If wood be placed in a position where it comes into contact with water immediately after or shortly after impregnation, contact will be established between the solution in the wood and the water outside, and a rapid transfer of salt will result. In wood which has been dried after impregnation the water from without must first of all force an entrance into the dry wood, which is a slow process. In the dry wood impregnated with zinc or copper salts, for instance, these salts are deposited in the lumen of the wood fibers as the water evaporates. The greater portion of the lumen is filled with air, which makes the entrance of water from without an exceedingly slow process. It follows from this that impregnated wood (i. e., impregnated with a water solution) will retain its antiseptic salts much longer when placed under conditions unfavorable to lasting, if such wood has been thoroughly dried after the impregnation. As this is a point of considerable economic importance, reference will be made to it later.

The changes which wood impregnated with substances insoluble in water undergoes are as yet little known. Wood impregnated with products of coal-tar distillation may lose some of these products by evaporation. Many of the coal-tar derivatives are slowly volatilized at temperatures reached during the summer. In cases where light oils have been used all of these may disappear in the course of a few years. As noted by the writer some years ago, this was the case in some timbers impregnated with creosote and laid in the hot sands of New Jersey. When impregnated with products which do not boil below 175° C., wood may last almost forever, at least without decaying.[a] (See Pl. XIII, fig. 3, representing a post of Baltic pine (*Pinus sylvestris*) impregnated forty years ago.) In moist tropical countries the changes in wood treated with coal-tar derivatives are different from those in temperate climates. The writer is informed that the creosoted sleepers on the Chilean State railways last but a short time in the moist, warm forests of that country; but then, again, the excellent results obtained on the Indian railways with Baltic pine sleepers impregnated with creosote point to the fact that even under the most severe conditions, when properly treated with proper oils, the coal-tar products remain in the wood. The poor results obtained in Chile, Spain, and Portugal with creosoted timbers are probably to be explained by the fact that inferior work was done for the sake of cheapening the process. As will be pointed out below, it is a rather suggestive fact that wherever poor results were obtained with tar-oil impregnation there the cost of the process is also very low. (See the tables given by Herzenstein.)

The changes which other insoluble salts (see below) undergo are not yet known, because the processes using these salts are of too recent development.

It may be stated again at this time that as soon as the preservatives disappear from the wood the decay can begin.

RESULTS OF TIMBER IMPREGNATION.

INTRODUCTION.

Timber impregnation has been carried on for so long that there has been ample time to secure some results. The decay of ship timbers aroused the inventive spirit of the British at the beginning of the eighteenth century, but it was not until the general use of timber for

[a] Throughout this report mechanical destruction will be expressly mentioned; in all other cases decay by fungi will be understood.

railway ties began that much attention was paid to the treatment of timber. Boulton[a] states that "by the year 1838 four several systems of antiseptic treatment were fairly before the public and competing for the favor of engineers. These were corrosive sublimate, sulphate of copper, chloride of zinc, and heavy oil of tar." Since that time these four processes have been tried with varying success in many climates and countries. The impregnation was carried on by railway companies in particular, for they used the larger proportion of that timber supply which was placed under conditions favorable to decay. Experiments of various kinds were conducted, generally by separate companies, by engineers, or scientific bodies. These experiments, and the experience of railway engineers and others, have shown beyond question that there are certain salts which, when injected into timber, will prevent decay, and by so doing increase the length of life of the timber. It may be said with safety that the four processes referred to by Boulton all prevent decay of timber more or less. It is, then, no longer a question whether decay can be prevented, or, to put it otherwise, whether an increased length of life can be obtained for any given kind of wood; nor is it a question whether it is possible to do this economically, i. e., whether it will pay under the conditions which obtain in the different parts of the United States to-day. There can be no doubt that there are processes which do increase the length of life of timber, and do so at a reasonable cost. The question which is before those who use timber for any structural purpose is: Which one of the numerous processes advocated shall we use? This applies to railroad ties, fence posts, bridge timbers, telegraph and telephone poles, and in fact structural timber of all kinds. The answer to this question must take into consideration (1) the cost of the operation; (2) the comparative efficiency of the various treatments; (3) the readiness and ease with which any one treatment can be employed. The answer must be no uncertain one. A decision one way or the other will involve a considerable outlay of capital, the returns from which will not be evident or even certain for many years. While the results obtained during the last forty years are beyond question of great value as indicating the extent to which one or another process may be trusted, we have few indications as to the comparative value of these various processes. The results were obtained in particular sections of country; they are restricted to particular soil conditions of which we have only scant records, and to particular kinds of timber. While it is without doubt true that all timbers when placed under the same conditions will decay, and will probably behave in a similar manner when injected with any salt, there will be differences in the length of time which they will resist—a most important factor from the economic standpoint.

Anyone who has gone over the published statements of results of

[a] Boulton. The Antiseptic Treatment of Timber, p. 9.

timber treatment can not but be struck by the numerous contradictory statements found in these reports. Voluminous discussions upon this question have appeared every year, and yet there seems to be no well-defined understanding of the best method of timber treatment. The difficulty has been that many have tried to compare results obtained with the same or similar processes in different localities under different conditions. It is obviously unfair to condemn a process because it has given poorer results in Georgia than in a Northern State, if the work has been done equally well, and to draw the conclusion that it will prove disappointing on that account in the Northern States. The trials given any one process have been made with different timbers, and oftentimes while using the same salts different methods of impregnation have been employed. One may be warranted in stating that it may prove economic to employ one system in one place, another in a second part of the country. Discussions of results obtained in that way have little value and tend to confusion and cloudy conceptions. One must face the problem squarely, and experiment with a definite end in view. The absolute value of an impregnating method in terms of years will probably never be known because of the variability in conditions, but one can obtain results as to the comparative value of the different methods.

In a following chapter an experiment will be described, which was begun this year, with the intention of getting at some of the data spoken of above. Similar experiments have been made on some of the European lines, but these have been for the most part (with one exception) conducted by many people and with variable conditions, so that the results obtained are questionable. Reference need only be made to the results obtained on one of the Austrian roads, the record of which is given on Diagram I. (See also p. 46.)

EXPERIMENT MADE IN TEXAS.

The chief difficulty encountered in obtaining results with any one method of timber treatment is, as has been pointed out, that one must wait for such a long number of years before arriving at satisfactory conclusions. It is well known that treated timbers decay with greater rapidity in some parts of this country than in other parts. It was thought possible that, by selecting a region where decay took place with the greatest rapidity, the retrogressive changes which take place in timber might be hastened. After an inspection of different sections, the southern part of Texas was selected as fulfilling the desirable conditions. The ties treated with chloride of zinc had decayed in from two to four years in this section, while untreated timber decayed in twelve to fourteen months. A portion of track belonging to the Santa Fe Railroad was selected, lying some 75 miles east of Somerville, Tex. The ground in which the timber is placed admits of little drainage. The annual rainfall and the average temperature are high. The track is shaded for some distance. These conditions favor not only rapid changes in the salts injected into timber, but also rapid growth of the destructive fungi when once the amount of salt injected has fallen below the minimum. The experiment was begun with ties, for the reasons mentioned in the introduction, that they offer the best means of obtaining rapid results.

The plan of the experiment was as follows. It was outlined with a view of answering these questions: (1) Which treatment now advocated gives the best results (under the same conditions) in increasing the length of life of the timber? (2) Does one and the same kind of treatment give the same results with different timber? (3) Can inferior timbers be made to pay for the cost of renewal by impregnating them with one salt or another?

It was fully realized that practical results could be obtained only under actual conditions. Laboratory experiments are valuable as indicating what may be expected, but they rarely are borne out absolutely in practice. The timbers used were donated by various railroad companies. Owing to this fact a certain amount of experimental freedom had to be sacrificed. It would have been desirable to use a much larger number of ties and also several other kinds of wood. The experiment is, therefore, to be regarded as a first step, which will have to be improved upon as rapidly as it may be possible. Too much emphasis can not be laid upon this test, which, if conducted properly, can be made to answer most of the unsolved questions now awaiting answers.

The following timbers were used, their sources being given as nearly as it was possible to learn them. After each kind of timber the mark assigned to each in the record nails is indicated:

White oak	W
Red oak	RO
Black oak	BO
Spanish oak	SO
Willow oak	WO
Beech	B
Hemlock	H
Tamarack	T
Long-leaf pine	L
Short-leaf pine	S
Loblolly pine	LL
Red-heart pine	RH

The table following shows the number of ties used and the treatments given each. The treatment was carried out by the representatives of the various companies now doing business in this country. The ties were dried several months before laying, and were then placed in the track. Each tie is marked with three nails. These nails are of heavy wire, coated with zinc. In the head the letters or marks were stamped. Each tie has nails showing the date, the kind of timber, and kind of treatment. The nails were placed about 4 inches outside the rail.[a] Accurate records will be kept by this Department, and reports will be issued from time to time, showing what progress is being made.

While this experiment will without doubt yield some valuable results, the writer can not refrain from adding that it could be very much improved upon. The circumstances under which the experiment was made were of such a nature that many of the factors involved could not be controlled. The ties were donated by various railway companies. They were cut at different seasons and in different sections of the country. They were seasoned different lengths of time before treatment and, owing to delays in shipment, for different periods after treatment. Then, again, there ought to have been many more ties of each kind, to do away with the variability of individual ties. In spite of these defects, the experiment is a beginning in the right direction. As pointed out in the conclusion, every railroad which does any treating ought to consider its treating as part of a large series of tests. These might be watched, and the results correlated by the Government. It is only when this work is done on a large scale that absolutely trustworthy records will be obtained.

Besides the experiment in Texas, an experimental greenhouse and culture pit was constructed at St. Louis for the purpose of investigating the comparative rate of decay of different timbers. Pieces of wood, one half treated, the other half untreated, are inoculated with destructive fungi and are placed under the most favorable conditions for rapid decay. It is too early as yet to give any results.

TABLE I.—*Variety and number of railroad ties laid on Atchison, Topeka and Santa Fe Railroad and the kind of preservative treatment each received.*

NOVEMBER 20, 1901.

Process.	Rock Island Railroad.	Atchison, Topeka and Santa Fe Railroad.					Pennsylvania Railroad.	
	Hemlock. H.	Long leaf pine. L.	Short leaf pine. S.	Loblolly pine. LL.	Red heart. RH.	Red oak. RO.	Beech. B.	Black oak. BO.
Burnett. Zinc chloride. BU	100	100	100	100		100	100	100
Wellhouse. Zinc tannin. WE	100	100	100	100			100	100
Alderdyce. Zinc creosote. AL	50	50	50	50			50	50
Alderdyce. Zinc creosote, English oil. AL**	50	50	50	50			50	50
Barschall. BA	100	100	100	100	100	100	100	100
Beaumont oil		100		100				
Zinc chloride, Beaumont oil. BZ		100		100		50		
Spiritine. SP		100		100				
Untreated	100	100	100	100			100	100

[a] The nails had to be placed outside because the middle of the ties was completely covered with ballast.

TABLE I.—*Variety and number of railroad ties laid on Atchison, Topeka and Santa Fe Railroad, etc.*—Continued.

NOVEMBER 20, 1901—Continued.

Process.	Messrs. Wm Ripley & Son.	Missouri Pacific Railroad.	Cotton Belt Railroad.	Illinois Central Railroad.	Ayer & Lord Tie Company.				
	Tamarack. T.	White oak. W			Red oak. RO.	Black oak. BO.	Turkey oak. YB.	Spanish oak. SO.	Willow oak. WO.
Burnett. Zinc chloride. BU	50	100	....	100	20	20	20	20	20
Wellhouse. Zinc tannin. WE	100	100	....	100	20	20	20	20	20
Alderdyce. Zinc creosote. AL	50	....	50	50	10	10	10	10	10
Alderdyce. Zinc creosote, English oil. AL**	50	....	50	50	10	10	10	10	10
Barschall. BA	100	....	100	100	20	20	20	20	20
Untreated	50	....	100	100	20	20	20	20	20

RESULTS OF TIMBER IMPREGNATION IN EUROPE.

For many years experiments and practical tests have been made in Europe to determine the value of preservative processes. Reports concerning results have from time to time appeared, notably that of Flad and recently that of Mr. O. Chanute. In the present account much that these writers mentioned is verified, and here and there quotations from the earlier reports are given.

During the past summer the writer visited various European countries, including England, Belgium, Germany, Switzerland, Italy, Austria, Russia, and France, for the purpose of making a personal investigation of the results of timber impregnation, as obtained by railroad companies and others interested in the impregnation of timber. During the entire trip attention was paid in particular to the increased length of life which various methods of treatment gave to timber, as shown by the actual position in service of railway ties, telegraph poles, mine timbers, etc.; furthermore, to all those attendant factors which influence the life of structural timber, such as the condition of the soil in which timber is placed, the drying before and after treatment, the shape of timbers, the relation of heart and sap wood, etc.

In the following pages the results of the observations will be given in brief, to be followed by general considerations. Before giving the writer's personal observations, attention is called to the report published under the direction of M. Vladimir Herzenstein, of St. Petersburg, by the Sixth International Railway Congress, entitled Question VIII—The Preservation of Timber, Paris, 1900. In this report the answers sent in by 87 railways, of these 79 European, to the 74 ques-

Fig. 1. Median section of new Baltic pine tie (England), impregnated with tar oil.

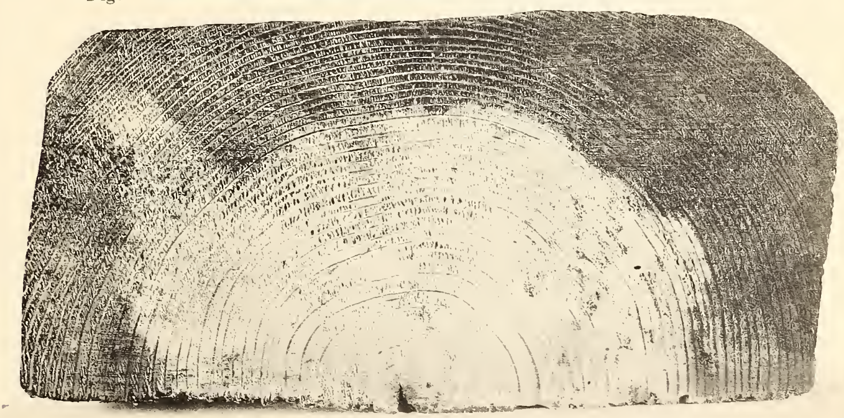


Fig. 2. Median section of Baltic pine tie after 16 years service, impregnated with tar oil.

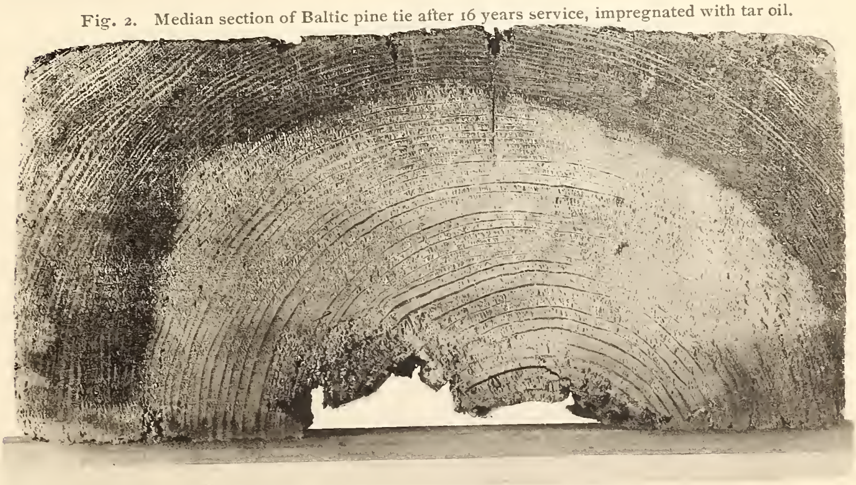


Fig. 3. Median section of Baltic pine tie, impregnated with tar oil, showing how decay starts. (This tie is still good for several years.)

Fig. 1. Median section of beech tie (France), impregnated with tar oil; laid in track in 1869.

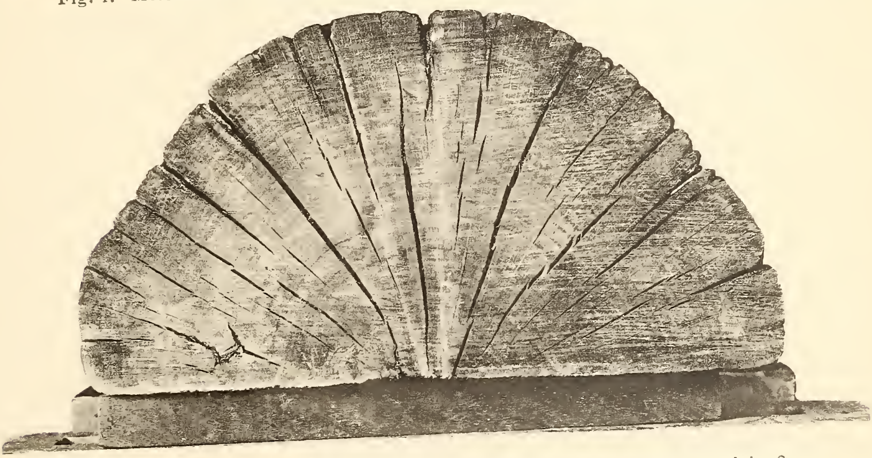


Fig. 2. Median section of beech tie (France), impregnated with tar oil; laid in track in 1870.

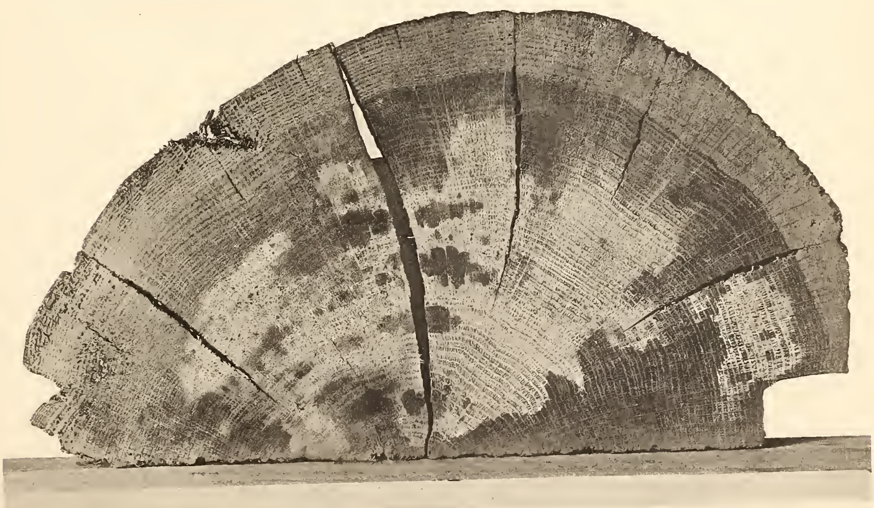


Fig. 3. End section of freshly impregnated oak tie (Belgium), using tar oil.

tions of the commission are tabulated, preceded by a brief statement by the author. The following passages are quoted from the English translation of this report, and will serve to show, better than any long discussion, the present situation of the timber-impregnation question in Europe. Under the heading of "Wood for all structural purposes" we read, page 8: "As far as the substances which are used by the different managements to prevent decay and to produce non-inflammability are concerned, we have to report that the majority of the managements do not pay much attention to this subject." Page 11: "The data we have received on the properties of pickled and unpickled wood are not very comparable, as the respective conditions are very different." Conclusions: "1. The chief defect of unpickled wood for structural purposes is that it is liable to rot. 2. Creosoting puts off such decay for a long time," etc.

Under the heading "Railway Sleepers" we read, page 20: "Unfortunately we are obliged to report that no special progress has been made in preservative processes, although any improvements in them would lead to considerable economy in the maintenance of railways. * * * The different managements have supplied us with much information as to the age of the wood, but without giving us any information on the influence which the age of the wood has on its life and on the efficacy of the pickling processes." Page 22: "The information we have received does not enable us to determine to what extent the life of sleepers is affected by the interval of time between the time the timber is felled and the time when it is cut up into sleepers."

These extracts might be carried on to great length, but they will suffice to show that some of the most vital points connected with timber impregnation are as yet unanswered. M. Herzenstein has put together an immense array of facts, but they are open to the objection that they are very incomplete because of the failure on the part of the railway companies to answer the questions put to them. The report ought to be carefully digested, for in its present condition one must hunt laboriously through long columns of figures, which is very unsatisfactory.

In the following the writer's observations will be grouped under the following headings:

Ties, poles, etc.
Ballast.
Tie plates.
Impregnation.
Life of ties.
Removal and disposal of ties.

TIES, POLES, ETC.

KINDS OF TIMBER.

The ties in use on European railroads consist mainly of Scotch pine (*Pinus sylvestris*), oak (*Quercus robur pedunculata*), and beech (*Fagus sylvatica*). In England the Australian woods karri (*Eucalyptus diversicolor*) and jarrah (*Eucalyptus marginata*) are being employed to some extent. Chilean quebracho has been tried in France. The ties are cut at different seasons of the year, generally in the fall or winter, and shipped, generally by water, to some receiving point, where they are inspected. The cost of ties varies considably, as may be observed from the appended table. A great deal of attention is devoted to the classification of ties. Exact specifications are drawn up in most countries, giving exact dimensions, terms of delivery, etc. Some of these are given in Appendix I. The terms of

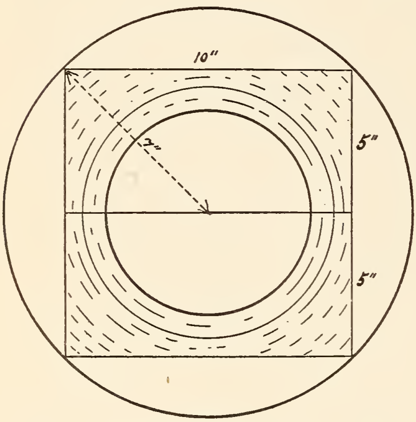


Fig. 13.—English system of cutting ties, tree 14 inches diameter (Baltic pine).

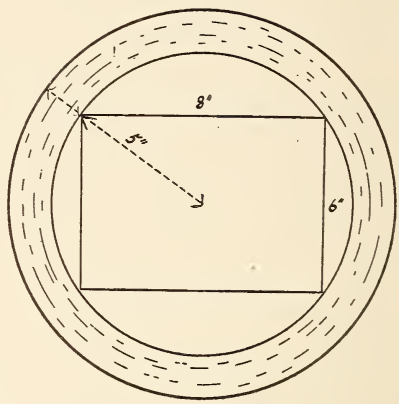


Fig. 14.—Extreme form of present American system of cutting ties; a "pole tie" of oak.

these specifications are rigidly adhered to. At every receiving point a corps of inspectors makes examination of the incoming ties, rejecting all those which do not come up to the established standard.

FORM.

On Plate XII are given the forms of cross sections as adopted on some lines. It will be noted that there is a good deal of diversity of form, brought about no doubt by strict adherence to long-established customs. Attention is called in particular to the form of the English tie and the half-round form commonly found in Belgium. The English ties are cut two from a log; the latter is sawn to form a square timber 10 by 10 inches. In this form it is delivered to the railroad, and is then sawn in two, making two ties, each 5 by 10 inches (see fig. 13). The Great Western Railway specifies particularly that the ties shall be delivered in the form of logs 10 by 10 inches. These ties consist of a large portion of sapwood, surrounding the heartwood on all sides but one. The ties after being creosoted are laid with the heartwood side down, as represented in the accompanying plate (Pl. X, fig. 1). The more resistant wood is thus brought into contact with whatever moisture there may be in the soil. This fact will be referred to at another place. The Belgian tie is of similar character, with this difference, that it is left half round. Its flat heartwood side is laid downward. Deep cuts are made into the rounded side to give a flat base for the rail. The specifications for all European ties include clauses excluding decayed or injured timber.

TIE SPECIFICATIONS.

The high price of timber has led to the adoption of specifications for ties on the European roads which allow of the greatest possible utilization of material from one tree. England and Belgium lead in

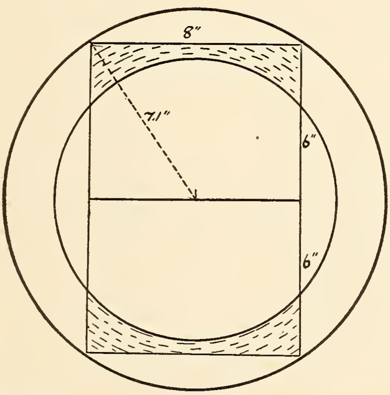


FIG. 15.—Proposed system of cutting ties (oak).

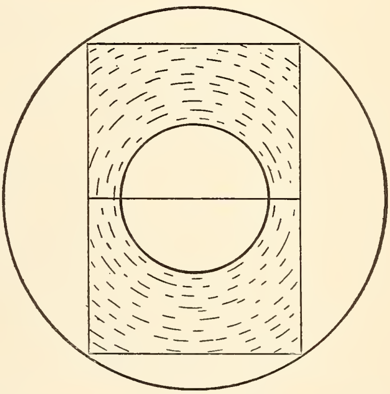


FIG. 16,—Proposed system of cutting ties (loblolly pine).

that respect, since they get two ties from a log from which, as a rule, but one would be obtained in this country. This is made possible only because they make use of all the sapwood, and make this last as long as the heartwood by impregnating it. Any consideration of their way of cutting ties must take this into account. One must remember, furthermore, that sawed timber is used in all cases.

Figure 13 shows a log of Baltic pine, and illustrates the manner in which the English lines cut two ties from a tree. Figure 14 shows an extreme case of the present method of cutting a tie from a small tree, i. e. a tree which would make but one heartwood tie. The dimensions given are taken for the sake of illustration, and need not be considered final.

As the more economic use of timber is one of the problems which will engage active attention in the future, the writer ventures to suggest the possibility of imitating the method of tie cutting as practiced in England, with some modifications, chiefly of size. This will refer only to treated timber. It may not be practicable to do this in all parts of the United States, but it is a point which is worthy of consideration and discussion.

Figures 15 and 16 show how two ties could be cut from a tree,

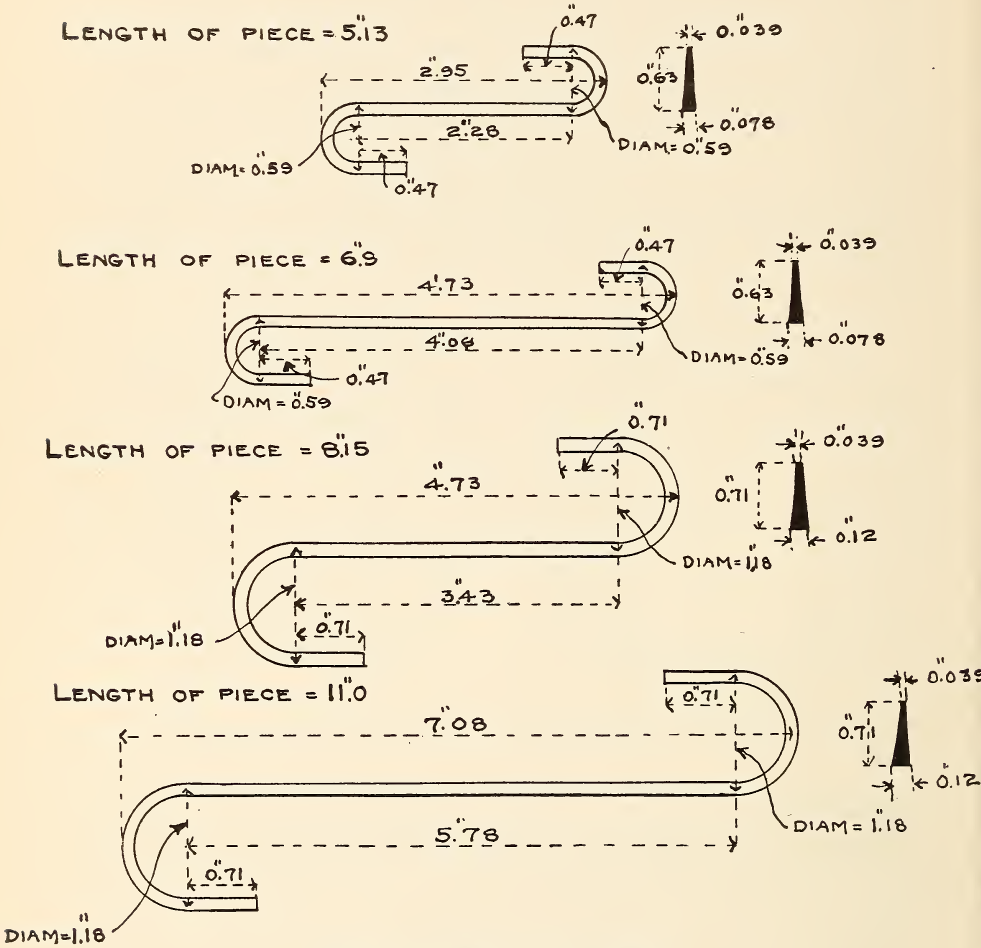


FIG. 17.—"S" used to prevent checking.

assuming that the present depth be sufficient. The new method would mean a wider tie, and one which would require more care in laying, as the heartwood side would have to be at the bottom. This would be no objection, for when ties are treated they become objects worthy of more care than is now given to untreated timbers. The writer believes that a section man could be taught to lay a tie properly, despite the objections made by some engineers and superintendents. Our workmen are surely as intelligent as those on the European roads, and if properly directed there is no reason why the same care in laying ties can not be obtained here as abroad.

Ties cut two from a log would be somewhat less expensive; they would all have approximately the same form, which would be of great value in impregnating. An experiment will be tried during the coming year with ties cut in this manner, to determine exactly what may be expected of such a system.

SPLITTING.

Various devices are employed to prevent wood from severe checking and cracking. Many roads employ S-shaped steel bands, which are driven into the ends of badly cracked ties at right angles to the crack, thus preventing any further splitting (fig. 17). On some of the French lines bolts are inserted through the end to hold badly split beech ties. Various forms of wooden pegs are also used on some roads.

STACKING.

In all countries the ties are stacked and dried before being treated. The time varies considerably in the different countries, but is never

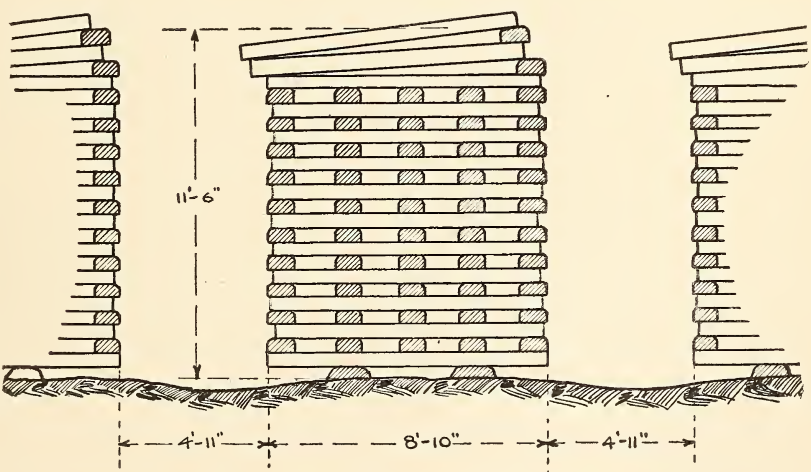


FIG. 18.—Pile of ties on French Eastern Railway.

less than four to six months. In some cases it is dependent upon the demand for ties. At the impregnating plant of the Great Western Railway in England the ties are allowed to season for six months before treatment with creosote. The Eastern Railway of France allows fifteen to twenty months for oak and six months for beech. The European engineers have found out by long experience that it is absolutely essential that the ties be thoroughly dried before submitting them to any one of the different treatments. A great deal of care is taken in piling the ties, so that their greatest amount of surface may be exposed to the sun. The Eastern Railway of France has probably brought the piling methods to the highest state of perfection. They build the piles, as shown in the annexed diagram (fig. 18).[a]

The slanting ties at the top are so arranged that the rain water runs off almost wholly. Before treatment (in all countries) the ties are prepared in various ways to give the proper slant to the rails. In some cases holes are bored for the screw spikes or treenails, and those which are to receive chairs are adzed. Wherever a water impregnation is used the treated ties are stacked for two months or more after treatment in order to have as much of the water as possible evaporate before laying the tie in the roadbed.

SUMMARY.

How far the rigid requirements of the European roads can be followed here is questionable. Tie inspection is now carried on in this country after a fashion. Some attention is paid to defects and to small ties. It is probably not desirable to make the specifications for ties as stringent as abroad, because ties are cut with us from trees of all sizes. The tie supply of most European roads is determined by the forestry regulations. In their forests trees of uniform size are cut, and it is therefore easy to obtain thousands of ties which conform accurately to a prescribed size. This would be almost impossible under our present conditions for the reason stated, and the advantage would hardly be great enough to warrant taking so much trouble. Defective ties can and ought to be inspected against rigidly, as such ties will create trouble when impregnated and afterwards.

The long seasoning before treatment, almost universally practiced abroad, is one of the greatest factors leading to successful impregnation with methods employing pressure. Its value can hardly be questioned. The seasoning after treatment is fully as important, and perhaps more so. This is a feature not sufficiently attended to in this country, and yet it is almost as vital as the impregnating itself. During this seasoning process the water or volatile substances in the wood are given an opportunity to leave the wood under the most favorable circumstances. When once placed in the soil in contact with moisture, the water in the wood has no opportunity of evaporating. In the case of a soluble salt, this leaches out with the greatest rapidity from wet wood, while dry wood is penetrated more slowly by water, and consequently lasts longer. The same is true of a process such as the Hasselmann treatment, where it appears to be necessary to dry the wood in order to render the union between the cellulose wall and the impregnated salt more certain.

The drying of ties before laying might be attended to with excellent results in this country, where no subsequent treatment is given to the

[a] Dufaux. Note sur la preparation des traverses, p. 11.

timber. A tie laid into the track while still full of water will decay very rapidly. The extra care used in piling ties so as to leave sufficient air space between ties would be amply repaid by the longer service which would be obtained from such seasoned ties.

The methods of preventing splitting by means of S has been referred to.

BALLAST.

The ballasting of most roads is attended to abroad with extreme care. On Plates XV-XVIII are shown sections of roadbeds in England, France, and Germany. It will be noted that in most cases the depth of ballast under the ties is considerable. The base line upon which the ballast rests is usually arranged so as to allow any water to run into a lateral ditch. The material of which the ballast is composed varies as much as in the United States, preference being given to broken stone or pebbles wherever possible. The ties are usually covered with the ballast. This would seem to increase the danger as far as decay is concerned, but with good drainage this is counterbalanced many times by the increased stability obtained for the whole roadbed.

TIE PLATES.

Tie plates are used universally. Where chairs are employed to hold the rails, the base of the chair acts as a tie plate. The writer was informed that on some of the English roads it was due largely to the increase in the base area of the chairs that the recent long increase in the lasting powers of Baltic pine ties was obtained. In Germany the tie plates are flat steel plates, considerably larger than the base of the rail. The most remarkable results of all those seen were obtained in France on the Eastern Railway. This company has for many years used tie plates of felt about one-fourth inch thick. Of late it has employed plates made of poplar wood one-eighth inch in thickness. These pieces are impregnated with creosote and laid in the adzed part of the tie. The wear which usually goes to disintegrate the wood of the tie is there taken up by the poplar, which is renewed at short intervals. The cost of these plates is given at $3 per thousand.

There can be no question that the increase of the bearing surface has added materially to the length of life of most European ties and that it would do so to a marked extent to our ties. It is hardly fair to apply European standards to the conditions obtaining in this country. The utility of the tie plate depends so much on the weight of the rolling stock and the speed of trains that a conclusion as to the value of any one form ought to be drawn solely from experience here. For soft woods a broader bearing surface than that of the rail will prevent the rapid cutting in of the fiber. It remains to be seen how far the cutting of the fiber by flanges or spines, intended to anchor the plate in the timber, counterbalances the saving of rail cutting.

FASTENING.

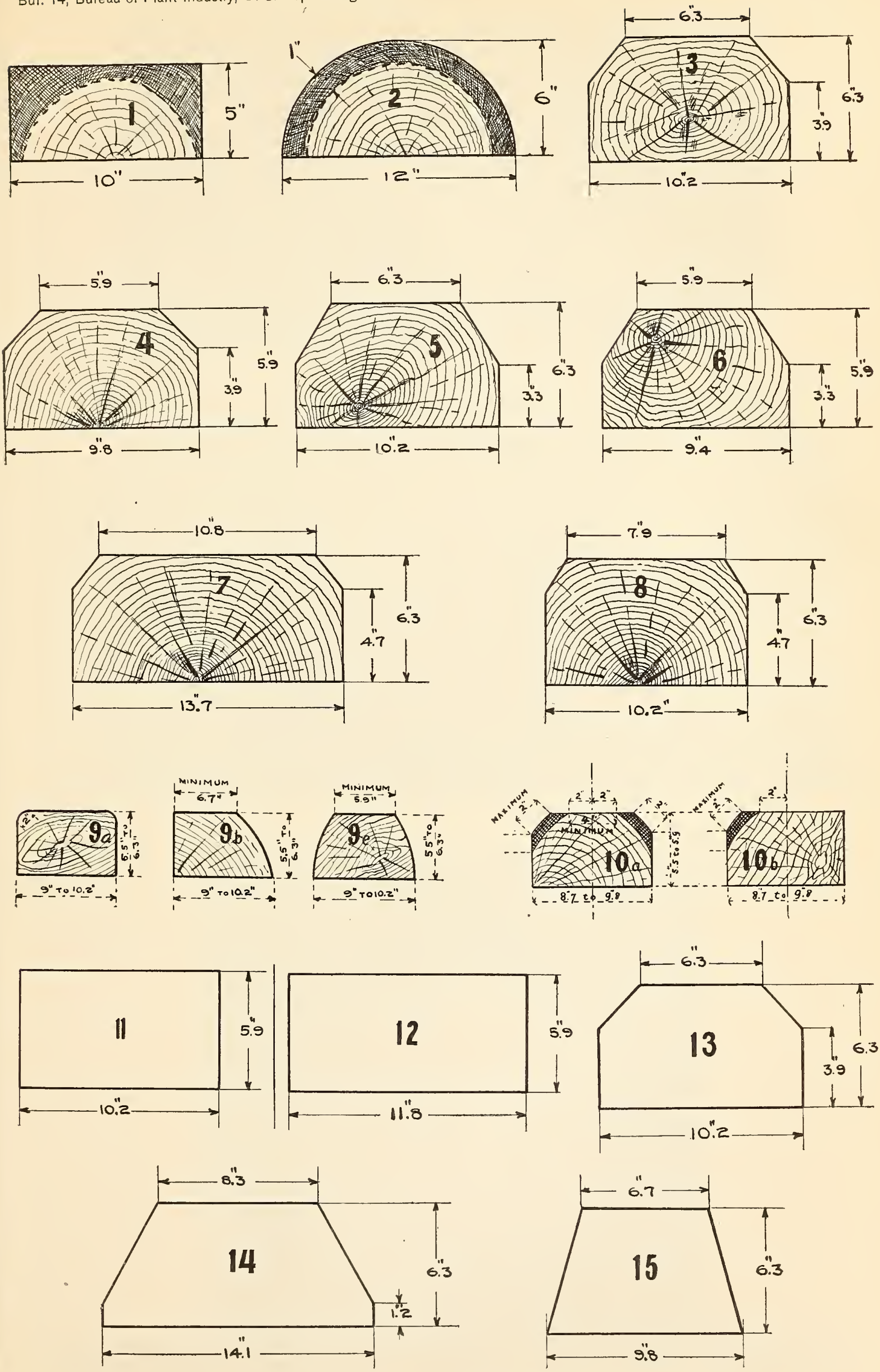
Attention is called to the superior mode of fastening the rail to the tie generally in use all over the better European lines. Spikes are found rarely, as it has been found that the tearing incident to driving spikes into wood and the subsequent "working" of spikes, rapidly renders ties unfit for use. Screw spikes and wooden treenails are commonly employed. Holes are bored in the ties at proper points, sometimes by machinery, in other cases by hand. The screw spikes or the treenails are then inserted and screwed or driven in. The screw spikes do not injure the fiber and hold the rail very firmly to the tie. Such a thing as working out is absolutely unknown. The managements without exception expressed themselves to the effect that the use of screw spikes had materially aided in prolonging the life of the timber. A recent invention is now being tried on several lines, which would permit the use of such ties where for any reason the wood around the screw spike has begun to rot so as to cause loosening of the screw spike. A hollow wooden cylinder, several times the diameter of a screw spike, called a "düvel" is screwed into the enlarged hole left by the loosened screw spike, and the latter is then screwed into the central hole of the düvel. The manufacturers claim that an additional life of four or more years is assured the tie by this method.

The chairs in use on some lines are fastened by means of treenails. These are made of various hard woods and have given universal satisfaction.

METHODS OF IMPREGNATION.

INTRODUCTION.

The methods of impregnation now in use in Europe are, with two exceptions, the same that have been in use for fifty years. The prices of timber, of labor, and of impregnating materials have changed somewhat, and there have been changes in detail, but on the whole the processes are the same. Wood impregnation is carried on by nearly all railroad, telegraph, and mine companies, because it is an absolute financial necessity. The price of timber is so high that its lasting powers under ordinary conditions are too short to assure its economic use. The processes now used differ in the character of the material used and in the cost of operation. The one used in England, Belgium, and France—the creosoting process—is the most costly and at the same time the most effective in preserving the wood. In Germany and Austria a process making use of zinc chloride and tar oil is now in use, which is cheaper than the English system, and in some other countries the still cheaper zinc chloride process is used. The reason why certain processes are used in the different countries is difficult to define. In England and France, where the cost of timber is very high, it pays to use the very best process; in Germany and Austria certain processes are now used because the various interests



FORMS OF TIES USED ON SOME EUROPEAN RAILWAYS.

[For explanation see list of illustrations.]

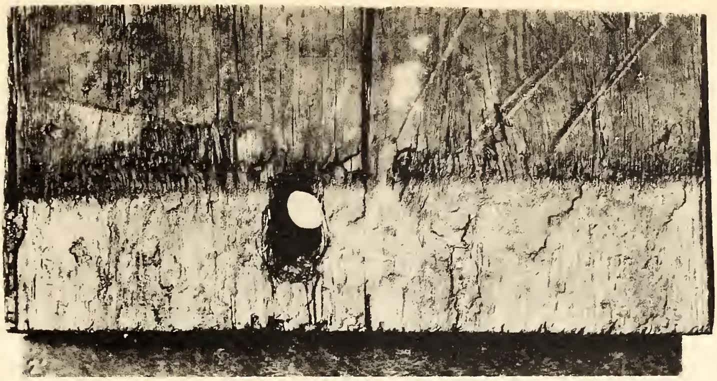


Fig. 1. Baltic pine tie, showing small wear of wood under chair, and of spike hole; 16 years service.

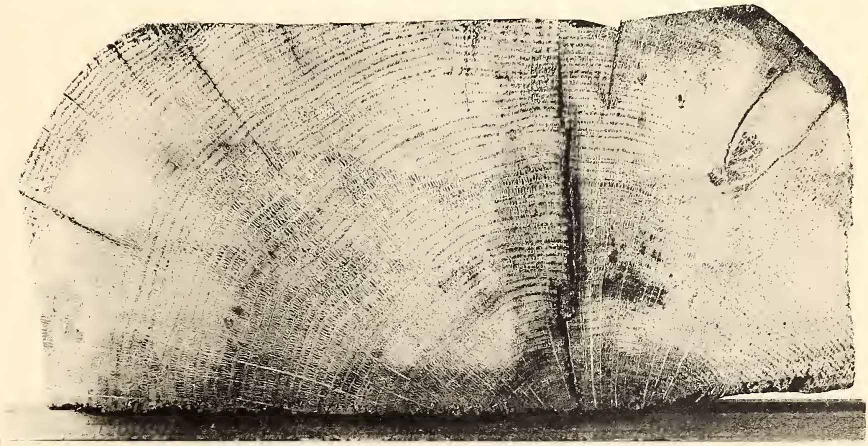


Fig. 2. Belgian oak tie; 18 years service.

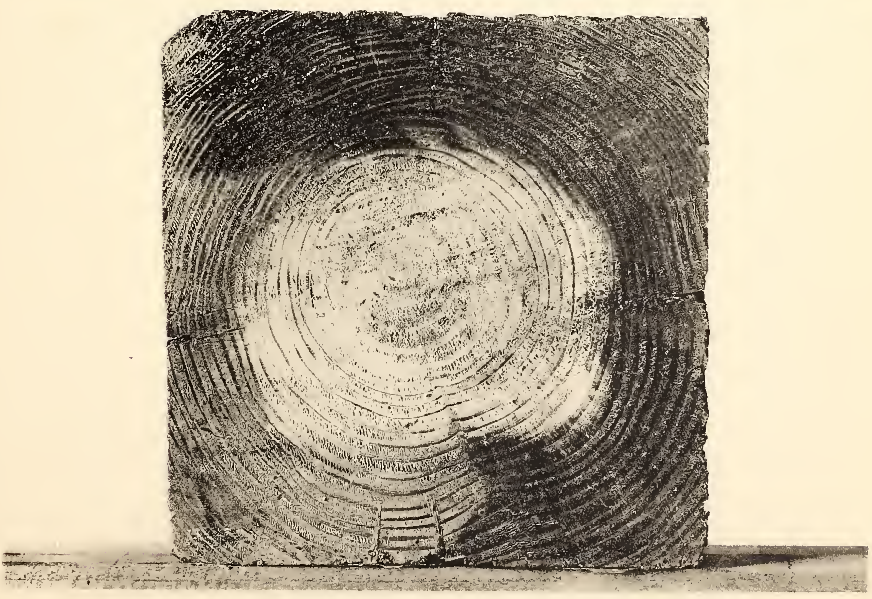


Fig. 3. Fence post of Baltic pine, 40 years old, impregnated with tar oil.

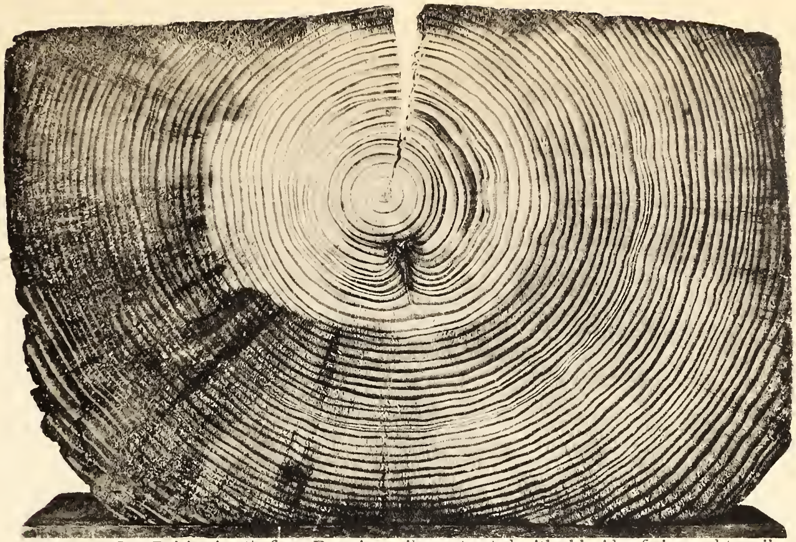


Fig. 1. New Baltic pine tie from Prussian railway, treated with chloride of zinc and tar oil.

Fig. 2. Baltic pine tie laid in Prussia (Marschbahn) in 1885, treated with chloride of zinc and tar oil.

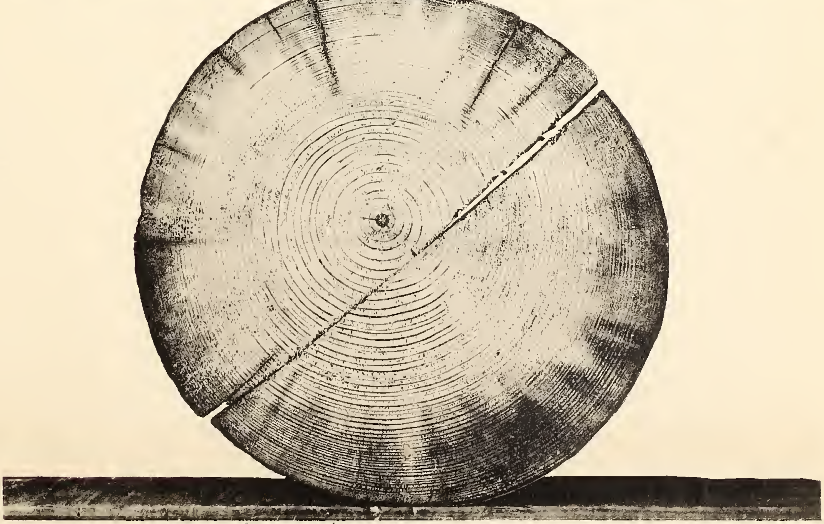
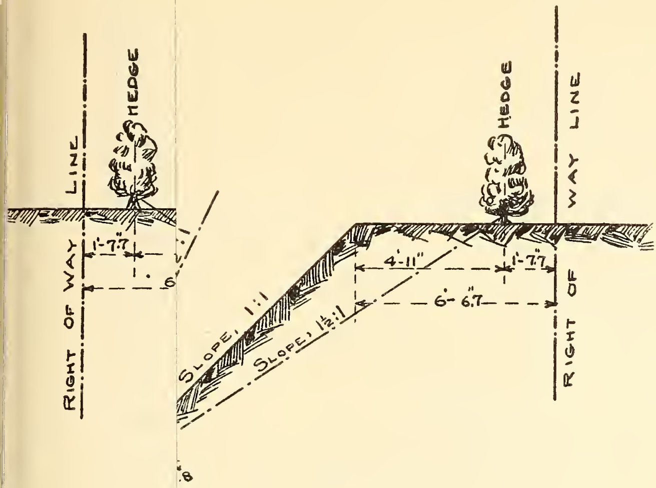
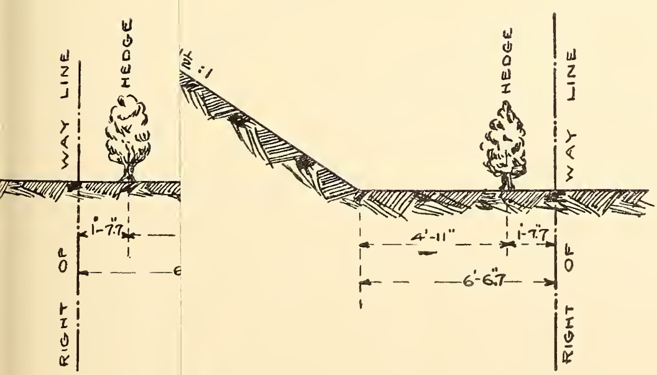


Fig. 3. Section of telegraph pole, Imperial German Postal service, treated with tar oil; in service since 1873.



NOTE: IN ALL CASES THE
BOTTOM OF THE DITCH IS 1'.8"



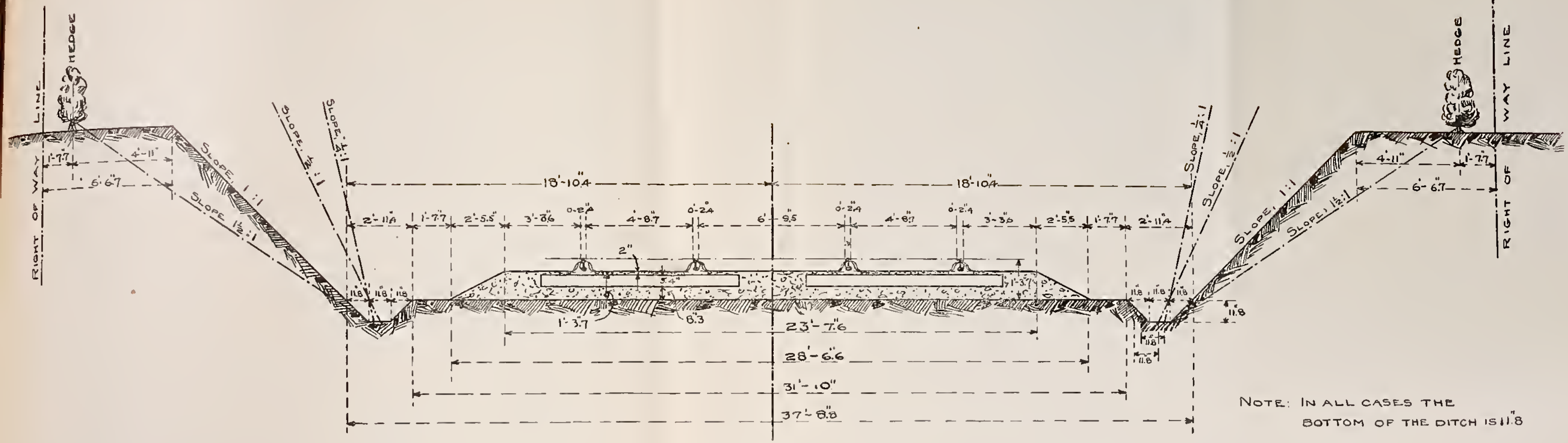


Fig. 1.—Section in a Cut.

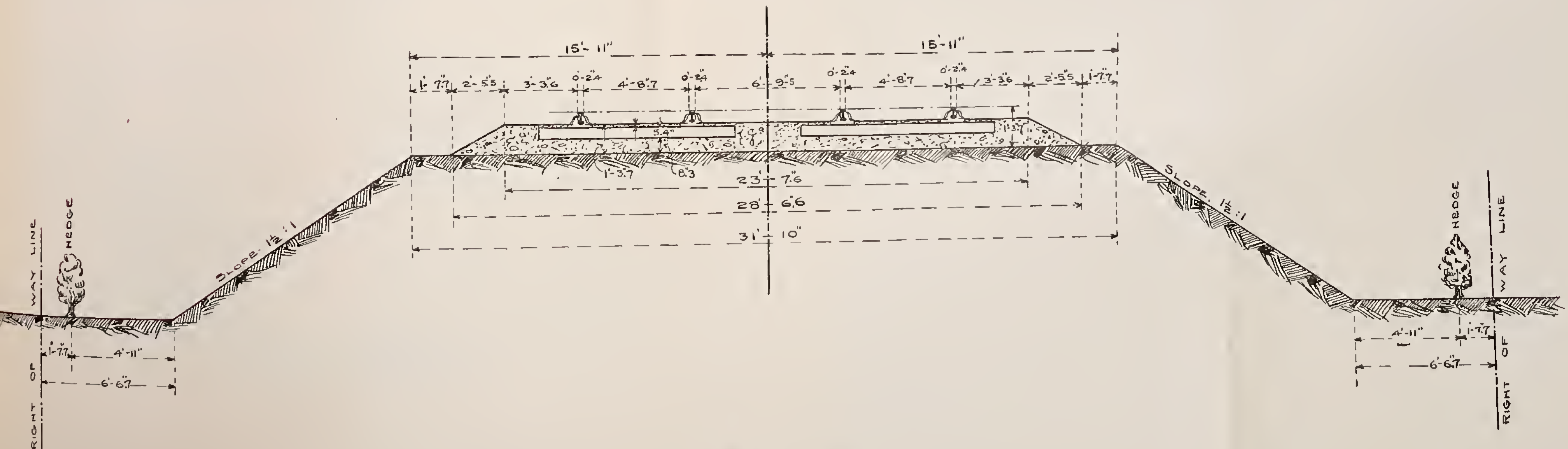


Fig. 2.—Section of an Embankment.

Cross Section of Roadbed, Western Railway of France.

concerned claim that their past experience with one or more processes has led them to prefer one or the other. Records have been kept on most railroads with great fidelity, i. e., records which deal with the number of renewed and replaced treated ties. Some of these records deal with ties treated with different processes at almost the same periods of time in one and the same country. These are of particular value as indicating the comparative value of the treatments used. Unfortunately the trial of processes in localities where the factors of soil, climate, rainfall are approximately the same are very few in number. In Germany the writer learned of two trial stretches of track where experiments are being carried on now in a way similar to that described for the one started in Texas this summer. One of these is on the Prussian railways near Berlin, the other between Munich and Augsburg in Bavaria. The results obtained on the Prussian line were not accessible. The track near Munich was laid with a small number of ties in 1888. It is as yet too soon to expect final results, but the results obtained up to date are of sufficient value to warrant giving them. For convenience they are given in two tables, showing the detailed removal of the ties.

Table II gives the results with ties which were seasoned for some months after treatment, while the results shown in Table III were obtained with ties laid soon after treatment. Table IV gives the percentage removal, calculated from Tables II and III.

TABLE II.

[All ties laid in 1889. Ties seasoned before laying. Number of ties laid in all cases, 121.]

Kind of timber.	Treatment.	Ties removed, by years.							Total.
		1894.	1895.	1896.	1897.	1898.	1899.	1900.	
Oak	Untreated					3	3		6
Pine	do	14	14	10	2	13	15	31	99
	Treated with zinc chloride					1	4	6	11
Spruce	Untreated [a]	76	37	7	1				121
						23	30	23	76
	Treated with zinc chloride			3	4	6	26	23	62
	Mercuric chloride		12	42	21	19	9	2	105
Beech	Untreated [a]	103	6	2	10				121
					19	47	45	12	121
								7	7
	Treated with zinc chloride			2	2	4	7	7	22
	Red heart timber			3		11	6	16	36

[a] Double sets of figures show double renewal.

TABLE III.

[All ties laid in May, 1888. Ties not seasoned before laying. Number of ties laid in all cases, 121.]

Kind of timber.	Treatment.	Ties removed, by years.								Total.
		1893.	1894.	1895.	1896.	1897.	1898.	1899.	1900.	
Oak	Untreated	......	......	......	4	......	5	2	......	11
	Treated with zinc chloride	......	......	......	......	......	......	......	3	3
Pine	Untreated	......	59	6	9	4	11	11	21	121
	Treated with zinc chloride[a]	......	......	......	......	......	......	......	12	12
		......	......	......	......	1	10	3	10	24
	Mercuric chloride	......	......	......	1	......	3	3	3	11
	Copper sulphate	......	......	......	......	......	4	......	16	20
Spruce	Untreated[a]	84	36	......	......	1	......	......	......	121
		......	......	......	......	39	58	13	19	121
		......	......	......	......	......	......	......	4	4
	Treated with zinc chloride	......	......	......	3	13	30	15	17	78
	Mercuric chloride	......	......	15	45	24	14	2	10	110
Beech	Untreated[a]	112	8	......	1	......	......	......	......	121
		......	......	......	98	14	5	3	1	121
	Treated with zinc chloride, no red heart.[a]	......	......	......	......	......	......	72	34	96
		......	......	1	......	11	11	14	18	53
	Zinc chloride, red heart	......	......	......	1	......	14	17	16	48

[a] Double sets of figures show double renewals.

TABLE IV.—*Summary showing per cent of ties removed.*

Kind of timber.	Untreated.		Zinc chloride.		Mercuric chloride.		Copper sulphate.	
	Not seasoned.	Seasoned.	Not seasoned.	Seasoned.	Not seasoned.	Seasoned.	Not seasoned.	Seasoned.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Oak	9.0	4.9	2.4	......	......	......	......	......
Pine	109.9	81.8	19.8	9.0	16.5	......	9.0	......
Spruce	203.3	162.8	64.4	51.2	......	......	90.9	6.7
Beech	279.32	205.7	43.8	18.1	......	......	......	......
Beech, red heart	......	......	39.6	29.7	......	......	......	......

These tables require little comment, as the figures tell their own story. By consulting Table IV it is possible to deduce the following:

EFFECT OF SEASONING AFTER TREATMENT.

That seasoning after treatment increases the life of the treated as well as the untreated timber is very evident even with this small number of ties. Note that in twelve years twice as many untreated oak ties came out as did of the dried ones. The same difference is noticeable with the treated timbers, particularly with pine, spruce, and beech, because more of these came out as a whole than of the oak. Note beech treated with zinc chloride, dried, 18.1 per cent, not dried, 43.8 per cent; pine treated with zinc chloride, dried, 9 per cent, not dried, 19.8 per cent.

RESULTS OF TREATMENT.

The experiment has gone far enough to show that treatment increases the length of life of the timber. Taking the timber which decayed most rapidly—the beech—it appears that treatment with zinc chloride increased the length of life more than three times. Thus, all of the 121 untreated ties had come out at the end of the seventh year (the greater number at the end of the fifth). These were all replaced, and again they all came out in seven years. This is an extremely valuable showing, as it demonstrates conclusively that the test made in this region is a fair one, for when the results are so exactly alike in two successive periods of seven years it is probable that the remainder will prove equally trustworthy. Turning now to the treated ties, we find that after eleven years 82 per cent of those treated with zinc chloride are still in service. With the spruce the results are not as favorable, for here only 49 per cent were in service after eleven years. With oak the effectiveness of treatment had not shown itself sufficiently to allow of any conclusion.

As for the different treatments employed, the results are somewhat at variance for the different timbers. With the pine the copper sulphate gave better results than the zinc chloride (copper sulphate, 16.5 per cent removal; zinc chloride, 19.8 per cent removal. For ties, not dried, and copper sulphate, no removals; zinc chloride, 9 per cent removals for seasoned ties). No tests were made with copper sulphate with the other timbers. Mercuric chloride (corrosive sublimate) gave better results than zinc chloride with pine, and poorer results than zinc chloride with spruce. The differences are very small, however.

The most important lesson to be learned from this experiment is the fact that here the principle of comparative tests under similar circumstances was carried out under rigid scientific inspection. Similar timbers were treated by the same person and with the view of answering a definite series of questions. The only objection that can be made is that the number of ties used was too small.

If all the ties treated in the United States were incorporated in an experiment of this kind, conducted not only in one place but in all sections of the country, results would be forthcoming whose value can fairly be appreciated by this test of the Bavarian Government. The writer was impressed with the business-like method with which those in charge of railway affairs in that country were attempting to answer the question of timber treatment.

Some interesting comparative results were obtained by several Austrian railways. These roads, several of them being private corporations, had to deal with the impregnating question with the idea of finding as cheap a process as possible. They impregnated various stretches with different materials and kept records for a number of years.

A graphic representation of the length of life of ties treated by various processes on the Imperial Railway of Austria is shown in figure 19 (published in 1898). The vertical lines represent years of service, the horizontal lines the renewal in per cents, each line representing 5 per cent. The diagram is very instructive, as it demonstrates several points. In the first place, it shows that the average life of unimpregnated pine ties, on the particular line shown, is about six years, while the same ties when impregnated with zinc chloride lasted on an average twenty years, and probably more, as there were still 18 per cent

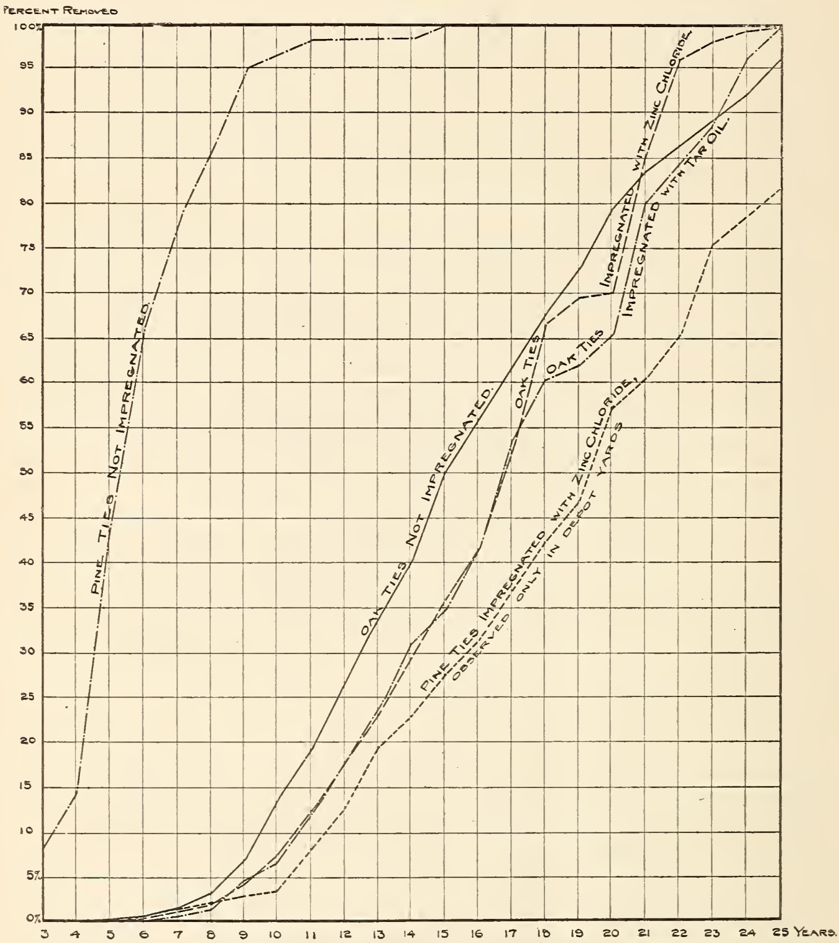
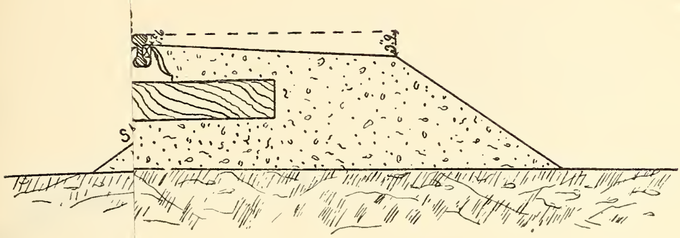


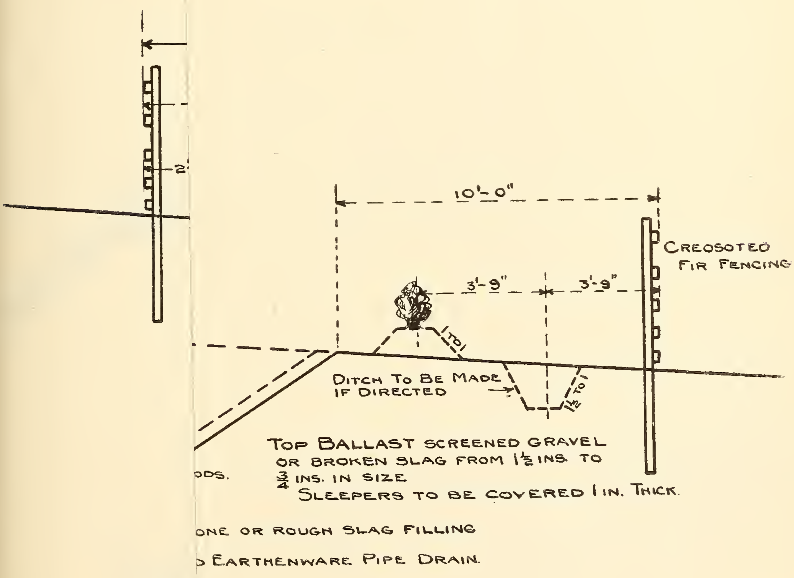
FIG. 19.—Diagram showing length of life of ties on the K. Ferd. North. Railway, Austria.

in service after twenty-five years. It is true that these ties were in station yards, but that detracts little from the general results, so far as the matter of decay is concerned.

Turning to the oak ties, we note a rather surprising state of affairs. It will be seen that the unimpregnated oak ties lasted on an average as long as those impregnated with zinc chloride or tar oil, while those impregnated with tar oil came out before those treated with zinc

PLATE XVI.




10'-0"
3'-9"
3'-9"
Creosoted
Fir Fencing
1 to 1
Ditch To Be Made
If Directed
1½ to 1
Top Ballast screened gravel
or broken slag from 1½ ins. to
¾ ins. in size
Sleepers to be covered 1 in. Thick.
ods.
one or rough slag filling
Earthenware Pipe Drain.

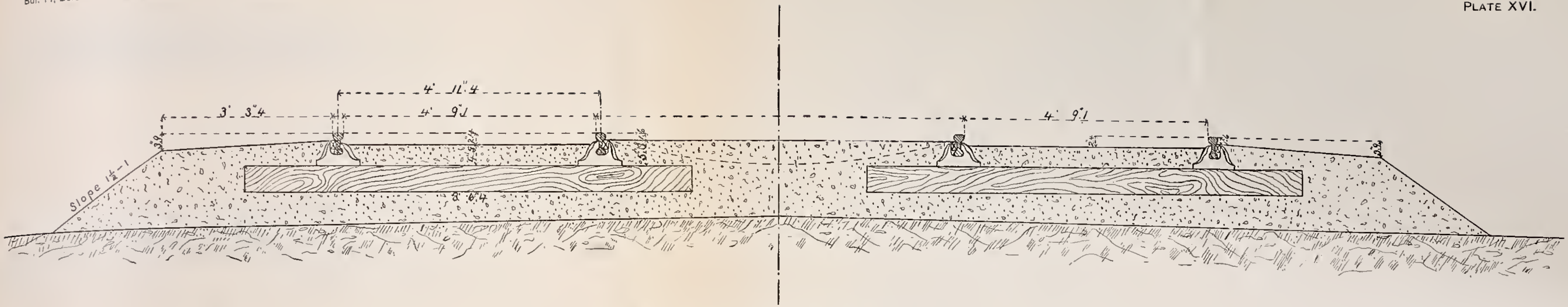


FIG. 1.—SECTION OF ROADBED, ORLEANS RAILWAY OF FRANCE.

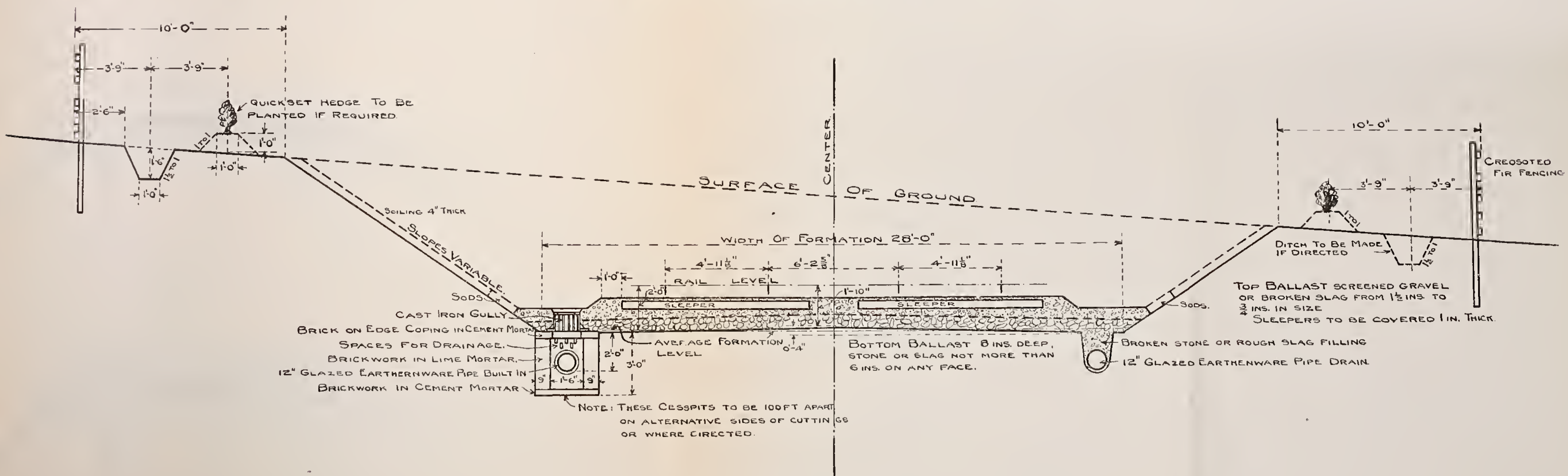


FIG. 2.—SYSTEM OF BALLASTING, GREAT NORTHERN RAILWAY. SECTION OF CUTTING ON STRAIGHT.

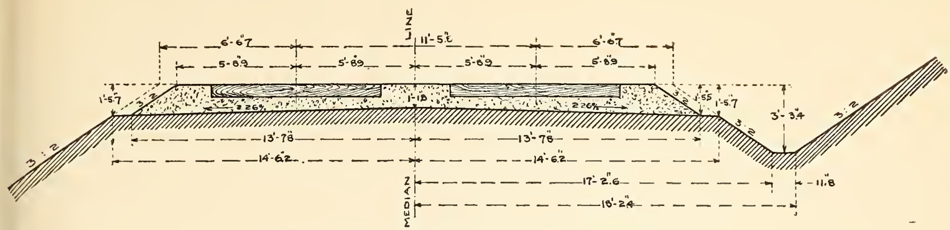


Fig. 1.—Section for Double Track, with Sand Ballast.

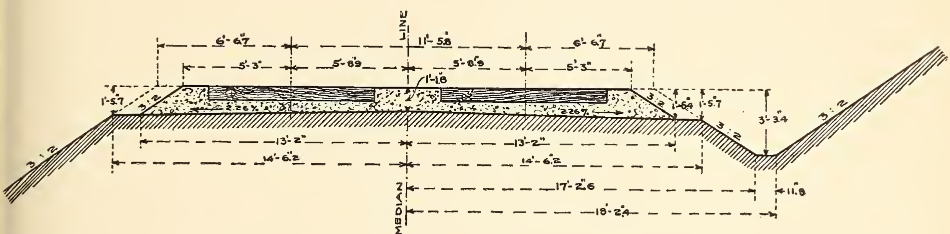


Fig. 2.—Section for Double Track, with Gravel or Rock Ballast.

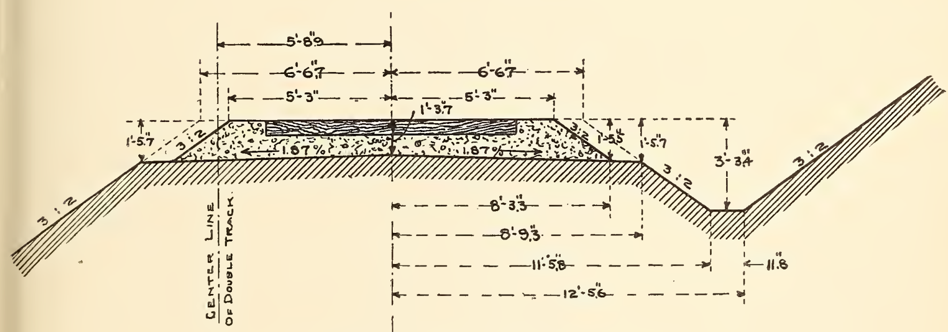


Fig. 3.—Section for Single Track, with Sand Ballast.

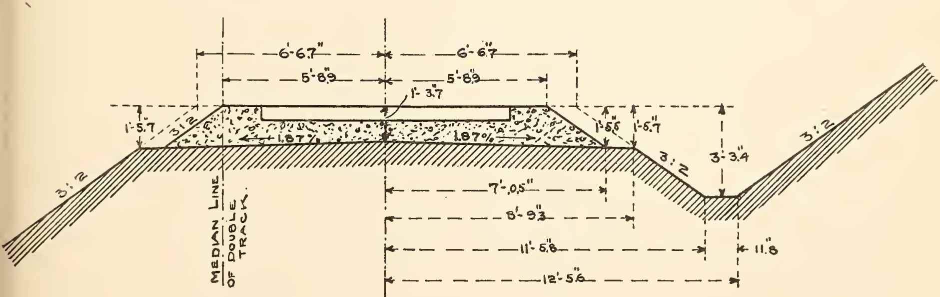
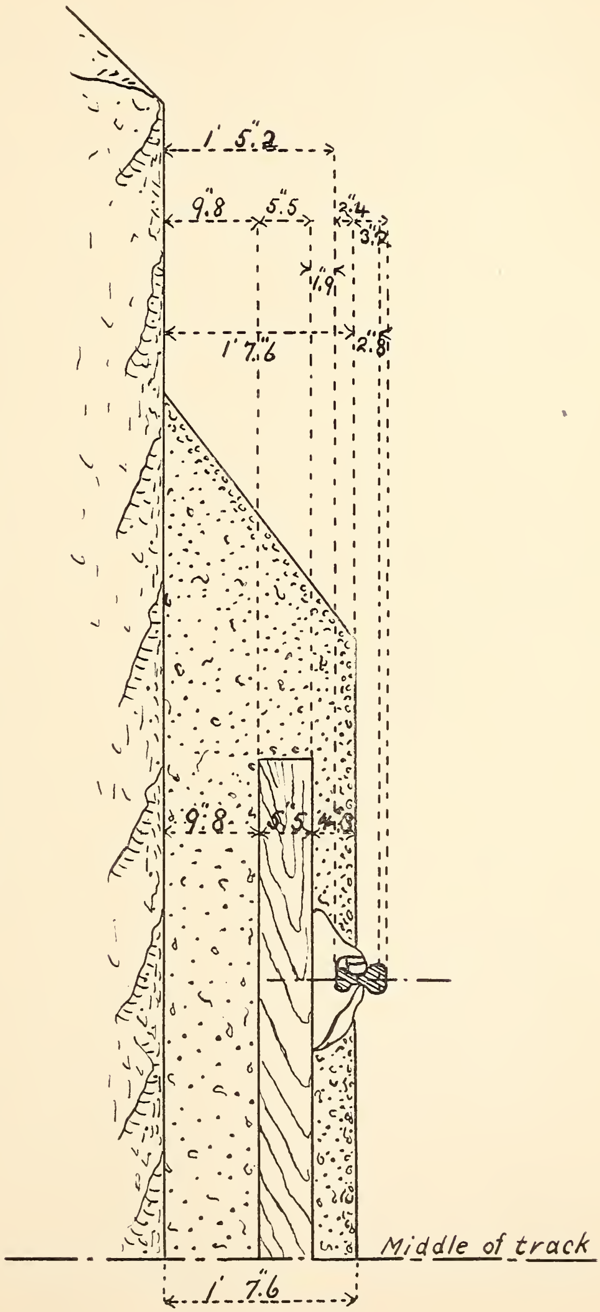


Fig. 4.—Section for Single Track, with Rock Ballast.

SECTIONS FOR TRACK, BAVARIAN STATE RAILWAYS.



FRANCE WESTERN RAILWAY. SECTION OF ROADBED.

chloride. In view of the fact that the experience of all other roads has shown the unquestioned superiority of the tar-oil impregnation, one can draw but one conclusion from this diagram, and that is that the work originally done with zinc chloride as well as the tar oil was probably very poorly done. It is very much to be regretted that the exact prices of treatment and the amount of material used could not be obtained.

One could hardly find a more striking instance of the fact that impregnation is worth nothing at all if it is not well done.

Turning now to another series of data, first published in 1885, we find additional facts which are given here, as they show distinctly the relative results on some Austrian roads. The vertical lines show the number of years which the particular timbers have been in use, while the horizontal lines indicate the percentage removal. Beginning with the oak chart, we see that unimpregnated oak ties lasted,

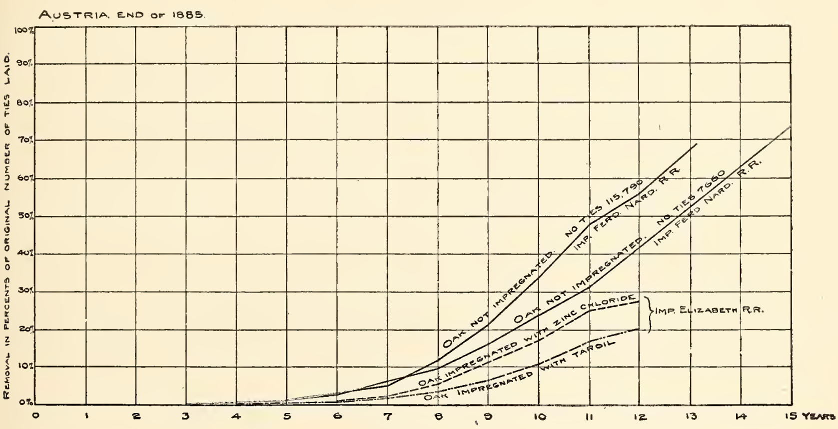


FIG. 20.—Diagram showing removal of impregnated and nonimpregnated oak ties.

on an average, eleven years, while those treated with zinc chloride were for the most part still in position after twelve years, and of those treated with tar oil still more. The long life of untreated timber is striking and requires some explanation, particularly as we are liable to give the name of oak to any oak. The European oak is a kind of timber which belongs to the white-oak class. It is very much superior to our white oak, however, and when properly seasoned (as is the case in most countries) it lasts about twelve to fourteen years. The Austrian Southern Railway get fifteen to sixteen years' life out of them, and they claim that these ties came out because of wear rather than decay. It is important to note that on the diagram shown there are two lines giving duration of unimpregnated ties, and that these lines show very different lasting powers. In one case 115,790 ties are accounted for; in the other, 7,660. The two series probably came from different sections of country, and seem to emphasize the fact that only with large numbers of ties and under various conditions, kept under strict observation, can reliable data be obtained.

The zinc chloride ties and the tar-oil ties show duration until the twelfth year. After that no record was obtainable. To judge from the trend of the lines it seems probable that they would have lasted for many years.

CONCLUSIONS.

From this series of ties one may conclude that in Austria oak ties last twelve to fourteen years, that when treated with zinc chloride

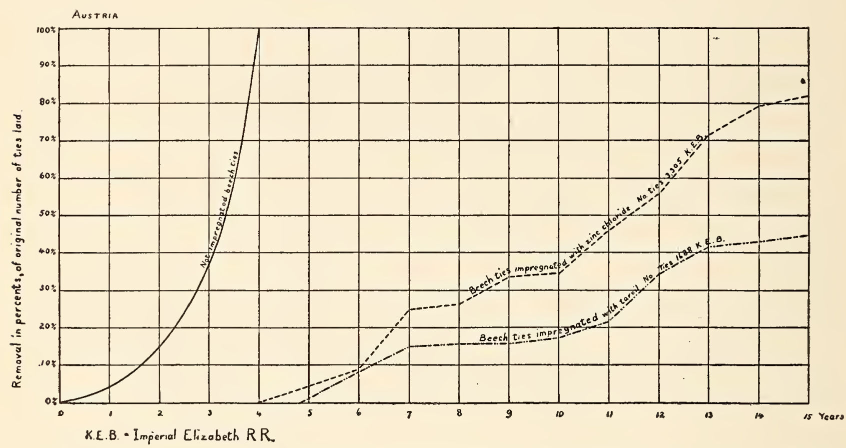


FIG. 21.—Diagram showing removal of impregnated and nonimpregnated beech ties (trial track).

they give a much longer service, and still more when treated with tar oil.

Turning now to beech ties, figure 21 shows the result of an exten-

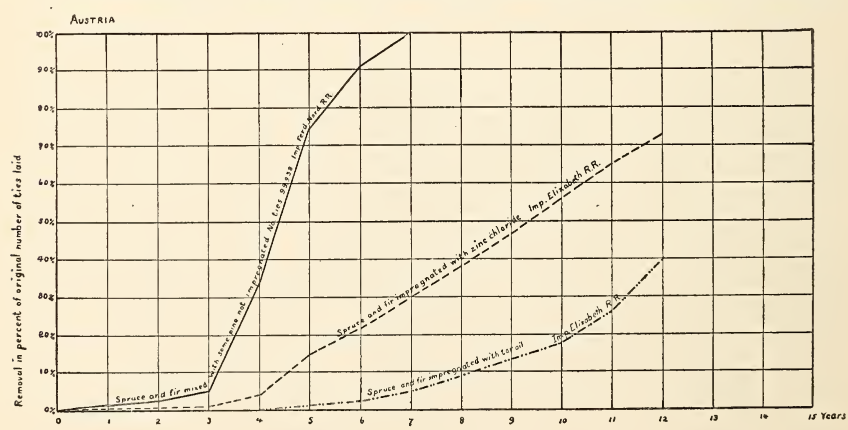


FIG. 22.—Diagram showing removal of impregnated and nonimpregnated spruce and fir ties.

sive test on the Imperial Elizabeth Railroad of Austria. It is a striking picture of the comparative results and needs little comment. The unimpregnated timber was all gone after four years. The ties treated with zinc chloride lasted on an average eleven to twelve years, and those impregnated with tar oil over fifteen years. It shows that zinc chloride more than doubled the length of life of this timber, which rots more rapidly than almost any other. The large number of ties used is also a favorable point. The zinc chloride compares favorably with the tar oil. No record of how the treatment was made was obtainable.

Equally striking is the table showing the results with spruce and fir ties.

The average life of these ties may be given as: Unimpregnated, four to five years; impregnated with zinc chloride, nine to ten years; impregnated with tar oil, twelve years or more.

Here again the zinc chloride doubled the length of life.

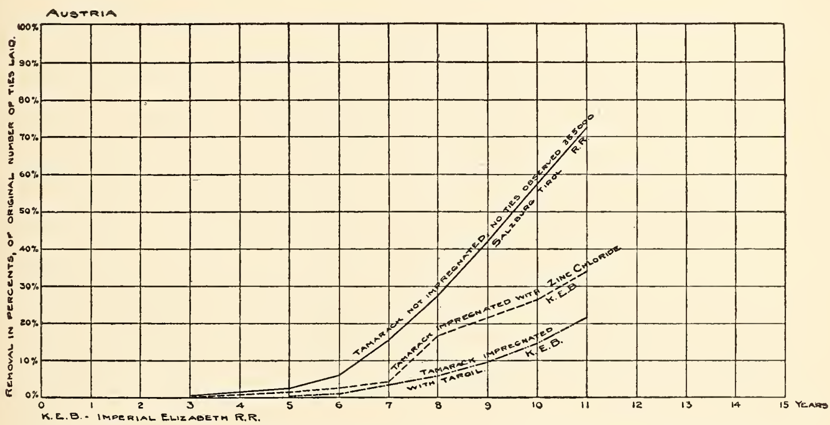


FIG. 23.—Diagram showing removal of impregnated and nonimpregnated tamarack ties.

Figure 23 gives the result with tamarack ties on the Imperial Elizabeth Railway and the Salzburg Tirol Railroad.

The result may be given as follows: Unimpregnated, nine to ten years; impregnated with zinc chloride, probably thirteen years; impregnated with tar oil, over fifteen years.

This diagram is not so satisfactory as the rest, because the curves do not extend out far enough. One can, therefore, only conjecture what would have been the results by following out the curves as given. Attention must be called to the fact that the European tamarack is a very resinous wood which lasts almost as long as oak. It is entirely different from our tamarack.

Pine ties are among those which decay most rapidly. In England the Baltic pine untreated lasts about eight years, while the same timber lasts only four years in Russia. On figure 24 it will be noted that the first curve, obtained from data involving 55,270 ties on the Imperial Northern Railway of Austria, shows an average life of untreated pine (Scotch pine[a]—*Pinus sylvestris*) of five to six years. The second curve shows a lasting of about eight years, data coming from six German lines involving 880,000 ties. The curves 3 and 4 show remarkable lengthening of life by zinc chloride treatment, also by tar-oil treatment. The curves are not continued out far enough, but they show a probable average of life of over seventeen years for the zinc chloride treatment and considerably more for the tar-oil.

A comparison of the various tables permits of some conclusions as to the relative value of the different kinds of treatment according to Austrian experience, and also of the relative effects of the treatment on different timbers. In the first place the general results show that treatment of timber with zinc chloride increases the length of life of treated timber very materially and treatment with tar oil does so still

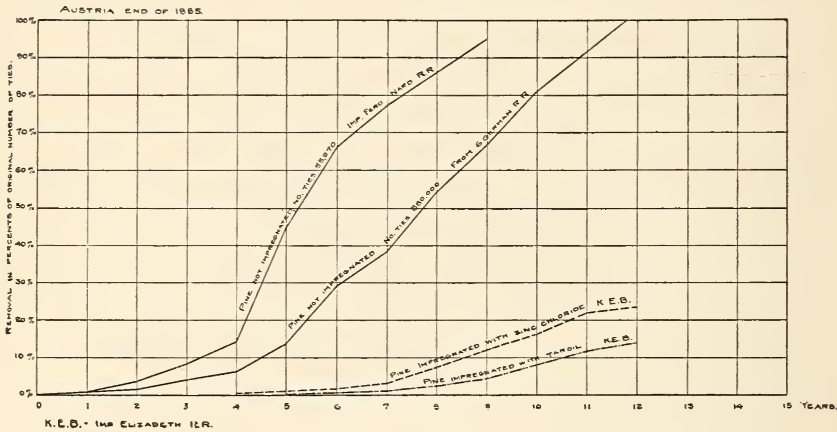


FIG. 24.—Diagram showing removal of impregnated and nonimpregnated pine ties.

more. The difference in effectiveness varies very materially with the kind of timber used. Beginning with oak ties treated with zinc chloride it appears that the average length of life of untreated ties is eleven to twelve years, of treated ties twelve to thirteen years. That is not a very great lengthening of life. One must not forget, however, that this oak, as has been pointed out, is an unusually resistant timber, and when reading these figures the American reader must not compare it with our oaks. The lengthening of life of tamarack ties (fig. 23) is much like that of the oak. It is a resistant timber naturally. When we come to the less resistant timbers, such as beech, pine, and spruce, the result of zinc chloride impregnation is surely very striking, particularly with the beech. With all of these timbers the length of life was more than doubled.

The results obtained with the tar oil considerably exceed those

[a] Scotch pine is called "Baltic" pine in most European contracts.

shown with zinc chloride. A glance at the tables will suffice to show this without any further comment.

We come now to a brief consideration of the various methods themselves.

CREOSOTING.

There is probably no reason for discussing the value of the creosoting process in this report, for it is believed that there is no longer any question at this time as to its positive value, provided that it is well done, and under conditions which permit its economical use.

Creosoting is used on all English and on most French lines. It is also used in Belgium. So much has been written on the subject of creosoting timber that only a few points will be emphasized at this time, especially as the object of this investigation was to see results, rather than methods. A good deal of time was spent in the examination of creosoted Scotch pine in England. The Scotch pine is a kind of timber which corresponds closely to some of our Southern pines. It is a soft wood which would last but few years in an untreated condition. When treated according to the best English methods, ties made of this timber have lasted twenty-five years or more. A careful inspection was made of a stretch of track on the Great Western Railway where relaying was in progress. The custom of relaying entire stretches of track in vogue in England makes it possible to examine side by side many hundred ties of the same age. On Plate XIII, figure 1, is shown the section of a tie which had been in the track sixteen years. It is a good example of thousands of similar ties which were removed from a main line to be put into a secondary line. Especial attention is called to the small amount of wear of the hole which held the treenail and of the tie itself. This is due in no small part to the use of the chair, which distributes the load over a large surface. The use of a chair with a wider base has resulted in extending the life of ties on some roads for five to ten years.

The Bethell process of impregnation is used by most English lines. The injection results in a complete impregnation of the sapwood (Pl. X, fig. 1), with a very small penetration of the heartwood. This total impregnation of that part of the wood from which decay usually starts retards the destruction of this timber for many years. Whenever decay does start, it begins on the lower side (Pl. X, fig. 3) and progresses very slowly upward. It is rather remarkable that the heartwood remains sound for so long a time with so very small a penetration of the creosote on the lower side of the tie. It serves to emphasize the fact that the sapwood probably is the base from which the decay starts in most cases. A tie of the kind shown on Plate X, figure 3, will still be of service for many years.

The quality of creosote used is carefully controlled. Specifications have been printed by Chanute.[a] The cost of the creosoting process varies with the amount of creosote injected. The following prices from the balance sheet of one road for May, 1901, may be taken as a fair average at the present time:

	English money.		United States equivalent.
	s.	*d.*	
Clear sleeper	3	10.00	$0.950
Treatment:			
Creosote	0	6.74	.134
Coal and stores	0	4.18	.083
Wages	0	3.98	.079
	1	2.90	.296
Total cost of impregnated sleeper	5	0.90	1.246

In Belgium oak ties are treated much as in England. Ties were examined which had been in the track for fifteen years. They were sound and showed no changes. The sapwood, which is very narrow, is the only part which can be injected, yet the quantity of creosote which it absorbs is ample to protect the timber for long periods of time. The following is the average cost of the operation:

	French money.	United States equivalent.
	Francs.	
Tie (including adzing and boring)	6.000	$1.20
Creosote and labor (8 liters=18 pounds of creosote per tie)	.487	.10
Total	6.487	1.30

Note that the French Eastern Railroad put in 60 pounds.

The Belgian State Railway uses two kinds of creosote, boiling at 200° C. and 250° C., respectively.

In France the Eastern Railway has obtained the best results of any roads in Europe. This is due (1) to the unlimited amount of creosote of a high grade which they inject; (2) to their use of beech timber for ties. This is capable of absorbing the creosote so as to become almost completely penetrated. M. Dufaux, in an elaborate treatise on the process as practiced by the Eastern Railway, describes at length the methods in use by that company, and anyone contemplating the use of creosote is referred to this report. Through the kindness of M. Dufaux and M. Müntz the writer was enabled to examine a long stretch of track in which ties treated in the years

[a] Chanute. Octave. The Preservation of Railway Ties in Europe (Am. Soc. C. E., vol. 45, p. 498, 1901).

1869–1873 were in position. Sections of these ties are shown on Plate XI. Their state of preservation was certainly remarkable. As a result of their experience with beech timber French engineers claim that it pays to inject as much creosote as the tie will hold. The extra pound or two will be amply compensated for by the greatly extended life of the timber. Oak ties lasted about fifteen years, and had to be removed because they were worn out; beech ties, as indicated, lasted thirty years.

The cost of the operation is given as 1 franc (20 cents) for oak ties and 2.25 francs (45 cents) for beech ties, exclusive of transportation or boring.

SUMMARY.

The use of creosote for preserving timber has been shown by the experience of the English and French lines to be beyond question a method which protects those parts injected with it absolutely. Such timbers as can be wholly impregnated with creosote will never rot; they may wear out because of mechanical abrasion.

ZINC CHLORIDE.

The zinc chloride treatment, once so generally in use, is gradually being abandoned, because tar oil is so much more effective. On a large scale it is now used only on some of the Austrian roads and on a few small German lines. The general results obtained on several Austrian roads and in Bavaria were discussed above. The Austrian Northern Ferdinand Railway still employs this process, because it has been doing so for many years, and as the road is soon to be turned over to the Government it regards the results which are being achieved to be sufficient for their present purpose. On the Austrian Southern Railway beech, oak, pine, and larch ties are in use, of which the first three have been impregnated with zinc chloride for four years.

This is too short a time to give results. The objections made to the zinc chloride are that it leaches out rapidly, and that it causes the spikes to wear out more rapidly. Attention is here called to the so-called decay of many ties impregnated with zinc chloride, especially near the spikes. The wood turns bluish in color, and gradually becomes brittle and pulverizes easily, so that the spikes no longer hold. This change is not due to decay, but to the acid formed in the wood. This attacks not only the wood fiber, but also the spikes. These changes in the chloride of zinc were first studied by Grittner, in Austria, and are referred to by Schneidt. They require further exhaustive study in this country, where this action of the zinc chloride is as yet little understood. Oak ties are in use on some parts of the southern Austrian system, but they are not impregnated, for the reason that they generally wear out before rotting.

Zinc chloride was formerly very widely used in Russia. On the Warsaw-Vienna line oak ties are used exclusively at the present time.

These are not impregnated. They cost from 2 to 2.15 rubles ($1.08 to $1.16) and the treatment with zinc chloride costs 30 kopecks (16 cents), which is considered very high, especially as it was found that under the conditions obtaining in Poland the length of life of an oak tie was increased but two years by the treatment. This the management regarded as too small an increase to justify the expense. On the Russian lines zinc chloride is used in treating Scotch pine, and apparently with good success. In Germany the chloride of zinc treatment by itself was given up for the most part after the year 1897.

It appears from the foregoing that but little impregnation is now being done with chloride of zinc. It is beyond doubt a splendid antiseptic, but the rapidity with which it leaches out has brought it into discredit with European engineers. The impression was gained that many railroad managements had overrated the value of chloride of zinc as an antiseptic. It was known in a general way that the salt leached out, and as a result stronger and stronger solutions of the salt were pressed into the wood. Nothing very definite is known even at this day as to the rate at which this salt leaches out. Schneidt has given some results in his paper,[a] but these are based entirely on some tests of ties which had been in the roadbed for three years, and in these he found the larger part of the zinc chloride gone. The records of past years in Europe take little cognizance of this leaching out or the influence on the lasting effect of increased or lessened amounts. Furthermore, the same treatment was applied to all timbers. It is well known that pine ties take up more solution than oak, and also that woods like oak, with a solid heartwood, take up very little solution except in the sapwood. The leaching out goes on differently in pine and oak, faster from the oak in some cases, and then again more slowly, depending upon the timber and on the thoroughness with which the impregnation was done.

The general impression gained was that for soft timbers, like the pines, spruces, and beech, the chloride of zinc treatment might give satisfaction where the increased length of life desired was short, owing to repeated renewals because of wearing out; but that it had proved unsatisfactory where a largely increased length of life was looked for. For hard woods, such as the European oaks, it did not pay, because the increased length of life obtained was entirely out of proportion to the cost of impregnation. The feeling in Germany is very well voiced by Schneidt, as follows (p. 16): "Oak ties, which last thirteen to fourteen years, ought to be impregnated with tar oil only, since the small increase in price of this treatment, as compared with the zinc chloride, can not be considered in view of the high prices of oak ties, and in view of the fact that tar oil, of all preservatives, is the only one which can give oak wood a decided increase in life." And

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[a] See Bibliography, p. 68.

again: "But even for pine ties * * * the treatment with zinc chloride is not satisfactory in the long run."

The above is without question true for European conditions; but one can not apply the same reasoning to this country. In the first place, of our oaks, the white and post oak are not as high grade timber as the European oak, and our red, black, and swamp oaks are very much inferior. While the European oak takes little zinc chloride solution, our oaks take a good deal, especially the inferior ones. After all, it is largely a matter of prices. Where timber is not as expensive as it is in Europe, but where it is already costly enough to warrant treatment, a process which may not be the best, but which does increase the length of life and which is cheap, is certainly worth considering and worth trial. It costs about 80 cents to creosote a tie according to the best practice, and it pays to do this with the ties which cost $1.50, because thirty years of life are possible; but it hardly pays with ties costing but 40 to 50 cents. A consideration of the diagrams given on pages 44, 45, 46, 47, and 48 will be sufficient to convince anyone that zinc chloride does prolong the life of the treated timbers. Furthermore, a study of Mr. Curtis's paper will show that similar results have been obtained in this country.

ZINC CHLORIDE AND COAL-TAR OIL.

In Germany and Austria the larger number of ties are to-day being impregnated with a mixture of zinc chloride and tar oil. The tar oil penetrates but a short distance into the wood (see Pl. XIV), while the zinc chloride goes in to a considerable depth. The great advantage which this method is supposed to have over other processes is that the creosote prevents the leaching out of the zinc chloride. The cost is but little above straight burnettizing, as a small quantity of the coal-tar oil is deemed sufficient to prevent the leaching out of the zinc salt. Impregnation by this method has been carried on by a number of the German Government railways for some years, and it is claimed that the ties so treated last fifteen to sixteen years. Plate XIV, figure 2, shows a section of a Scotch pine tie laid on the Marschbahn in 1885. It will be noted that the wood is still sound, although there is little evidence of tar oil in the outer cells. Figure 19 shows some of the results as given by an Austrian line.

The writer examined a number of sections where ties treated with the double process were laid. In some instances the ties were well preserved after six years, although here and there rotted ones were found only a few years after laying.

The absorption of tar oil by the different ties varies between very wide limits. Some ties absorb very much higher quantities than others. This makes any control of this process very difficult, especially as one of the objects is not to put too much tar oil into a tie, so as to keep the cost down. A commission sent by one of the French railways to examine into the methods of impregnation with the mixture as now practiced in Germany reported adversely, claiming that the results obtained were not counterbalanced by the saving in the price of treatment. This commission recommended the use of tar oil alone.

The reasons given by this commission for the use of tar oil alone were that ties cost so much in France that, knowing the good results which follow the use of tar oil alone, it would pay to use the very best process known.

It is interesting to note in this connection that M. Merklen, in discussing the report made on the system of double impregnation by Besson, calls attention to the fact that on one of the German lines 17,375 ties were impregnated with the mixture of zinc chloride and tar oil. These ties were treated by two different companies. One lot was laid in 1895, the other in 1888. Of the former, after six years, 50 per cent had been renewed in 1901, while of the latter, after thirteen years, only 15.86 per cent had been removed. This shows most strikingly that, with one and the same process, exceedingly poor and very good results can be obtained, depending upon the way in which the work is done.

It is without doubt true that some of the results obtained on the German lines with this process are very satisfactory, although, as Mr. Chanute has pointed out, this is often due to the better drainage and ballasting. In view of the fact that some of the lines now using this method of treatment are actively engaged in searching for better processes, an unqualified indorsement can not be given to this one. Where a first-class tar oil can be obtained and can be pressed into the wood in sufficient amounts, the process may be worth trying. A poor tar oil, which will volatilize readily, is worse than nothing.

The ideal method of using the two solutions might be to inject the zinc chloride first, dry the timber somewhat, and then inject the tar oil. The difficulty here is to control the amount of tar oil injected. This process is of course out of the question at this time, because no double handling would pay. The new Alderdyce process injects first of all zinc chloride, and then tar oil, in one and the same operation.

The comparative price of treatment of zinc chloride alone and of the double process has been concisely tabulated in Mr. Chanute's report as follows:

Table V.

[Cents per tie.]

Timber.	With zinc chloride.		With zinc creosote.		With creosote and drying oven.		Boiling in creosote.	
	First class.	Second class.	First class.	Second class.	First class.	Second class.	First class.	Second class.
Pine	15.60	12.00	19.20	14.40	53.76	40.32	56.64	42.00
Oak	12.00	9.12	15.60	12.00	26.85	20.16	28.80	21.60
Beech	18.80	12.48	20.40	15.36	56.64	42.00	59.28	44.40

HASSELMANN TREATMENT.

One of the great drawbacks of most preserving processes in use at the present time is that the salts injected are soluble in water, and on that account leach out rapidly from the wood when the latter is brought into contact with moisture. During the last four years a process for treating timber has been presented to engineers, which makes the claim that the injected salts form an insoluble compound with the wood. The method of treatment differs from all those now in vogue, in that no pressure is used to inject the salts. The timber to be treated is put into closed cylinders, and a solution of copper sulphate, iron sulphate, aluminum sulphate, and a small amount of kainit is run in. By means of superheated steam the solution is brought to the boiling point. The timber is thus literally boiled in the solution for several hours. The process has numerous advantages to recommend it over the older methods. The salts used are cheaper than any of the other materials. The wood to be treated may be dry or wet. The treatment is cleanly and rapid. The iron and copper salts penetrate every fiber of the wood. This is a notable advance in the science of timber treatment. All salts heretofore injected remained in the cavity or lumen of the wood cells, left there when the water evaporated. In the present instance the salts penetrate the walls of the wood cells, and apparently form some insoluble compound with the wood substance. An investigation of this subject is now being made, with a view of determining what this insoluble compound is, and whether it will be destructive to the fungus cells. The chief value of the new process, however, lies in the fact that the injected salts are insoluble. The writer made a number of tests to demonstrate this fact, and is convinced of its truth. There are practical difficulties, however, which will have to be overcome. It has not yet been shown that wood thus impregnated is capable of resisting decay, and in view of the recent origin of the process it does not seem likely that results on a larger scale will be possible for some years. The first experiments made with this treatment were carried on in Bavaria by the Bavarian Government, and since that time a number of private companies have used this method of timber treatment.

The writer examined with care the ties treated by this process lying in several railway yards in Berlin, and on a stretch of track near Berlin; also several hundred of these ties on a stretch of track near Augsburg in Bavaria. Without going into details it may be said that, owing to attendant circumstances, it seems that the treatment as carried out on these stretches was done in a manner unfair to the system as advocated. In one case the extreme temperatures weakened the wood fibers, and in another case the treated ties were laid in the track very shortly after their treatment. The results obtained in the last years and any future results are therefore to be regarded with suspicion as far as these early tests are concerned.

The writer visited a large coal-mining village in the Bavarian Alps for the purpose of inspecting the results obtained with the Hasselmann treatment in the mines. The company operating these mines had after careful consideration built an impregnating plant, where they have been treating all of their mine timber for almost three years with the copper-iron-aluminum solution. Since 1895 they had been using chloride of zinc. The timbers treated are chiefly the Scotch pine (*Pinus sylvestris*), spruce (*Picea excelsa*), and fir (*Abies pectinata*). The sticks used, varying in age from 40 to 80 years, are about 8 inches in diameter, of which a large share is sapwood. Much of the wood seen in the yards ready for treatment had blue sapwood. This was not regarded as a defect by the manager of the treating works.

The timbers to be treated, after seasoning for some months, are placed in a cylinder, where they are heated in the solution up to a temperature of 130° C. for two hours. They are then taken out and stacked. After lying some six months they are built into the mine.

In August, 1898, the first timbers treated with the Hasselmann treatment were put in. Pine, spruce, and fir were treated. At the same time timbers treated with chloride of zinc were put in. All timbers in this mine are labeled with zinc labels giving the time of treatment, the month, and the year. Through the courtesy of the general manager, the writer was enabled to make a personal examination of the impregnated timbers in the mine and to have a good many treated timbers removed. The mine is what one might call a wet mine. The air is surcharged with moisture in the passages ("schlechte Wetter Stollen") giving probably as favorable an opportunity for leaching out of salts and the growth of fungi as could be desired. Both the vertical and horizontal timbers in the passages were covered with great masses of white fungus mycelium, and the general impression gained was that if timber would rot anywhere, it would be liable to do so there.

The conditions were very different in the passages with fresh, dry air. The manager stated that unimpregnated pine lasted three to four years in these localities. The same timbers lasted only a year and generally less in the very moist passages. Fir and spruce were very short lived in the wet passages. The experience of the managers led them to use unimpregnated timbers in temporary structures only.

Of impregnated timbers in the damper passages there are now in the mine: (1) Some pine treated with $ZnCl_2$ in 1896—i. e., they have given about three years' service. All fir and spruce came out before 1899. (2) The pine timbers treated with the copper-iron-aluminum mixtures. These were treated in August, 1898, and include pine, fir, and spruce. The larger per cent of these timbers is in good condition, but some of them, particularly the fir timbers, were beginning to decay. It is very much to be regretted that no unimpregnated timbers were placed with the impregnated ones at the time when the latter were placed in the mine. A good many timbers of pine and spruce of the 1898 impregnation were still standing in similar localities as the Hasselmann timbers, although, as has been said, most of them had been removed on account of decay. A great variability with respect to resistance to decay was noted. Too much stress can not be laid on this point, particularly as it is generally entirely disregarded. Some timbers absorb large quantities of zinc chloride, others very little; then again some timbers came from trees which had grown more rapidly than others, and therefore offered less resistance to decay than the denser timbers. One could not avoid being forcibly struck with this fact in this mine, where it was possible to deduce almost any conclusion as regards the rate of decay of the various timbers impregnated with zinc chloride. There were some pine timbers treated with zinc chloride which had been in the mine since 1895, while on the other hand many of those treated in 1898 were already rotted.

This test of the copper-iron-aluminum treatment in this mine is certainly a valuable one; in fact, the only one of this treatment which can be trusted up to date. It is rather early to state positively what its absolute value may be. but from the facts above stated one may conclude that it does retard the destruction of timber. In a mine where the life of a timber is reckoned by months it is already a very good sign to make a timber which would last twelve to eighteen months last thirty months. That it has done this in the Penzberg mine is beyond question. The owners of the mine are so well satisfied with this treatment that they have abandoned the zinc chloride treatment altogether. They regard the copper-iron-aluminum treatment as a good financial investment. The following figures were given by the general manager. They require no further explanation.

Cost of operation.

	German money.	United States equivalent.
Cost of timber:	*Marks.*	
Pine (*Pinus sylvestris*) per cubic meter	18	$4.50
Fir (*Abies pectinata*) do	18	4.50
Spruce (*Picea excelsa*) do	18	4.50
Salts, labor, etc do	4.01	1.00
License	1-2	.25-.50

To which is added interest.

Estimating that untreated pine lasts one year, they make the following estimate of cost for 1,000 cubic meters for two years:

	German money.	United States equivalent.
	Marks.	
1,000 cubic meters of unimpregnated wood for 2 years (lasting 1 year and then replaced), ignoring labor of replacing	36,000	$9,000.00
1,000 cubic meters of impregnated wood lasting only 2 years:		
Wood	18,000	4,500.00
License	1,000	250.00
Salts, etc	4,010	1,002.50
Interest	675	168.75
Total cost	23,685	5,921.25
Total amount saved	12,315	3,078.75

The further behavior of the timbers impregnated with the copper-iron-aluminum solution in 1898 at Penzberg will be watched with interest. The writer was impressed with the manner in which the impregnating work was done at Penzberg. The salts were carefully controlled; likewise the strength of the solution and the temperatures at which the wood was boiled. It was fully realized that one and the same kind of treatment will not apply to different woods.

NEW PROCESSES.

THE SENILIZATION PROCESS.

For about two years a French company has been impregnating wood, at first with creo-resinate of soda, now with magnesium sulphate, by means of an electric current. The timber to be treated is placed in a tank on a lead plate and is covered with a second plate. These plates serve as electrodes. The magnesium salt enters the wood cells by "electro-capillarity." Succeeding osmotic changes are supposed to bring about diffusion of the salt, so that all parts of the wood are finally impregnated. The electrolytic action of the current is said to cause the formation of a number of insoluble magnesium compounds in the walls of the wood fiber.

The cost of operation is said to be very small. Wood paving blocks treated with this process remained in good condition for two years on one of the bridges in Paris under heavy traffic.

EMULSION TREATMENT.

As one of the great objections to the use of coal-tar oil by itself is the great expense involved, any process which claims to make use of this substance in smaller quantities without reducing its efficiency is to be welcomed. The experiments have been made with various solvents of coal-tar oil, such as benzine, carbon bisulphide, etc., with the hope of introducing small quantities of the antiseptic, evenly distributed, and leaving it in the wood by distilling off the solvent. These have so far proved failures. The present method employs an emulsion of tar oil, made by dissolving various quantities of resin in the tar oil and adding a strong solution of soda lye (NaOH). In the resulting emulsion the tar oil is found in the form of exceedingly minute drops, which remain in the emulsified state for several weeks. This emulsion when pressed into wood distributes the tar oil evenly throughout the outer layers of the wood. In the account which the author gives of this new process he says that when tested as to its toxic action on some common molds the relative value of the tar oil and of zinc chloride was found to be 3:1. In other words, a relatively much smaller amount of tar oil will give the same protection to timber as a large amount of zinc chloride.

The process as outlined has the decided advantage over the zinc-chloride and tar-oil treatment in that a very much more perfect emulsion is formed, which allows of a much higher penetration of the antiseptic substance into the timber. No actual test of this method has yet been made.

CREO-RESINATE PROCESS.

This process resembles the last in that resin is dissolved in tar oil, but instead of adding lye the inventor adds formaldehyde.

The wood is first subjected to a high degree of heat in order to kill any organisms which may be in the wood. After creating a vacuum the impregnating solution is run in. This process is claimed to render the wood absolutely sterile at first and then to give it additional protection on the outside. As far as the original sterilization goes there seems to be no good reason for going to so much trouble. In a natural state there are no living organisms in the wood, and consequently they can not be destroyed. Decay "at the heart," which is so often mentioned, is due to entrance of destructive growths from without, just as decay on the outside is. In living trees some fungi grow into the heart through old branches, and when the timber is cut the fungus may be on the outside of a stick. There is no evidence at hand to-day which indicates that growth of such fungi continues after death. All other rotting agencies would have to get in from without.

The reason why decay takes place at the heart and not outside is easily understood when one remembers the unequal moisture conditions in the interior and outside of cut wood.

The vulcanizing idea dealt largely with the so-called coagulation of albuminous substances, and much discussion has been waged as to its ultimate effect on the timber. Without entering into any long discussion of this question here, it may be said that dry heat up to 212° F. certainly does injure wood by causing some of the volatile products of wood fiber to escape. How far moist heat does this is as yet unsolved. It is therefore better to heat wood to such high temperatures only when absolutely necessary.

The use of resin with creosote can only be commended from a theoretical standpoint. If good creosote is used the resin addition can only add to the antiseptic elements put into the wood. The process deserves extended trial.

FERRELL PROCESS.

This is a new process recently introduced by a company in this country. It claims to inject salts of various kinds into wood (aluminum sulphate, sodium chloride, calcium chloride, etc.) by means of a modification of the old Boucherie idea. The solution is forced into the end of a stick of timber. The inventors claim that the salts penetrate all fibers thoroughly and that they can cause the union of two salts in the wood, thereby forming insoluble compounds. The process sounds very attractive, but it has had no trial up to date. One great objection is that each stick of timber must be handled separately. So far there has been no cost estimate available. As with all new methods a thorough test of the process will have to be made, for theoretical considerations alone have never proved the value of anything which is so complicated as timber preservation.

CONCLUSIONS.

The universal use of different impregnating systems in Europe has brought many of them to a high state of perfection. In England and France engineers believe that their system gives them the best results, and they use (especially in France) as much of the impregnating material as the timber will hold, saying that the extra first cost is amply paid for by increased length of life. As has been pointed out, this system, which costs from 45 to 80 cents, pays with a tie which costs from $1 to $1.40. They know that with this system of impregnation they get about thirty years' life out of their timber.

In many other countries where the price of timber is not so high cheaper systems of impregnation are in use, and will continue to be used. Zinc chloride has given good results on some lines, even if it does leach out. Copper sulphate has done so likewise. The new Hasselmann treatment gives promise of good results, and is worthy of more extended trial.

The striking features about the impregnating work as now carried on in Europe may be alluded to again here. They are:

(1) Seasoning of ties before treatment.
(2) Strict inspection of ties and chemicals used.
(3) Injection of larger amounts of chemicals than are used here.
(4) Seasoning of the treated ties before placing in track.
(5) Care in all stages of treatment.

The most important comment which can be made is that the Europeans appreciate that a treated tie is different from an untreated tie. If one goes to the trouble of treating timber, it is worth while to do it well. It is worth while to regard a treated tie as an object which needs special attention. In other words, a treated piece of timber is worth more than the same timber untreated. The mere impregnation is only one step toward longer life. Subsequent care will only enhance the value of the material. Proper seasoning, careful laying, a properly drained ballast, and proper records, all go to make timber treatment a success.

Referring briefly to the situation in the United States, one may ask how far the results obtained abroad are applicable to our conditions. With the present prices of ties and tar oil we can hardly expect to get the best results obtained in Europe. For ties costing 25 to 45 cents we can not afford to pay 60 to 80 cents for treatment. It is possible that the tar oil may be available at a reduced cost, and of as high grade, in the future. At the present time the beehive ovens in which coke is burned allow all of the products of coal distillation to escape. The demand for tar oil may become great enough to warrant condensing these volatile products.

Without the tar oil our cheap ties will have to be impregnated with one or another of the cheaper processes, which will increase the length of life sufficiently to make it pay. Those which have claim to consideration are: Zinc chloride and its modification, the Wellhouse process; the mixture of zinc chloride and tar oil; and the Hasselmann process. To these one ought to add petroleum products. Very little has yet been done in the way of making use of the vast quantities of this material for timber treatment. If some means could be found for getting petroleum or some of its products into wood, so as to keep it there, a great step forward would have been taken. The suggestion is not a new one, but, in view of the fact that recent developments have brought to light such vast quantities of oil in Texas, it may not be amiss to call attention to it anew.

We know enough by this time to say that the old-fashioned way of cutting ties and laying them in the track to rot in three or four years must be abandoned, to be replaced by a careful, systematic treatment. That timber impregnation pays when properly done can not be doubted, and careful consideration of this question is urged upon all interested in the utilization of structural timber.

REMOVAL AND DISPOSAL OF TIES.

On most European lines the ties come out of the main track very much sooner, relative to their life, than they do in this country. This is no doubt due to the greater responsibility attached to the railway managements as regards prevention of accidents. This periodical removal, which occurs every fifteen years on the English lines, has brought about a system of classification of ties fit for main running lines, those for secondary lines, those for fence posts, those for firewood. In most cases long stretches of track are renewed at one time, a practice which seems of rather doubtful wisdom as far as this country is concerned. The ties which are badly cut under the rail or where the spikes will no longer hold are used as fence posts along the right of way, or are sold to farmers. Badly broken or partially decayed ties are sold for fuel at the rate of 20 cents apiece in England. In France similar use is made of old ties, and tie fences are familiar sights along the right of way. The transfer of ties before their complete wearing out has many advantages, and will, no doubt, be practiced generally in the United States, as it is now on some lines of road. Economy will still keep many a tie, which ought to come out, in the track. The necessity for doing this will be largely done away with when an impregnating method will make one year more or less of service of small account. By this the writer does not mean to argue contrary to the maxim used by inspectors, "to find out how much sound wood is in a tie."

RECORDS.

All roads which impregnate abroad keep careful records of the treatment before, during, and after impregnation, according to the following form:

Impregnating works
at Salloch.

DAILY REPORT NO. ......

Date .... 190..
Weather ....
Temperature, 7 a. m. ....

Concerning the impregnation of ties from ....

Work began [date] .... and closed [date] ....

No. of operation.	No. of ties.		Weight of five ties before and after impregnation (kilograms).						Admission of steam.	Vacuum.	Filling in of liquid.	Pressure.	Running off of liquid.	Handling of timber.	Total time of operation.		Density of $CuSO_4$ solution.	Amount of $CuSO_4$ solution added after every operation.	Remarks.
									Time of operation in minutes.						Hrs.	Min.			
1			Before																
			After																
2			Before																
			After																
3			Before																
			After																
4			Before																
			After																
5			Before																
			After																
6			Before																
			After																
7			Before																
			After																
8			Before																
			After																
9			Before																
			After																
10			Before																
			After																
11			Before																
			After																
12			Before																
			After																
Engineer in charge of works.														Together.					

Materials used.					10 kilogr. $CuSO_4$ per cu. meter correspond to a 1% solution.
Coal.	Waste.	Oi.	Old ties.	"S" pieces.	
Kilograms.			Pieces.		

The inspector of the plant,

——— ———.

The ties are marked with dating nails (fig. 25). These are placed between the rails on top of the tie, generally in the middle of the tie. They are made of steel, covered with zinc or tin, and have the year stamped in the head. When renewals take place the date at which each tie was laid is noted, and in that way an absolutely reliable record is obtained.

Too much can not be said in favor of such a plan. The nails cost very little,[a] and when put in by the section gang the labor is very slight. The value of an accurate record of the length of life of treated timber can not be overestimated, for it is the only way in which a reliable conclusion as to the value of the impregnating method used can be obtained. Several American railroads have already adopted this plan, and it is to be hoped that it will be made a matter of universal practice before long.

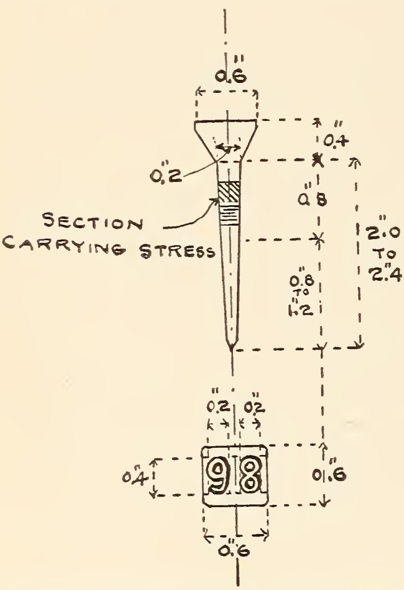

Fig. 25.—Dating nail used on French Eastern Railway.

CONCLUSIONS AND RECOMMENDATIONS.

The impregnation of timber to insure longer life has now been carried on for a hundred years or more, and yet we have not fully solved the problem. Much able work has been done on the question, but still we are far from the goal. The subject is one of the greatest complexity, and it is no doubt because of the great number of variable factors which enter into consideration that so little headway has been made. An experiment has to take into consideration all of these factors, and what the magnitude of such an experiment ought to be can be imagined by referring to some of these variable factors.

I. Timber:
   (1) Kind.
   (2) Age.
   (3) Season of cutting.
   (4) Seasoning.
   (5) Individual trees.

II. Condition of surroundings, soil, air, moisture, heat, etc.

III. Impregnating material:
   (1) Kind.
   (2) Amount used.
   (3) Method.

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[a] Same made in the United States cost 6 cents a pound (30 nails).

As mentioned at the outset, the most attention to timber impregnation has been given by the railroads. In making the following recommendations the tie phase is emphasized particularly, because it is believed that when something is found which will increase the length of life of ties the same will apply to all other classes of structural timber. Experiments have hitherto been made largely by railway companies on their own lines. It has often been the fate of these experiments that they were begun by a man much interested in the question, who gave a good deal of time and attention to the matter. His successor took a different view of things, and all the work of the years gone by was thrown away. At the present time a general feeling is spreading that some reliable data are wanted as to what may be expected of any one or all the systems advocated. In one of the preceding chapters a plan was described which has been put into operation during the past summer. It is urged that it will be necessary to continue an experiment of this kind before reliable data will be obtained. Experiments ought to be started in several parts of the United States, where climatic and soil conditions vary, and with different timbers. The most practicable way in which results could be reached would be as follows: Every railroad or telegraph company doing any timber treatment might do so with the aid and advice of this Bureau. A central body would be able to use the practical results of all sections, and could (by having slightly additional timber treated) secure data which the individual could not obtain. It is suggested that the work of this department be extended so as to include all impregnation on all roads subject to its supervision, etc.

The questions which seem most urgent at this time may be presented in conclusion.

SEASONING OF TIMBER.

A test on a large scale should be made to determine how long different kinds of wood must be seasoned to give the best results. The different methods of piling should be investigated to demonstrate on a practical scale which gives the best results. As indicated above, it is believed that a very great saving could be obtained by giving more attention to a proper drying of timber before use.

SAWN AND HEWN TIMBER.

Probably no one of the problems discussed requires solution more urgently than that of sawn and hewn timber. This ought to be a very simple matter, in view of the fact that thousands of ties of both kinds are laid every year. When laid, the two kinds ought to be indiscriminately mixed, so as to place them under identical conditions.

FORM OF TIE.

It is recommended that ties cut according to the English system be experimented with to determine whether such a system could be used in the United States.

PRESERVATIVE PROCESSES.

As already stated, it will be desirable to test the relative value of the various preservative processes which have been shown to be of any value, and such new ones as may have appeared in the meantime. All timbers used for structural purposes should be tested. Experimental tracks should be laid in various sections of the country, with different timbers, subject to rigid scientific inspection and care by trained persons. These experimental tracks should be placed with a view of maintaining them under actual service for a long series of years. Care should be taken to make each one extensive enough to guard against the mistake of drawing conclusions from too meager data. Connected with this examination are the questions of the influence of the age of the timber to be treated, time of cutting, seasoning, etc.

CHANGES WHICH TREATED TIMBER UNDERGO.

The changes, both mechanical and chemical, which treated and untreated timber undergo in the course of time should be studied. The relative strength of treated and untreated timbers should be investigated further. The mechanical and chemical changes which the wood fibers undergo during treatment are as yet unknown. They are of the greatest importance to the engineer and architect.

UTILIZATION OF INFERIOR TIMBERS.

An examination should be made of the possibility of utilizing timbers for structural purposes which are now regarded for various reasons as unfit. The question of utilization of inferior timbers is one of the most important. The tamarack and the swamp oak are kinds of timber which few will touch to-day. They are cheap—cheaper than the sought-after pine and white oak. Their chief drawback is that they will not last. Could the larger supply of these timbers be drawn on rationally it would tend to establish an equilibrium, which would react favorably on the lumber industry, and at the same time tend to save some of those timbers more valuable for the higher kinds of structural requirements. It is therefore recommended that special attention be paid to these timbers, of which there are a number in every section of this country; that they be treated in various ways and tested as to their mechanical fitness and their lasting powers after such treatment.

THE GROWING OF TIE TIMBER.

Closely connected with this is the question of growing of timber for ties and telegraph poles in particular. In the future it will be the object to grow such timbers as will make ties and poles in the smallest number of years, and at the same time ties and poles which shall be as good and lasting as any others. The catalpa and eucalyptus timbers are without question among those which will receive more and more favorable consideration. One of the objections is their slight resisting power to mechanical stress and, in some instances, to decay. It is recommended that experiments be made in treating these timbers so as to render them more resistant in all respects.

CAUSES OF DECAY OF TIMBER.

We now know in a general way that fungi and bacteria are the agents which cause the decay of timber. There are many questions connected with their life histories which we know practically nothing of. Some of these may be pointed out—the transmission of spores from the wood to the structural material, how it takes place and how it could be prevented; the rate with which various fungi grow; the influence of soil conditions on their growth; the minimum amount of antiseptics which will prevent growth; will fungi which grow in live trees continue in wood cut from the trees, etc. It is of paramount importance that investigations be carried on to answer these questions.

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APPENDIX.

The following specifications and contracts are added as samples to show what the present practice on European lines is. The writer regrets that some of the specifications which he obtained can not be printed, because the railroads in question objected.

A general consideration of these contracts and specifications will show that the business as conducted falls into two parts—the delivery of timber and its treatment. The requirements differ in details, but in general there is considerable uniformity. The point which is most striking is the rigid inspection everywhere prevalent. That there is much to be commended in this goes without saying, and it would be well if some system of this kind were adopted wherever impregnation is carried on in this country.

Exhibit A.

PRUSSIAN RAILWAYS.

Description of the Various Impregnating Processes.

A. IMPREGNATION WITH ZINC CHLORIDE.

The impregnation is divided into three operations:

1. Steaming.
2. Establishing of a vacuum.
3. Introducing of the zinc chloride and applying of the force pump.

After the ties have been loaded on iron cars and put into impregnating tanks hermetically closed, they are subjected to the influence of steam in order to expel or render harmless the sap, which readily ferments, and also to prepare the wood for the absorption of the impregnating fluid. Besides this, by this steaming process, as much absorption as possible of the impregnating fluid should take place, to which end it is necessary that the dry surface of the ends of the ties should become softened and that the hardened gum should be removed, which runs from the ends and, combined with sand and dirt, often forms a mass impervious to fluids.

The steaming must last a longer or shorter time, according to the time of the year, the condition and kind of wood. The influx of the steam from the boiler into the impregnating tank must be managed in such a manner that the pressure of the steam in the tank will reach 1.5 atmospheres within thirty minutes.

With dry pine and oak ties it is sufficient to maintain the pressure in the impregnating tank for thirty minutes. With green pine or oak ties the duration of the steaming must be correspondingly lengthened. It will take longer for the pressure of the steam in the impregnating tank to reach 1.5 atmospheric pressure with these timbers, and therefore the pressure of the steam must be maintained for an hour longer.

Accordingly, for dry timbers the steaming lasts at least one hour, while with green timbers it must last one and one-half hours, and in some cases this period must be lengthened according to the time necessary for the pressure in the tank to reach 1.5 atmospheres. In impregnating beech timbers, whether the wood be dry or green, the steam must be continued during a period of three hours with the pressure of 1.5 atmospheres, so that it may be safely assumed that the heating of 100° C. has penetrated to the inmost heart of the wood.

A steam gauge attached to the impregnating tank will indicate the presence of the prescribed pressure.

In order to drive the air out of the tank, when the steam is first turned on a cock at the bottom of the tank must be opened until steam comes out of it. During the steaming this cock must be repeatedly opened in order to let out the water in proportion as the steam condenses. After the steaming the steam in the tank must be allowed to escape. Then a vacuum of at least 60 centimeters of mercury must be established; this vacuum must be maintained from thirty to sixty minutes, according as the wood is dry or green.

At the end of this time, in a steadily maintained vacuum, zinc chloride lye warmed to 65° or more must be forced into the impregnating tanks by means of outside atmospheric pressure until the tank is full. Then the force pump must be used in order to produce a pressure of 6⅔ atmospheres, which pressure must be maintained for at least sixty minutes, if, owing to the indications concerning the strength of the zinc chloride lye, or in order to reach the prescribed absorption of the impregnating fluid, a longer period of pressure is not required.

When this operation is completed the zinc chloride lye must be drawn off. The zinc chloride used for the impregnation must be as free as possible from foreign matter, especially surplus acid, and it must indicate a strength of 3° Beaumé at 14° R. As a regulation to make the impregnation of the wood as thorough as possible, one must determine that an air-dried railway tie of 0.106 cubic meter contents must absorb, for—

	Kilograms.	Pounds.
(*a*) Pine timber	30	65
(*b*) Oak timber	10	22
(*c*) Beech timber	30	65

And that an air-dried tie of 0.090 cubic meter content (3.1 cubic feet) must absorb at least 27 kilograms (59 pounds), while the air-dried ties, reckoning by the cubic contents, must absorb per cubic meter (35.31 cubic feet)—

	Kilograms.	Pounds per cubic foot.
(*a*) Pine timber	300	18.6
(*b*) Oak timber	100	6.2
(*c*) Beech timber	300	18.6

Should the foregoing specified absorption of impregnating fluid not be possible by the prescribed process, because the wood to be impregnated is green, or exceptionally knotty wood is to be impregnated, then the zinc chloride lye must be so strengthened that the absorption of zinc chloride free from water shall correspond with the amount of lye 3° Beaumé strong which is contained in the specified amount.

Thence it follows, that if, e. g., only 200 kilograms can be absorbed by 1 cubic meter of pine wood (1.2 pounds per cubic foot), the zinc chloride lye used must be 4½° B. strong. The samples necessary for the testing of the zinc chloride must be drawn from the outflow from the safety valve. If, according to a sample drawn, it should be necessary to strengthen the lye with concentrated zinc chloride, then it must be determined by the regulation that the specified lye has been present in the tank for half an hour. The amount of impregnating fluid absorbed by the timbers must be ascertained by weighing all the timbers directly before and after impregnating, the difference in the weight showing the amount of impregnating fluid absorbed. For the amount of zinc chloride found lacking, a deduction will be made of 15 kreutzers per 10 kilograms of zinc chloride lye of 3° B.

B.—IMPREGNATION WITH ZINC CHLORIDE MIXED WITH COAL-TAR OIL CONTAINING CARBOLIC ACID.

The treatment is carried out in just the same manner as is specified for the process with pure zinc chloride: all the specifications given for this process remain the same. In addition, while the zinc chloride is being heated, the following amount of coal-tar oil containing from 20 to 25 per cent creosote (i. e., carbolic acid) is added: 2 kilograms (4 pounds 6 ounces) for each tie, or, in other words, 20 kilograms for every cubic meter of timber.[a]

The proportion of acid oils (creosote, in other words, carbolic acid) will be shown by their solubility in sodium hydrate of 1.15 specific gravity.

The mixing of the coal-tar oil with the zinc chloride must take place by means of a good mixing apparatus and under an influx of steam.

C.—IMPREGNATION WITH COAL TAR CONTAINING CARBOLIC ACID.

The impregnation consists in three operations:

(1) The drying and heating of the ties to 110° C., in a drying oven or in the impregnating tank.

(2) The establishing of a vacuum.

(3) Running in and forcing in of the coal-tar oil by means of the force pump.

(I) Method of impregnation, using the drying oven:

First the ties must be brought on iron cars to a well-constructed drying oven, and then subjected to a heat, gradually increasing to 110° C., and dried for at least eight hours until no steam escapes and the wood has been evenly heated throughout. After the drying, the ties, while still warm, must be carried immediately on the same cars to the iron impregnating tank, which must be thereupon hermetically closed.

Then a vacuum of at least 60 cm. of mercury must be established within the impregnating tank. This vacuum must be created after the expiration of thirty minutes at most and maintained for thirty minutes longer.

At the end of this time, with continuous application of the air pump, the tank must be filled with the coal-tar oil containing creosote, which must be previously warmed indirectly by steam pipes in basins or a tank to 45° to 60° C.

(II) Method of impregnation, using hot solution:

In case the heating should take place in the impregnating tank, the ties and timbers to be impregnated must be brought directly to the impregnating tank, which must be hermetically closed.

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[a] 1 meter = 39.37 inches.
1 kilogram = 2 pounds 3 ounces.
1 cubic meter = 35.31 cubic feet.

Then a vacuum of at least 60 cm. of mercury must be created in the tank filled with timber, and the impregnating oil, previously heated to about 60° C., or more, must be run in in the presence of a continued vacuum.

During and after the filling, the coal-tar oil in the impregnating tank must be warmed to 105°, in some cases 110° C., indirectly, by means of steam, either by a system of pipes lying in the lower part of the tank, or by a cylinder arranged under the same. This temperature of the impregnating oil must be reached within three hours and then maintained for a full hour longer.

Should the temperature of 105° not be reached within three hours, then the duration of the heating must be lengthened until 105° C. is reached. From this point the impregnating of the wood will be carried on in the same manner, whether the wood has been heated in a drying oven or in a tank.

Now, by use of the pump, a pressure must be produced at least 6⅔ atmospheres more than the outer atmospheric pressure; this pressure must be maintained for at least sixty minutes longer, if a lengthening of the duration of the pressure is not necessary to induce the specified absorption of the impregnating fluid.

The oil produced from coal tar must contain only a minimum of easily volatilized elements; the oils must be so heavy, that, determining by the greatest part, the boiling point between 180° C. and 400° C. will lie beyond 235° C.

The proportion of acid elements (creosote, i. e., carbolic acid) soluble in concentrated alkaline lye must amount to at least 10 per cent. In spite of the high boiling point, the oil must be thinly fluid and sufficiently free from solid elements to penetrate immediately when poured on dry crosscut timber, and to leave no other residue than that mentioned above. At the same time the oil must be sufficiently dense to be retained as completely as possible in the pores of the wood after the treatment. It must contain no oils, or at most 3 per cent of oils having a specific gravity of the oil, and must not amount to more than 1.10. At most 25 per cent of other oils produced from wood coal, peat, and wood may be mixed with the coal-tar oil, if the former oils answer satisfactorily in the specified properties to the coal-tar oil.

The contractor guarantees that the average amount of creosote, or, in other words, tar oil containing carbolic acid, absorbed by each air-dried pine or beech railway tie of the larger sort, of 0.104 cubic meter (3.67 cubic feet) contents, shall be at least 20 kilograms (23.6 pounds), and that absorbed by ties of the smaller kind, of 0.090 to 0.083 cubic meter contents, shall be at least 18 kilograms, and that absorbed by each air-dried oak railway tie at least 8.5 kilograms (18.5 pounds), and the amount absorbed by timbers which are reckoned by the cubic contents shall be—

	Kilograms.	Pounds per cubic foot.
Per cubic meter of pine and beech timber	200	12.4
Per cubic meter of oak wood	85	5.2

The amount of coal tar absorbed by the timbers must be ascertained in the following manner: All the timbers must be weighed, after the drying in the drying oven, or, if the timbers are not put in the drying oven, before the treatment in the impregnating tank, and for a second time after the impregnation.

For the amount of coal tar found wanting by the method stated above a deduction of 6 florins (Austrian) per 100 kilograms will be made. If the amount of oil found wanting is more than one-sixth of the specified amount to be absorbed, then the impregnation must be repeated.

Exhibit B.

Bavarian State Railways.

EXTRACT FROM SPECIFICATIONS FOR IMPREGNATING FIR RAILWAY TIES WITH ZINC CHLORIDE MIXED WITH COAL TAR CONTAINING CARBOLIC ACID.

1.

[Omitted.]

2.

The impregnating process is divided into three parts:

(1) The steaming of the ties.

(2) The establishing of a vacuum and the introducing of the impregnating fluid into the tank.

(3) The forcing in of the impregnating fluid by the use of the force pump.

3. *Steaming of the ties.*

The ties must be loaded on iron cars, put into the impregnating tank, and, after the latter has been hermetically closed, the ties must be heated by having steam turned into the tank. This should make the wood fit for absorption, cleanse it, and soften and remove the gum mixed with sand and dirt adhering, especially to the ends.

According to the season and the condition of the ties, the steaming must be continued for a longer or shorter period.

The influx of the steam must be so conducted that the steam gauge connected with the impregnating tank will indicate a pressure of 1½ atmospheres after, at most, thirty minutes.

Dry wood must be subjected to this steam pressure for thirty minutes longer, green wood for sixty minutes longer; so that the steaming of dry ties will last for at least one hour, of green ties at least one and one-half hours.

With the influx of the steam the air in the impregnating tank will be expelled by the opening of a crack in the lower part of the tank. During the steaming this crack must be opened repeatedly in order to let out the water by degrees as the steam condenses; but this must be done every half hour at least, and for the last time immediately before the air is pumped out.

After the wood has been treated with steam for a sufficiently long period the steam must be drawn off from the impregnating tank.

4. *The establishing of the vacuum and the pouring in of the impregnating fluid.*

After the steam has been drawn off, a vacuum of 600 mm. (23½ inches) of mercury by the vacuum meter must be established in the impregnating tank filled with ties, and this vacuum must be maintained for ten minutes.

At the end of this time, without reducing the vacuum, the impregnating fluid, which must be previously put in a special tank and heated to at least 65° Celsius, must be turned into the tank.

The impregnating fluid is produced by adding to the zinc chloride solution, while it is being heated, 1 kg. of tar oil to every 10.76 kg. of zinc chloride (i. e., 9.2 pounds of tar oil to every 100 pounds of zinc chloride). Accordingly, every tie 2.7 m. (8.85 feet) long requires 3 kg. (6 pounds 9 ounces) of tar oil. In order that the mixing may be as complete as possible, proper arrangements must be made for mixing the fluids in the presence of steam and air.

5. *The forcing in of the impregnating fluid by means of a force pump.*

After the tank has been completely filled the impregnating fluid must be forced into the wood by means of a pump, the pressure being raised to at least 7 atmospheres.

That the saturation of the wood may be as complete as possible, this pressure must be maintained for at least thirty minutes, and, if it is necessary, the time must be lengthened until the specified amount of impregnating fluid has been absorbed.

This completes the impregnating of the wood, after which the fluid must be drawn off.

Suitable distilling apparatus must be ready for the removal of any impurities in the impregnating fluid brought about during the treatment.

6. *Composition of the impregnating fluid.*

a. Zinc-chloride solution:

This must be as free as possible from impurities and especially free from free acids.

The solution must have a strength of 3.5° Beaumé—1.0244 specific gravity at 15° Celsius.

The proportion of metallic zinc in this solution amounts to 1.26 parts.

It will be admissible to mix in only the very least traces of other metals, especially iron, and only in so far as they can not be avoided in the manufacture.

b. Tar oil:

This tar oil must be so composed that by distillation to 150° Celsius, at most 3 per cent, from 150–235° Celsius, at most 30 per cent, and from 150–355° Celsius about 85 per cent is distilled over. The specific gravity at 15° Celsius should be between 1.03 and 1.10. At 20° Celsius the oil should be so clear that a few drops poured on filter paper folded several times will be entirely absorbed without leaving more than a trace of undissolved solid elements. The proportion of acid elements (like carbolic acid), that is, elements soluble at 15° Celsius in sodium hydrate, specific gravity 1.15, must amount to at least 10 per cent.

7. *Guarantee of the absorption of impregnating fluid.*

It is guaranteed that the average absorption of impregnating fluid for every full tank considered must amount to 35 kg. (76 pounds) for a fir railway tie 2.7 m. long and 16 cm. by 26 cm. cross section (8 feet 10 inches by 6.2 inches by 10.2 inches).

To ascertain the amount of impregnating fluid taken up by the ties, a float must be fixed in the reservoir from which this fluid is run into the tank, with a legible scale above the reservoir. This scale must be graduated according to the ground plan of the reservoir, with the assumption that the fluid has a medium specific gravity of 1.02 according to each 100 kg. (220 pounds). At the beginning of the absorption the reservoir must be quite full. At the end of the impregnating, i. e., when the impregnating fluid has all run back into the reservoir, the depth of the fluid in the reservoir will be shown on the scale. The difference between this depth and the depth when the reservoir was full will give in kilograms the fluid absorbed.

If, as ascertained above, less than the specified amount of impregnating fluid should be absorbed, a deduction in money of fifteen pfennig will be made for every 10 kg. (16 cents per 100 pounds) lacking; but if the absorption should be less than five-sixths of the specified amount, the impregnation must be repeated without any extra charge.

8. *Superintendence of the impregnation.*

In each case, eight days before beginning the treatment of the ties, the contractor must send a notification stating the source of the zinc chloride solution and of the coal-tar oil. so that an agent of the K. B. State Railway may be sent in time to superintend the work.

The agent must at any time be free to enter all the working rooms of the contractor; all desired information must be given him readily, and all implements, materials, and means to assist his work, necessary to carry out his office, must be put at his disposal. His instructions must be accurately followed.

This agent must ascertain that the impregnating apparatus is fit for the use to which it is to be put and that the instructions for impregnating are exactly followed. He will accept the ties impregnated according to the specifications. He will take samples of the fluid and of the wood for chemical analysis, and he will have remedied any deficiencies he may find.

The railway company has the right to have a chemical analysis of the impregnating fluid made at any time and at the cost of the contractor.

9. *Impregnating journal.*

The contractor must keep a journal in which are carefully recorded the several processes of the impregnation, the number of ties impregnated, the beginning and end of the impregnation, information concerning the amount of impregnating fluid absorbed by the ties, and also the strict observation of the various specifications. This journal must always be open to the registering agent for inspection.

Exhibit C.

Method of Impregnating Railroad Ties as Applied in the Imperial Impregnating Works at Kircheson, Bavaria.

I.—*Impregnation of ties in general.*

All ties are impregnated with zinc chloride in order to increase their durability. This method of preparing wood consists in steaming it in order to dissolve the more or less dried substances in the wood fiber which induce decay. This fluid is then expelled from the wood as completely as possible by means of air pumps, and antiseptic fluids are forced into the wood. The albumen remaining in the wood cells is congealed and also all substances capable of fermenting.

A weak solution of water and neutral zinc chloride is forced into the wood by a pressure of about eight atmospheres, in order to reach every possible part of the wood, to prevent decay.

II.—*Particulars.*

The method of impregnating the ties, which are to be without bark, is as follows:

In order to convey the ties as quickly and as cheaply as possible to the wrought-iron cylinder, the wood is stacked as near the workshop as possible and carried from there to the workshop by means of small cars on narrow-gauge tracks. The most advantageous means of conveying the wood in and out of the cylinder is by loading it onto an iron car. While the wood is going through the process in the cylinder it rests on iron tracks that are fastened to the cylinder.

When, as an exception, single pieces of wood are put into the cylinder, care must be taken to avoid contact with the pipes in the bottom of the cylinder which are to carry off the fluids from the wood and convey zinc chloride and the like. After the cylinder is filled with wood it must be sealed air-tight by means of the door of the cylinder, which is fastened with bolts and screws. In order to seal the cylinder completely an air-tight substance must be put between the top of the cylinder and the inner edge of the cover.

This is accomplished by means of an iron ring whose cross section is $\frac{0035}{0.004}$. Long strips of linen must be wound around the ring until it is pretty thickly covered, and then the whole is saturated with tallow. Tallow must be applied to the ring each time before wood is placed in the cylinder, but at all other times the ring must be in its place.

III.

While the wood is being brought in and the closing of the cylinder is taking place. the cylinder is heated and sealed. Then steam of 5 to 6 kg. (11 to 13 pounds) is admitted. After steam has been pouring into the vat for thirty minutes the waste faucet at the bottom of the cylinder, for drawing off the wood fluids, must be opened until steam pours out. This process must be repeated from two to three times. The time of steaming ties that are not completely dry, with highest pressure of steam, is about three hours. The pressure of steam in the cylinder at the end of the steaming must be at least one-half atmosphere for fifteen minutes. After the steaming the steam faucet is checked and the refuse faucet is opened to draw off the wood fluids. This faucet is left open until the escaping steam emits no sound.

IV.

After this process all steam and air must be forced from the cylinder by means of an air pump. Steam vacuum pumps are applied until the air in the cylinder has reached 550 mm. (21½ inches) by the barometer. This is quite possible with an apparatus in good condition. But since not only the air in the cylinder and the steam about the wood must be removed, but also the fluids that come from the wood, this work must continue at least one hour more, and if the work of preparing the wood be not too pressing even two hours would be advantageous.

V.

After this has been completed, the solution of zinc chloride is allowed to flow into the cylinder. The air pump continues to operate during all this time. The zinc chloride rises rapidly in the cylinder. The height to which the fluid has risen can be determined by placing the hand on the cylinder, since the cold chloride cools its sides, which are still hot from the steam. A register attached to the side of the cylinder is a more exact means for ascertaining the height of the chloride.

The air pumps remain in action until they begin to pump out the preparing fluid.

VI.

After the cylinder had been filled with the solution of zinc chloride and the air pumps have ceased their work, the pipes admitting the chloride are checked, though the force pumps are brought into action and the valve at the top of the preparing cylinder is opened, and thus the air left in the preparing cylinder is expelled.

When the cylinder is so filled with the chloride that it runs over through the valve, then the valve is closed. The force pumps continue to work for about three-quarters of an hour, the pressure reached at this time being about 8½ atmospheres. This pressure must continue in action for the entire time, but the pumping may be slowed up gradually.

The fluid being forced into the wood lessens the pressure, and for this reason the pumping must continue during the entire process. With oak wood, a pressure of $8\frac{1}{2}$ atmospheres can be reached in ten minutes, because oak absorbs little fluid; with pine wood fifteen minutes are needed, and with fir forty minutes; beech wood takes fifty minutes.

VII.

After the necessary time allowed for the fluid to affect the wood has elapsed, the air valve is opened, and the fluid which has not been absorbed is returned to the reservoir from which it was drawn. Then the cover is taken off the treating cylinder and the wood is lifted out and carried away to be stacked up. After this the preparing cylinder is thoroughly cleansed and the sediment at the bottom removed. Then the process is repeated exactly as described above with the next batch of wood. For this whole process, from the carrying in of the wood to the carrying out of the impregnated ties, the method of procedure is written out and posted for the workmen who follow it in every detail.

VIII.

The entire time occupied by the process is eight hours for ties not entirely dry and six hours for entirely dry ones.

The scheme for impregnation posted in the workshop is to be referred to often and to be followed by the workmen in every detail under the most careful supervision of the man in charge.

IX.—*The preparation of the impregnating fluid.*

The chloride of zinc used must be neither acid nor base, but neutral. It is to have a specific weight of 1.60 to 1.50.

The impregnating fluid is made up of 1 part chloride of zinc to 49 parts of water, and contains 0.66 per cent zinc, 0.72 per cent chloride, and 98.62 per cent water.

In testing the chemicals special care is to be taken to make sure that zinc and chloride are in the above-prescribed proportion. But since zinc chloride can not be procured in an absolutely pure state in great quantities, therefore it is not demanded that the substance be chemically pure. The presence of other metals in small quantities, particularly iron, does no harm, since these foreign substances of the combination are also soluble in water and have the same antiseptic properties. In case the solution of zinc chloride is kept a long time the particles of the combination separate into zinc sulphate and other basic salts and thus change the composition of the zinc chloride. For this reason it is necessary to dissolve the salt sediment in a proportional quantity of acid in order to bring about a regeneration of zinc chloride. A surplus quantity of acid is to be avoided. This can be accomplished by the introduction of raw zinc. The quantity of chloride of zinc contained in the fluid, which is to be used continually and regenerated as it becomes necessary, does not stay the same. The exact proportion can not be ascertained exactly, since the fluid becomes heavier by the unavoidable addition of wood saps and other impurities and, on the other hand, lighter by the loss of the above-mentioned sediments. The water used at Kiercheson, even when the fluid is kept for months, has no detrimental effect upon the solution. This variable impregnating fluid must be tested at least once a month and oftener, if necessary, for the purpose of seeing that the solution contains the proper quantity of zinc chloride, and when found lacking to improve it.

Moreover, it is required to examine the apparatus from time to time in all its parts in order to make sure of its efficiency. To this end the supervisor must examine the prepared ties in order to see whether the zinc chloride has thoroughly penetrated. If this is not the case, the matter must be looked into at once, the source of trouble discovered, and the matter remedied.

EXHIBIT D.

FRENCH EASTERN RAILWAY.

SPECIFICATIONS CONCERNING THE SUPPLY OF OAK TIES.

ARTICLE 1.—*The nature of the wood and its origin.*

The ties shall be of the best quality of oak wood. All wood must be rejected which has grown on damp fertile ground, or which was not felled at the proper season.

The wood must be taken from such places as are indicated in the agreement; the engineer of the company shall have the right to exclude wood from other sources whose quality seems inferior to him.

ARTICLE 2.—*Shape of ties.*

The ties shall be cut square; the upper and under surface must be dressed with a saw; the lateral surfaces may be hewn with an ax.

The under side, which rests on the roadbed, must have sharp, angular edges. On the opposite side the good wood must be on top, exposing a surface of at least five centimeters ($0^{m}.05$=2 inches) on either side of the middle of the tie, in the place where the groove extends toward each end, for a distance of from fifty centimeters ($0^{m}.50$=19.7 inches) to one meter ($1^{m}.00$=39.37 inches) from the middle of the length, as a starting point. (The parts marked with cross lines, as shown in the above sketch, indicate the minimum of good wood, required to be exposed, on the upper surface of the tie.) Imperfections may be tolerated on this upper surface if they do not measure more than five centimeters ($0^{m}.05$=2 inches), as is indicated in the cross sections below.

ARTICLE 3.—*Dimensions of the ties.*

The ties shall be from two meters sixty centimeters ($2^{m}.60$=8 feet 6 inches) to two meters seventy centimeters ($2^{m}.70$=8.85 feet) in length. Their thickness shall be between fourteen and fifteen centimeters ($0^{m}.14$=5.5 inches; $0^{m}.15$=5.9 inches).

The width may vary from twenty-two ($0^{m}.22$=8.66 inches) to twenty-five centimeters ($0^{m}.25$=9.8 inches).

ARTICLE 4.—*Curvature of the wood; of the ends.*

The upper and under surfaces must be perfectly level and parallel. As for the lateral surfaces a curvature whose angle of inclination does not exceed ten centimetres ($0^{m}.10$=3.937 inches) is allowed.

The ends of all the ties shall be finished with a section perpendicular to the length.

ARTICLE 5.—*Quality of the wood.*

The ties must be perfectly healthy and of straight grain; they must be free from decay, bad knots, twists, frost clefts, stings, double bark, and whatsoever imperfections there may be. The bad wood, as well as that which has its inner bark in bad condition, shall be refused.

ARTICLE 6.—*The delivery and measurement of the wood.*

The ties shall be delivered at those depots indicated in the contract and at the time agreed upon, in batches of not less than 200 pieces per station. Orders demanding less than 200 pieces shall be filled in one shipment. The ties shall be examined and measured with the greatest care by an agent of the company, in the presence of the contractor or his agent, and the dimensions shall be immediately written on the bill of lading, which the agent of the company must sign, before the wood is finally given over by the contractor. The measuring shall be done with 5 centimetres (2 inches) as a unit of measure for the lengths and 1 centimetre (0.39 inch) for the widths and thicknesses. The latter are to be measured in the narrowest parts. All fractional parts of 5 centimetres (2 inches) or of 1 centimetre (0.39 inch) in measuring lengths and widths and thicknesses, respectively, shall not be counted. The average cube is not to be less than the cube which is the result of the average of the upper and lower surfaces. In case it is less, the price stipulated in the contract shall be reduced in the proportion in which the actual cube stands to the required cube. In case of excess the contractor shall be granted no increase in price.

All the pieces which have one, or better two or three, dimensions that do not come up to the minimum requirements as stated in article 3 shall be refused. The pieces whose dimensions exceed those indicated as maximum requirements may be accepted, but no account is to be taken of the excess. The ties that have been accepted shall be stamped with the trade-mark of the company.

The ties that have been refused must be removed from the depot by the contractor after each delivery. The bill of lading shall not be returned to the contractor after the receipt of goods until all the refused ties have been cleared away.

Article 7.—*Charges and stacking of ties.*

All expenses of transport, loading and unloading, and all hand labor involved in the delivery shall be at the cost of the contractor.

The ties after they have been accepted shall be loaded onto wagons, if the company can put them at the disposal of the contractor, immediately after delivery. If this is not the case the ties are to be stacked up in regular piles in the places meant for this, and it shall not be required of the contractor to attend to the loading. The contractor shall guarantee to be held responsible for all claims of damage done neighboring roads or the forests owned by the company or other ownership.

Article 8.

It is the object of these resolutions concerning the charges to forbid the selling of any part whatsoever of the supply without the written consent of the company.

RESOLUTIONS CONCERNING THE REQUIREMENTS OF THE SUPPLY OF OAK WOOD FOR CHANGES AND ROAD CROSSINGS.

Article 1.—*Object of these resolutions.*

These resolutions have for their object the supply of ties destined to the establishment of machinery for changes and crossings in the road.

Article 2.—*Kind of wood and its source.*

The wood shall be of the best quality of oak wood. The wood which has been grown in damp fertile lands and has not been felled at the right time shall be refused. The wood must be taken from such lands as are indicated in the contract. The engineer of the company shall have the right to reject wood of other source, whose quality seems to him to be inferior.

Article 3.

The ties shall be square, the upper and lower surfaces shall be dressed with a saw, and the lateral surfaces may be hewn with an ax. The lower side shall have sharp angular edges without bark. Imperfections shall be tolerated on the opposite surface, that is if they do not measure more than 5 centimetres (2 inches).

ARTICLE 4.—*Dimensions of the ties.*

The normal dimensions of the ties shall be indicated in a picture accompanying the contract.

The following exceptions shall be added to the normal dimensions:

(1) For the lengths, 10 centimetres ($0^m.10$=3.937 inches), more or less.

(2) For the widths, 1 centimetre ($0^m.01$=0.39 inch), more or less.

(3) For the thicknesses of 15 centimetres ($0^m.15$=5.9 inches) and above, 1 centimetre ($0^m.01$=0.39 inch) more or less.

The company besides may order ties purposed for extraordinary machinery, whose dimensions shall be indicated during the course of the work. Their ——— shall be restricted to the limits of the picture, and their cube shall not exceed the twentieth of the total supply.

The upper and under surfaces shall be perfectly level and parallel. In the sides a curvature, whose angle of inclination shall not exceed 1 centimetre (0.39 inch) in a length of 1 metre (39.37 inches) (that is one one-hundredth of the total length of the piece of wood). The ends shall all be finished off by a cross-section perpendicular to the length.

ARTICLE 5.—*Quality of the wood.*

All the pieces must be perfectly healthy and of straight grain; they must be free from decay, bad knots, twists, frost clefts, stings, double bark and cracks, and whatever other imperfections there may be; also the wood whose inner bark has deteriorated shall be refused.

ARTICLE 6.—*The delivery and measurement of the wood.*

The ties shall be delivered at those depots indicated in the contract and at the time agreed upon. They shall be examined and measured with the greatest care, by an agent of the company, in the presence of the contractor or his agent, and the dimensions shall be noted down immediately on the bill of lading, which the agent of the company must sign in order to accept the wood.

The pieces shall be marked with the letters of the trade-mark indicated in the picture accompanying the contract.

The measurement shall be made with a unit of 5 centimetres (2 inches) for the lengths and of 1 centimetre (0.39 inch) for the widths and thicknesses, the last being measured where the wood is narrowest. All fractional parts of 5 centimeter (2 inches) in the lengths and of 1 centimeter (0.39 inch) in the widths and thicknesses, shall not be counted.

All the pieces which have one, or better two, dimensions that do not come up to the minimum requirements in article 4, shall be rejected. The pieces whose dimensions exceed those indicated as maximum requirements may be accepted, but without taking the excess into account.

The ties that have been accepted shall be stamped with the trade-mark of the company.

The ties that have been refused must be removed from the depot by the contractor after each delivery. The bill of lading shall not be returned to the contractor after the receipt of the goods until all the refused ties have been cleared away.

ARTICLE 7.—*Charges of the contractor.*

All the expenses of transportation, loading, and unloading, and all hand labor involved, shall be at the cost of the contractor. The wood received at the stations indicated in the contract shall be stacked up with care by the contractor, on the place designed for this purpose. The contractor shall guarantee to be held responsible for all claims of damage done the neighboring roads and forests, owned by the company or of other ownership.

RESOLUTIONS FOR THE SUPPLY OF BEECH-WOOD TIES.

ARTICLE 1.—*Kind of wood and source of supply.*

The ties shall be of beech wood. All wood that was not felled between October 1st and March 1st, and that was not delivered before the 1st of June, shall be refused. The wood shall be gotten from those places indicated in the contract. The engineer of the company shall have the right to exclude wood of other source which seems to him to be of inferior quality.

ARTICLE 2.

The ties shall be square. The upper and lower surfaces shall be dressed with a saw: the sides may be hewn with an ax.

The under side, which rests on the roadbed, shall have sharp, angular edges.

Imperfections shall be allowable on the opposite surface, if they do not measure more than 5 centimeters ($0^m.05=2$ inches). Ties with three sawed surfaces and one rounded one, as well as ties with two parallel sawed surfaces, shall be accepted as square. All beech ties shall be completely stripped of their bark.

ARTICLE 3.—*Dimensions of the ties.*

All ties have for their length: From 2 metres 60 centimetres ($2^m.60-8.53$ feet) to 2 metres 70 centimetres ($2^m.70=8.85$ feet).

Their thickness shall be: From 14 centimetres ($0^m.14=5.5$ inches) to 16 centimeters ($0^m.16=6.3$ inches). Their width shall be: From 23 centimetres ($0^m.23=9.05$ inches) to 26 centimetres ($0^m.26=10.24$ inches).

The ends of all ties shall be finished off with a cross-section perpendicular to the length.

ARTICLE 4.—*The quality of the wood.*

The ties shall be of perfectly straight grain. The wood shall be free from decay; the inner wood must neither be red nor grey; the wood must be free from bad knots, twists, frost clefts, stings, and all other blemishes.

All wood that is defective shall be absolutely refused, and the agents of the company shall be allowed to use all possible means of control which they deem necessary in order to make sure that the wood shall be free from these faults.

ARTICLE 5.—*The provisionary delivery and the measurement.*

The ties shall be delivered at the depots indicated in the contract and at the time agreed upon, in batches of not less than 200 pieces per station. All orders demanding less than 200 pieces shall be filled in one shipment.

They shall be examined and measured with the greatest care by the agents of the company, in the presence of the contractor, and the dimensions of each tie shall be written on the bill of lading, which shall be signed before the goods have been finally accepted. The measurements shall be taken with 5 centimetres (2 inches) as a unit of measure for the lengths and 1 centimetre (0.39 inch) for the widths and thicknesses. The last two dimensions shall be measured in the narrowest part of the wood. All fractional parts of 5 centimetres (2 inches) in the lengths and of 1 centimetre (0.39 inch) in the thicknesses and widths shall not be counted. The average cube of the ties shall not be less than the cube which is the result of the average of the upper and lower dimensions. In case it is not large enough, the price stipulated in the contract shall be reduced in the proportion in which the actual cube stands to the required cube.

All pieces which have one, or, better, two or three dimensions that do not come up to the minimum requirements as stated in article 4 shall be refused. Those pieces whose dimensions exceed the measurements of the maximum requirements may be accepted, but without taking any account of the excess. The ties that have been accepted shall be stamped at both ends with the trade-mark of the company.

The ties which have been refused shall be removed from the depots by the contractor after each delivery. The bill of lading shall not be returned to the contractor until all the refused ties have been cleared away.

ARTICLE 6.

All expedients which the agents think necessary in order to insure the quality of the wood, all expenses of transportation, all hand labor involved in delivery, and loading and unloading shall be charged to the contractor.

The ties which have been accepted shall be piled up by the contractor at his own expense. The stacking shall be done in regular piles and with all precautions necessary to insure the preservation of the wood.

It is the object of these resolutions to forbid absolutely the selling of any part of the supply without the written consent of the company.

EXHIBIT E.

TESTING OF IMPREGNATING SOLUTIONS FOR IMPERIAL PRUSSIAN RAILWAYS.

For the impregnation of timber there are at present two products in use: 1st, chloride of zinc; 2d, tar oil.

TESTING OF CHLORIDE OF ZINC.

The chloride of zinc for impregnating purposes will be manufactured as a concentrated solution, containing about 50 per cent of anhydrous chloride of zinc. It is best to use such a strong solution for testing, and for that purpose samples are to be taken directly from the shipping tank or carboy.

The zinc chloride solution used must be as free from impurities as possible, particularly from iron and free acid. Therefore it is to be determined whether or not iron and acid are present.

TEST FOR FREE ACID.

Twenty grammes (by weight) of the above strong zinc chloride solution are to be mixed with distilled water; the whole to amount to 100 cu. cm. (by measure), the mixture to be well shaken.

(*a*) There is no free acid present if the mixture by shaking becomes cloudy, and particularly if, after a short period of rest, flakes settle down which will again dissolve to a clear fluid upon the addition of a few drops of muriatic acid (HCl). No further test is then required.

(*b*) If after shaking the mixture remains clear, then an excess of acid is present, the amount of which can be determined by the following manipulation:

Take several reagent bottles and put in each 10 cu. cm. of the above-described mixture; then add to each bottle a measured successively increasing quantity of a solution of one-tenth normal soda. For example: Add to the first reagent bottle 0.1 cu. cm.; to the second, 0.2 cu. cm.; to the third, 0.4 cu. cm., and so on. Shake well and observe in which bottle a remaining white, flaky precipitation will settle. The proportion of soda which lies between the mixture where a precipitation is produced and that where no precipitation is produced exactly represents the quantity of free acid present in the solution. For example, the mixture in the bottle to which 0.2 cu. cm. of the soda solution was added remains clear, while in the following reagent bottle, where 0.4 cu. cm. soda solution was added, a precipitation is produced, then 0.3 cu. cm. soda solution is exactly the quantity corresponding to the free acid present in the chloride of zinc solution.

Should there be required for this test more than 0.4 cu. cm. of the one-tenth normal soda solution, then the percentage of free acid is too high in the chloride of zinc solution, and such solution must not be used for impregnation.

TESTING FOR IRON.

Take 10 cu. cm. from the above-described mixture of zinc chloride solution and distilled water, and add a few drops of concentrated nitric acid (HNO_3) and shake well. Divide this mixture into two equal parts. To one part, without diluting, add a quantity of ammonia (NH_4OH) and shake well. If this mixture remains clear, no iron is present. Through the presence of iron in the mixture, more or less brown flakes will precipitate, corresponding to the amount of iron present. Should there precipitate in the mixture a quantity of gray-white (not brown) flakes, then not only iron, but also another impurity (nearly always magnesia) is present. In this latter case a more complete test has to be made, and therefore the zinc chloride solution must be sent to a chemist. But this case will happen very seldom.

The second part of the mixture of 10 cu. cm. to which nitric acid was added, should be diluted with distilled water, and 5 cu. cm. of a solution of 10 per cent yellow prussiate of potash added, the whole to be well shaken. A very ample precipitation will be produced, which will look snow white or very light yellowish if the zinc chloride solution is free from iron; but in the presence of iron it will look more or less blue, according to the amount of iron. If the precipitation shows a corn-flower-blue color, then the zinc chloride solution surely contains a high percentage of iron and must therefore be rejected.

To avoid, in testing, the weighing of the 20 grammes of the strong solution, the use is recommended of the easier method of measuring. First find the specific gravity, at 15° Celsius, of the strong concentrated zinc chloride solution. The quotient of this specific gravity into 20 grammes shows the number of cubic centimeters which must be measured off and which represent exactly 20 grammes by weight. For instance, the specific gravity of the strong zinc chloride solution is 1.6, then 1.6 divided into 20 grammes gives the number of cubic centimeters $\left(\frac{20}{1.6} = 12.5 \text{ cu. cm.}\right)$ which have to be measured off to be used for testing as described above.

TESTING OF TAR OIL.

At a temperature of 20° Celsius the tar oil must be limpid, and to test it shake the tar oil well, pour a few drops on a folded filter paper, and observe whether after absorption there remain undissolved particles on top of the paper. If the amount of these is large, the tar oil must not be used for impregnation. To find the specific gravity, the tar oil must be heated, or cooled off, to a temperature of 15° Celsius; then drop slowly an hydrometer into the same, and read the number at the surface of the oil. This number indicates the specific gravity of the tar oil at 15° Celsius; small variations in temperature are of minor importance, and can be corrected closely enough by adding or substracting 3 to the figure in the third place of the specific gravity for every 2° variation from 15° Celsius.

LABORATORY DISTILLATION OF THE TAR OIL.

By means of a funnel, 102 cu. cm. of tar oil at about 15° Celsius are to be filled into a retort, a thermometer is to be inserted, but in such a manner that the quicksilver ball shall be in or below the neck of the retort but shall not touch the oil, or will not be covered by the same. The retort must be heated slowly, until all the water, which is contained in nearly every tar oil, is evaporated. . Stronger heat can then be applied to the retort, but it must be so regulated that in one second two drops will distill over. The distilled product will be caught in a graduated glass cylinder, and the different quantities are to be read and noted which distill over from the oil (become volatile), within the various intervals of temperature, say from 125° to 150° Celsius, from 150° to 235°, and again from 150° to 355° Celsius, and which are specified in the "Description of the Process and Specifications" as to the composition and proportions of the impregnating fluid.

FINDING THE PERCENTAGE OF CARBOLIC ACID (ACID CONSTITUENTS OF THE OIL).

The entire amount of the distilled tar oil is to be mixed in a separating funnel with 50 cu. cm. of caustic soda of 1.15 specific gravity at 15° Celsius, shaken well for about five minutes, after which let it stand and settle. The caustic soda absorbs the carbolic acid and precipitates; the stopcock of the funnel is to be opened and the precipitated caustic soda is caught in a 200 cu. cm. graduated glass cylinder. The same operation must also be repeated with 50 cu. cm. of fresh caustic soda, to make sure that all carbolic acid is extracted from the oil. The caustic soda of both manipulations is then to be combined, about two tablespoonfuls of salt (NaCl) added and this dissolved by means of stirring; the required quantity of concentrated muriatic acid (HCl) added, and the combination again stirred up until well mixed. After cooling off the hot mixture, read the quantity of the separated carbolic acid in percentage of cubic centimeters, and add to this number $\frac{1}{2}$ per cent for the small amout of carbolic acid still remaining in the acid solution.

All the figures obtained are to be compared with those specified in the description of the composition and proportions of the impregnating fluids. Small differences should not be cause for rejection, as small variations in testing, resulting from barometric changes, can not be avoided, and the result of the test is influenced by them. However, the figures obtained by the above-described tests are sufficiently close to judge of the quality of the impregnating fluids. It is not advisable that the tar oil for testing be taken directly from the shipping tank, but it is better to take the samples from the receptacle of the apparatus in the impregnating plant from which the mixing vessels, or the impregnating cylinder (in the impregnation with pure oil) will be supplied.

The Chief of the Operating Inspection 3.

SETTGAST.

BERLIN, *June 14, 1899.*

EXHIBIT F.

WESTERN RAILWAY OF FRANCE—IMPREGNATION WITH CREOSOTE.

ARTICLE 7.—*Process for impregnating with creosote.*

The impregnation with creosote shall consist in the injection, by means of a vacuum and pressure, of crude creosote previously raised to a temperature between fifty and sixty degrees (50 and 60) centigrade (=112° to 140° F.).

ARTICLE 8.—*Composition of the creosote.*

The crude creosote shall be the product of the distillation of gas tar.

It shall be of the first quality and like the samples which the contractors shall give and submit to the approbation of the engineers of the company.

Creosote which does not contain at least five per cent (5%) of phenic acid may be refused.

ARTICLE 9.—*Origin of the creosote.*

The contractors shall be obliged to make known the works from which each of the supplies of creosote come.

ARTICLE 10.—*Condition of the ties before impregnated with creosote.*

The ties to be impregnated must be very dry, and they shall be previously notched by the contractors at the expense of the company, to receive the chairs or Vignoles rails.

That the wood is quite dry shall be assured by weighing a certain number of ties taken at random. The weight of the wood thus ascertained shall not be over eight hundred and fifty kilograms (850 kg.=1,874 pounds) per cubic meter (1.308 cubic yards) for the oak, and seven hundred and fifty kilograms (750 kg.=1,653 pounds) per cubic meter for the beech.

ARTICLE 11.—*Impregnation with creosote.*

The ties to be impregnated shall be placed in a sheet-iron cylinder. After having closed the cylinder filled with ties, a vacuum shall be made within. This vacuum shall be carried to a pressure of $0^{m}.20$ (7.87 inches) of mercury. It shall be maintained during about a quarter of an hour: then the hot creosote shall be introduced by atmospheric pressure at first and then by means of forcing pumps until the cylinder is perfectly full.

These pumps shall continue to work so as to maintain in the interior of the cylinder a pressure which may reach 8 kilograms (17.6 pounds) per square centimeter (0.155 square inch) if that be considered necessary to insure as even as possible a distribution of the creosote absorbed.

The length of each of the preceding operations shall be varied to produce this result, if the usefulness of it should be recognized.

The diameter of the creosote supply pipe in the cylinder and the dimensions of the forcing pumps shall be determined so as to insure the filling of the cylinder in less than fifteen minutes.

ARTICLE 12.—*Reservations relating to the impregnation.*

The processes followed in these operations shall be subject to the approbation of the engineers of the Company, who may, if they think it best for the success of the impregnation, vary the degree and the duration of the vacuum, the temperature of the creosote, and the pressure in the cylinder, as well as the duration of each of the parts of the process.

The temperature in the interior of the cylinder, measured by means of thermometers suitably placed, must never go below thirty degrees (30°) centigrade (=86° F.) during the whole length of the process.

ARTICLE 13.—*Quantity of creosote to be applied to each tie.*

1. The creosoting of the oak ties with sapwood shall be conducted in such a manner that the sapwood shall be entirely impregnated with creosote.

2. Ties of beech: The impregnating of the beech ties shall be conducted in such a manner that the average absorption per tie shall be fifteen (15) kilograms (33.07 pounds) of creosote.

If the engineers of the company see fit to increase or diminish this quantity of creosote, the contractors shall be obliged to conform to the instructions they receive on this subject.

In that case the difference, either greater or less, between the amount of creosote really used and the amount fixed upon above shall be taken into account on the value of the ties at the price fixed by the contract.

The absorption shall be ascertained by means of a gauge, which shall indicate in the reservoir a diminishing of the liquid supposedly brought to an ambient temperature corresponding to as many times fifteen (15) kilograms (33.07 pounds) as there are ties in the cylinder.

When the ties are taken from the cylinder the absorption of the creosote shall be ascertained by boring with a gouge. All ties in which the creosote has not penetrated to a depth of three centimeters ($0^m.03$=1.18 inches) shall be refused and subjected to another injection.

By virtue of experiment the absorption of the creosote may be ascertained, besides, by weighing, before and after impregnating, the ties which are put in the cylinder. For this purpose the contractors must place scales in the lumber yard.

The agents of the company may take any other means which they think necessary to ascertain the amount of creosote absorbed by the ties.

ARTICLE 14.—*Supervisor of the impregnating of the ties.*

The company shall have one or more agents supervise all the processes relating to the impregnating of the wood, in order to ascertain that the work is carried on under favorable conditions.

ARTICLE 15.—*Room reserved for the agents charged with the supervision of the creosoting.*

A room with a separate entrance shall be reserved on the premises of the lumber yard, to be put at the disposal of the company's agents. It shall be warmed, lighted, and kept in order by the care of the contractors.

ARTICLE 16.—*Renting of the company land occupied by the lumber yard.*

The grounds where the creosoting yard is set up shall be rented of the company by the contractors, in virtue of a special lease whose duration shall be equal to that of the contract.

ARTICLE 17.

Patent right.—The amount to be paid to the inventors for patent rights shall be entirely at the cost of the contractors, who will insure the company against any claim of that sort.

D. T.

MANAGEMENT OF WORKS. WESTERN RAILROADS OF FRANCE. GENERAL SERVICE.

CIRCULAR.

Object: Instructions concerning the depth to be given to the ballasting of tracks.

PARIS, *July 5th, 1893.*

The depth to be given to the ballasting, which was usually fixed at $0^m.60$ (23.6 inches) on the lines established previous to the last few years, has been reduced by various ministerial decisions to $0^m.50$ (19.7 inches) for the lines now in construction.

The depth of $0^m.60$ (23.6 inches) presumed the upper surface of the ballasting to be level with the top of the rail in order that the spikes which hold the rails in the chairs might be well covered with ballasting. According to this supposition, the depth of $0^m.60$ (23.6 inches) is distributed in the following manner:

	Meter.	Inches.
Depth corresponding to the height of the rail	0.13	5.1
Depth corresponding to the base of the chair	.05	2.0
Depth corresponding to the thickness of the tie	.14	5.5
Total	.32	12.6
Remainder for the depth of the ballasting under the tie	.28	11.0
Total depth of the ballasting	.60	23.6

In reducing the total depth of the ballasting to $0^m.50$ (19.7 inches), it is necessary to determine in what manner this depth is to be distributed.

The steel spikes, the use of which is becoming more general, do not need to be covered by the ballasting, and therefore it is not necessary that the ballasting should be level with the top of the rail. On the other hand, the depth of the ballasting under the tie forming the true roadbed can not be perceptibly reduced. Starting, then, with the ballasting under the tie of a depth of $0^m.25$ (9.84 inches), considered indispensable, the total depth of $0^m.50$ (19.7 inches) will be distributed thus:

	Meter.	Inches.
Depth of the ballasting under the tie	0.25	9.8
Depth of the ballasting corresponding to the thickness of the tie	.14	5.5
Depth of the ballasting corresponding to the base of the chair	.05	2.0
Total	.44	17.3
There will remain, therefore, for the depth of the ballasting, corresponding to the height of the rail	.06	2.4
Total depth of the ballasting	.50	19.7

The total height of the rail being $0^m.130$ (5.1 inches) for the rail D. C. of 38 K. 75 and $0^m.142$ (5.6 inches) for the rail D. C. of 44 K., the ballasting must be leveled off below the surface of the rail—$0^m.07$ (2.76 inches) for the rail of 38 K. 75 and $0^m.082$ (3.23 inches) for the rail of 4 K.

For the roads already established with a depth of ballasting of $0^m.60$ (23.6 inches), and having wooden spikes, this depth may, as stated above, be reduced to $0^m.50$ (19.7 inches) by degrees as the ballasting is renewed and steel spikes substituted.

Under no circumstances should the depth of the ballasting under the tie be reduced to less than $0^m.20$ (7.87 inches).

In curves, where, on account of the increased height of the outer rail, the position of the tie on the ballasting is inclined, the depth of the ballasting in the axis of the track must be regulated in such a manner as to have the minimum depth at least $0^m.20$ (7.87 inches) under the end of the tie on the inside of the curve.

As to the width of the driftway of the ballasting, it is fixed at $1^m.00$ (39.37 inches) by article 7 of the specifications of June 11th, 1859. However, it is absolutely impossible to obtain this width on lines where the roadbed has been made with a reduced width, such as on a few tracks constructed when railroads were first built, on certain lines of local concerns which have been brought in, or on others actually in construction. for which a width of 5 meters (16.4 feet) has been adopted as the width of the roadbed for a single track. Under no circumstances should the width of these driftways be reduced to less than $0^m.80$ (31.5 inches). To obtain this width the slope of the ballasting may, if necessary, be made as steep as its nature will permit, or, if this can not be done, the footway at the base of the ballasting may be diminished. This footway when normal should have a width of $0^m.50$ (19.7 inches), and should always be clearly defined even when reduced in width.

Only for roads with a narrow track shall the width of the driftway of the ballasting be reduced to $0^m.75$ (29.5 inches), conformably with article 2 of the convention of March 25th, 1885.

DIRECTOR OF WORKS.
E. CLERK.

EXHIBIT G.[a]

LONDON, BRIGHTON AND SOUTH COAST RAILWAY COMPANY.

SPECIFICATIONS AND CONDITIONS OF CONTRACT FOR CREOSOTED REDWOOD SLEEPERS.

1. This proposed contract is for the supply and delivery of—

——— sleepers at Deptford Wharf,

——— sleepers at New Haven Wharf,

or any less number that the directors may decide to accept.

2. The dimensions are to be the customary 9-ft. length (say $8\frac{11}{12}$ ft.) 10 by 5 ins. rectangular, cut from square blocks out of which neither more nor less than two sleepers can be sawn (no centers will be accepted).

3. The quality shall be the best Baltic redwood fir, in good condition, free from shakes, dead knots, and other defects.

4. Sixty per cent of the sleepers to have on one side a flat surface not less than 9 ins. wide throughout the length, and the remainder to have on that side a flat surface not less than 8 ins. wide throughout the length. All sleepers to have a flat surface not less than 10 ins. wide on the other side, with sharp edges throughout the length.

5. Ninety per cent of the sleepers to have not less than $8\frac{1}{2}$ ins. and the remainder not less than 7 ins. diameter of heart at both ends.

6. The blocks from which the sleepers are cut must be of last autumn's deflotation at the port of shipment; any delivered of an earlier deflotation will be rejected.

7. The sleepers are to be cut and stacked from four to six months (or until they are considered sufficiently dry by the company's engineer or his inspector) before they are creosoted. They are to be adzed to a true plane for a width of 17 ins. at each end for the chair seating, and 40 per cent, or such other percentage as may be required, are to be bored with eight holes, namely: Two $1\frac{1}{8}$ ins. diameter at each end (for trenails) and two $\frac{5}{8}$ in. diameter at each end (for spikes). A template showing the position of these holes will be provided by the company, and the contractors must bore the holes exact to it and perfectly true through the sleepers.

8. The sleepers will be inspected at the contractor's wharf before being creosoted, and the engineer shall have power, personally or by deputy, to reject any sleepers he may consider inferior, either in quality of timber or from any deviation from the specification, and his decision in the manner shall be final.

9. The sleepers when sufficiently dry are to be placed in a wrought-iron cylinder, and when closed a vacuum is to be created by air pumps. The creosote, at a temperature of 120° Fahr., is to be allowed to enter the exhausted cylinder, and afterward maintained there by pumping at a pressure of not less than 120 lbs. to the square inch. The sleepers are to be kept under this pressure until each sleeper has absorbed at least 3 galls. of creosote on the average, the quantity to be ascertained by weighing,[b] any charge of sleepers not giving the average impregnation of at least 3 galls. to be returned to the cylinder for further treatment.

10. The creosote to be a pure coal-tar distillate of the very best quality, free from water and all impurities, and on analysis to give the following results:

To be entirely liquid at a temperature of 120° Fahr. and remain so on cooling to 93 degrees.

To contain not less than 25 per cent of constituents that do not distil over at a temperature of 600° Fahrenheit.

To yield, to a solution of caustic soda, not less than 6 per cent by volume of tar acids.

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[a] Reprinted from Chanute. Preservation of Railway Ties in Europe.

[b] In practice one trolley is weighed out of each charge.

The specific gravity at 90° Fahr. to range between 1.040 and 1.065, water being taken as 1.000 at the same temperature.

11. The contractor is to supply a copy of the analysis of each delivery of the creosote oil used, in the terms of the specification, and the engineer shall be at liberty to take samples of the oil from time to time and have the same tested, the contractor paying the cost of the analysis to the extent of one analysis for each 10,000 sleepers. Any additional analysis to be made at the company's expense.

12. Delivery shall be made alongside the company's New Haven and Deptford wharves, at either of the rates mentioned below, at the option of the company's storekeeper, until the contract is completed. Delivery at Deptford will be taken by open barges containing not more than 1,800 sleepers each. The craft to take regular turns for discharging and conform to the regulations of the company's wharves: At Deptford, to commence ——— and continue at the rate of ——— sleepers per week. At New Haven, to commence ——— and continue at the rate of ——— sleepers per week.

13. Should the contractor fail to deliver the sleepers, or any portion of them, as stipulated in condition No. 12, the directors may cancel the contract, or the residue thereof, and obtain other supplies in such manner as they think fit, and the contractor shall pay to the company any extra cost and expenses incurred by such failure, or the directors may deduct the amount from any sum then due or becoming due to the contractor.

14. The shipping port or ports must be named in the tender; and if more than one port, the number of sleepers proposed to be shipped at each port must also be given; bills of lading to be produced by the contractor when required.

15. The price per sleeper is to include every charge except wharfage and landing at the company's wharves.

16. For sleepers delivered and approved during one month payment will be made at the company's next monthly pay day by cash, less 2½ per cent discount, provided the company have no claim on the contractor as specified in condition No. 13. In case of any dispute arising between the contractor and the company or their agents as to the meaning of any of the terms and conditions of this contract, the decision of the company's engineer shall be final and binding upon all parties.

17. The contractor shall, if required, enter into and sign a formal contract with the directors and find good and sufficient surety to guarantee its proper fulfilment; the expense of such contract and bond to be paid by the company.

18. The directors do not bind themselves to accept the lowest or any tender.

19. The tenders are to be returned by post, addressed to "The Secretary, L., B. & S. C. R., London Bridge, S. E.," and must reach him not later than first post on ———, endorsed on the outside cover "Tender for sleepers."

——— ———,
Storekeeper.

General Stores Office,
New Cross, S. E.

Exhibit H.

Northern Railway Company, France.

Specifications—1893.

For furnishing beech ties of usual shape, creosoted by the new "Blythe" process, called thermo-carbolization.

Article 1. The present specifications refer to the furnishing of ordinary ties for the extension and maintenance of tracks upon the company's various lines.

Article 2. The ties shall be of beech, creosoted by the new "Blythe" process (called thermo-carbolization).

ARTICLE 3. The ties shall be rectangular, or present one of the sections shown in figs. 26 and 27.

The top and bottom faces shall be sawed; the sides may be hewed.

The bottom face, which rests on the ballast, shall be square edged; the two lateral sides shall be without wane for a minimum height of 2 ins. The top face shall be at least 4.4 ins. wide in the middle and for the whole length of the tie.

The minimum dimensions of the ties shall be as follows:

Length (2.60 m.)	8.53 ft.
Width (0.26 m.)	10.2 ins.
Thickness (0.13 m.)	5.1 ins.

ARTICLE 4. The ties shall be practically straight. If curved sideways, the incurvation shall not be more than $\frac{1}{20}$ of the whole length. All ties will be rejected whose bottom face is longitudinally curved, being either convex or concave.

The ties shall be sawed off square at the ends.

ARTICLE 5. The beech wood must be perfectly sound and of the best quality. It shall be neither heart-shaken, nor frost-split, nor brashy, nor worm-eaten. It shall be exempt from dotiness, rotten knots, cracks, splits, bad knots, red-heart, or any other defect. The trees shall be felled between the 1st of November and the end of March. They shall be worked up into ties continuously, which work shall be completed by the end of April. Timber will be refused which has been felled before the 1st of November or not worked up before May 1st.

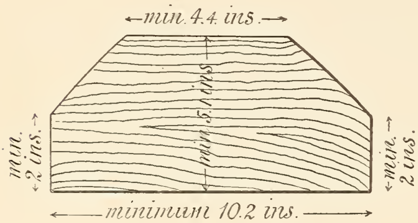

FIG. 26.—Cross-section of tie, Northern Railway of France.

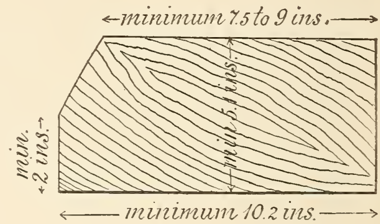

FIG. 27.—Cross-section of tie, Western Railway of France.

All the ties shall be completely barked. As fast as the ties are made they must be piled up carefully, cob-fashion. The chief engineer of the company reserves the right of putting on inspectors to follow up the felling and manufacture of the ties at various points.

ARTICLE 6.—The untreated ties will all be most carefully inspected, both as to quality and dimensions. Those accepted will be stamped at the ends with the company's marking hammer.

All the sticks with any dimensions less than the limits stated in article 3 will be rejected. Those with greater dimensions than required may be accepted, but no allowance will be made for oversize, the ties being purchased by the piece and not by the cubic meter.

If a tie of good quality and otherwise acceptable shows a crack likely to spread open the contractor shall bolt the two parts together or insert an S in the end at his own expense. Every tie split open at the end for its whole width or thickness shall be rejected.

The rejected ties will be left on the hands of the contractor at the point of inspection; they will be so marked as to preclude them from being again offered for inspection.

ARTICLE 7.—The untreated ties must be well seasoned before preparation, and, so far as possible, adzed and bored by the company to fit the rails and the lag screws. The seasoning will be tested by weighing a number of ties haphazard. The weight of the timber thus ascertained must not be more than 46.7 lbs. per cubic foot.

ARTICLE 8.—The ties will be injected with creosote by the new "Blythe" process, called "thermo-carbolization." In this process the ties are subjected to the two following operations:

1. They are enclosed in a cylinder of boiler plate and subjected to a current of steam mixed with creosote oil vapor for a length of time sufficient to insure, during the second operation, the absorption of the prescribed quantity of creosote.

2. The cylinder containing the ties is then filled with a sufficient quantity of crude creosote. This liquid, maintained at a temperature of at least 140° Fahr., is compressed in the cylinder by steam to five atmospheres from the generator, during a sufficient length of time so that the total quantity of creosote injected into the wood, both as a vapor and as a liquid, shall be at least 24.4 lbs.[a] per tie.

If the engineer of the company deems it advisable to increase this quantity of creosote, the contractor will comply with the indications which he may receive relating thereto.

ARTICLE 9.—The creosote shall consist of the mixture of volatile products heavier than water distilled from coal tar produced by gas works. It shall contain at least 6 per cent of carbolic acid, or of analogous products soluble in caustic soda. It shall be entirely soluble in benzine, and completely liquid at a temperature of 122° Fahrenheit. It must, moreover, conform to the samples which the contractor shall submit to the company's engineer.

The contractor shall specify from what gas works each shipment of creosote is received.

ARTICLE 10.—The company shall take cognizance of all the operations relative to the inspection of the wood, through an inspector appointed by the chief engineer. Such inspector shall satisfy himself as to the thorough application of the "Blythe" process, shall keep accounts of the wood injected, and shall verify the results of the injection. He will report, upon a special blank, the following points for each operation:

1. The length of time of application of the mixed steam and oils coming from the vaporizer, as well as the final pressure in this operation, which must be at least five atmospheres.

2. The time occupied in filling the cylinder with crude creosote, the final pressure, and the quantity of liquid absorbed during this operation.

3. The quantity of crude creosote introduced in the vaporizer and in the lower reservoir. This quantity shall not be less, for ten consecutive operations, than an average of 24.2 lbs. per tie injected.

4. Finally, the inspector shall keep an exact account of the total quantity of creosote which the contractor shall receive at the works for injection, so as to check the amount of liquid absorbed during each season's work.

The chief engineer of the company reserves, moreover, the right of using any other checks which he may deem desirable to control the quantity of creosote injection into the wood, either as a mixture of vapors or in the liquid state.

The royalties to be paid to Mr. Blythe or others for the use of the patents, etc., will be at the sole charge of the contractor, who guarantees the company against any claim of this nature.

All experiments made by the company to ascertain whether the creosote is of good quality, and if the injection of the wood is complete, shall be at the charge of the contractor.

ARTICLE 11.—Upon being withdrawn from the cylinder the ties shall be inspected one by one in order to ascertain whether the injection is homogeneous and

[a] Since increased to 35.2 lbs. per tie.

whether the quantity of 24.2 lbs. has been duly absorbed by each. This last verification shall be effected as described in section 3 of article 10.

Such ties as may be incompletely injected, a fact which shall be established by cutting into them with a gouging adze, shall be subjected to a second operation, or even to a third, after which they may be declared, in case of need, as unfit for injection, and finally rejected, as well as those ties which may be deformed by the action of heat in the cylinder.

The contractor shall make no extra charge for these repeatings of treatment, and shall, moreover, either insert a bolt or an S into any tie which shall split during the treatment.

The ties accepted shall be counted and either immediately loaded on cars or piled up at some point designated by the company's agent. The ties rejected shall receive a special mark at the rail seat and will be piled at special points to be indicated to the contractor. These ties shall only be taken away upon authority given by the engineer of the company, who may hold them until the season's contract is filled, so as to avoid their being again presented for inspection by agents.

ARTICLE 12.[a] The final acceptance of the ties shall only take place six months after the full delivery of the season's contract.

Until this final acceptance the company reserves the right of rejecting any ties which may possess defects not detected upon a first inspection, or which may split by reason of a bad quality of wood.

The ties so rejected will be surrendered to the contractor at the point of delivery, who shall either deduct them from his bill or furnish other ties if required by the company.

ARTICLE 13. The contractor shall be governed, save in such modifications as result from the present specifications, by the clauses and general conditions imposed upon contractors doing work for the Northern Railway Company, through the rules drawn up September 26th, 1892, by the chief engineer of the Ponts et Chaussées, Chief engineer of Maintenance of Way, approved October 21st, 1892, by the Executive Committee of said Company, and registered in Paris the 28th of the same month.

EXHIBIT I.

IMPERIAL RAILWAYS OF ALSACE-LORRAINE, GERMANY.

Specifications for impregnating wooden railroad ties—1898.

SECTION 1. For pine ties the impregnating fluid is a solution of chloride of zinc, with an addition of coal-tar oil containing carbolic acid; for beech or oak ties hot coal-tar oil containing carbolic acid must be used.

SECTION 2. The process of impregnating by chloride of zinc solution, with addition of coal-tar oil containing carbolic acid, is divided into three parts:

1. Steaming of the ties.
2. Production of a partial vacuum and admission of the impregnating fluid.
3. Compression (forcing in) of the impregnating fluid.

The ties are loaded on iron cars, which are pushed into the impregnating cylinder; this is closed air-tight, and they are exposed to the action of steam; steaming is continued for a longer or shorter period, according to the time of year and the condition of the ties. The admission of steam into the impregnating cylinder must be regulated in such manner that an inside pressure of 1.5 atmospheres

[a] The same contractor furnishes the ties and treats them.

(22 lbs. per square inch) above air pressure is reached within 30 minutes. For dry ties it will suffice to maintain this pressure in the impregnating cylinder for 30 minutes longer, but for green ties it should be kept up for another hour. For dry ties, therefore, the steaming takes at least 1 hour, while for green ties at least 1½ hours are necessary. A gauge attached to the cylinder indicates existence of the specified pressure. The valve at the bottom of the cylinder must be opened on admitting the steam, in order that the air contained in it may be driven out, but should be closed when steam begins to blow out. This valve should be opened repeatedly, as fast as steam condenses; open it at least every half-hour to draw off the water, and for the last time just before exhausting the air. When steaming is finished, the steam remaining in the impregnating cylinder is allowed to escape.

After steam is discharged a partial vacuum is produced in the cylinder containing the ties, until the vacuum gauge shows at the least a column of mercury of 60 cm. (23.6 ins.); this partial vacuum must be maintained for ten minutes. On expiration of this time, while continually preserving the partial vacuum, allow the impregnating fluid, which meanwhile has been prepared in a separate vessel and heated to at least 65° Cent. (149° Fahr.), to enter the impregnating cylinder, filling it entirely. To prepare the impregnating fluid, add, while heating, 1 kgr. (2.2 lbs.) of coal-tar oil to every 15 kgr. (33 lbs.) (6⅔ per cent) of the solution of zinc chloride.

To insure as perfect a mixture of the solution of zinc chloride with the coal-tar oil as possible, an effective stirring apparatus, combined with injection of steam and air, must be applied.

Next a pressure pump is used to exert an excess of seven atmospheres above air pressure, this pressure to be maintained for not less than 30 minutes. If necessary, continue it for a longer time until the ties have absorbed a certain amount of impregnating fluid, as specified hereafter. The impregnating fluid is then run off.

The chloride of zinc solution intended for impregnating must be as nearly as possible free from foreign substances, and there must be no free acid. An admixture of other metals, notably iron, can only be allowed in a very slight percentage and only if it can not be avoided in the manufacture. The solution must have a strength of 3.5° Baumé = 1.0244 specific gravity at a temperature of 15° Cent. (59° Fahr.).[a] The solution contains 1.26 per cent of metallic zinc.

The coal-tar oil used must not contain over 1 per cent of oils that boil below 125° Cent. (257° Fahr.). It must be so little volatile that its boiling point lies mainly between 150° and 400° Cent. (302° and 752° Fahr.). In no case is it permissible to have more than 25 per cent of its weight volatilized below 235° Cent. (455° Fahr.). It must contain at least 20 to 25 per cent of acid substances (creosote or oils resembling carbolic acid) that are soluble in caustic lye of soda of 1.15 specific gravity. The coal-tar oil must be entirely liquid at +15° Cent. (59° Fahr.), and as much as possible free from naphthalene, so that on evaporation (fractional distillation) produced in a glass vessel in groups of 50° each it shall leave a residue of not more than 5 per cent of naphthalene. Its specific gravity should not be less than 1.020 at a temperature of +15° Cent. (59° Fahr.) and should not exceed 1.055. To remove such impurities from the impregnating fluid as are due to the process, suitable settling (clarifying) apparatus should be provided.

The contractor is required to report where he obtains his supplies of zinc-chloride solution and of coal-tar oil, intended for use, and to furnish samples of the same to the supply office of the Imperial railways at Strassburg, in Alsace, before com-

[a] 3.5° B. corresponds to 2.62 per cent dry zinc chloride. Hence, 19 × 2.62 per cent amounts to 0.498 lb. of dry zinc chloride per cubic foot.

mencing to impregnate. He will be permitted to purchase the solution of zinc chloride and the carbolized oil of coal tar only from such factories whose samples have been approved by the management of the railways. The railway management reserves the right to test the fluids used at any time.

It is specified that the average absorption of impregnating fluid contained in every charge of the cylinder shall be the following:

(A) Absorption of 35 kgr. (77 lbs.) for each tie of the first class, length of 2.70 m. (8.85 ft.).

(B) Absorption of 26 kgr. (57 lbs.) for each tie of the second class, length of 2.50 m. (8.2 ft.).

(C) Absorption of 310 kgr. per cubic meter (19 lbs. per cubic foot[a]) for ties of other dimensions.

To determine the amount of impregnating fluid absorbed by the ties, the following method must be adopted:

Weigh all ties on a platform scale placed under roof immediately before steaming them and again after impregnating when dripping has ceased. The difference in weights equals amount of impregnating fluid absorbed. A deduction of 15 pfennigs per 10 kgr. (16 cents per 100 lbs.) will be made for shortage shown by this weighing test. In case the shortage amounts to more than one-sixth of the absorption specified the impregnation must be repeated. If, on the other hand, the weighing shows that the ties have absorbed more than the amount specified, a bonus of 15 pfennigs for every 10 kgr. (16 cents per 100 lbs.) will be paid for such increase up to a maximum of 15 per cent.

Section 3. The work of impregnating with hot carbolized oil of coal tar (i. e., oil of coal tar containing carbolic acid) must be divided into two parts:

(1) Drying of the ties, i. e., withdrawing water from them.

(2) Introduction of oil of coal tar under pressure.

The ties are run into the impregnating cylinder and this is closed air-tight. Next, a partial vacuum, equal to at least 60 cm. (23.6 ins.) column of mercury, is produced in the impregnating cylinder and maintained for 10 minutes, and thereupon, while keeping up the vacuum, the hot oil of coal tar is made to flow in until it rises to a level that will prevent sucking over by the air pumps. The flowing in of the coal-tar oil may be accomplished all at once or at intervals, according to the dryness of the ties. While thus filling up, and afterwards, the coal tar is heated up inside the cylinder to at least 105° Cent. (221° Fahr.), but not higher than 115° Cent. (239° Fahr.), by means of steam coils. This heating should be accomplished during a space of time not less than 3 hours. When this temperature is reached in the impregnating cylinder, it must be kept up for another hour, either with or without the partial vacuum, as may be judged necessary, in order that the ties may absorb the specified amount of oil of coal tar.

The impregnating cylinder is connected with a pipe condenser from the instant that filling with hot coal-tar oil commences, and all the aqueous vapors driven out of the ties are condensed in this, the water being carried to a tank. This receiver must have a water gauge from which one can read off the amount of water evaporated from the ties.

After the drying of the ties or the extraction of water from them is finished the impregnating cylinder is filled completely and the pressure pump started, which must produce a pressure of at least 7 atmospheres. This pressure is to be maintained for at least 30 minutes in treating beech ties and 60 minutes for oak ties, unless it proves necessary to prolong the time to obtain the amount of absorption specified. The oil of coal tar is then drawn off.

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[a] 3.5° B. corresponds to 2.62 per cent dry zinc chloride. Hence, 19 × 2.62 per cent amounts to 0.498 lb. of dry zinc chloride per cubic foot.

The coal-tar oil used must be heavy oil, derived from the distillation of coal tar, of greenish-black color, specific gravity of 1.045 to 1.100 at 15° Cent. (59° Fahr.), boiling point between 150° and 400° Cent. (302° and 752° Fahr.).

While making fractional distillation no oils must pass over below 150° Cent. (302° Fahr.) and not more than 25 per cent of the volume at temperature up to 235° Cent. (455° Fahr.).

The coal-tar oil must contain by volume at least 10 per cent of carbolic acid and, at a temperature of 15° Cent. (59° Fahr.), must be free from naphthalene and show no sediment.

To determine percentage of carbolic acid, apply agitation to the oils heated to 400° Cent. (752° Fahr.) with a caustic solution of soda having specific gravity of 1.15. The difference in volume of oil before and after agitation gives percentage of carbolic acid.

The contractor is required to state source of supply for his coal-tar oil and to furnish samples to the supply office of the Imperial railways at Strassburg before he commences work of impregnation. The coal-tar oil can only be purchased from factories whose samples have been approved by the railway management. The railway management reserves the privilege of at any time testing the coal-tar oil used.

It is specified that the average absorption of coal-tar oil for every charge of the cylinder shall be:

(*a*) For one railroad tie, 1st class, 2.70 m. (8.85 ft.) long, of oak wood, 11 kgr. (24 lbs.); of beech wood, 36 kgr. (79 lbs.).

(*b*) For one railroad tie, 2d class, 2.50 m. (8.20 ft.) long, of oak wood, 8 kgr. (18.6 lbs.); of beech wood, 28 kgr. (61.6 lbs.).

(*c*) For ties of other dimensions per cubic meter (35.3 cu. ft.), of oak wood, 100 kgr. (220 lbs.); of beech wood, 325 kgr. (715 lbs.).

To determine the amount of coal-tar oil absorbed by the ties, these are weighed before the impregnation and again after it, when dripping of oil has ceased, using a platform scale placed under a roof. The difference in weight is amount of coal-tar oil absorbed. Correct the weight of the ties before impregnation by deducting from it weight of water delivered by condenser to the tank and obtained from the vapors distilled while drying in hot coal-tar oil, as weight of ties is reduced to this extent by drying process. If on examination it is proved that absorption amounts to less than five-sixths of that specified, the impregnation must be repeated.

For every shortage in coal-tar oil shown by above test a deduction of 50 pfennigs for 10 kgrs. (54.5 cents per 100 lbs.) will be made, but, on the other hand, an increase in absorption will be paid for at the same rate, a maximum of 15 per cent increase being the limit of such payment.

Section 4. The contractor is required to give eight days' notice to the supply office of the time of intended commencing to impregnate ties, in order that the office may send an official to supervise same. This official must be freely admitted at all times to the plant of the contractor, and all desired information must be readily furnished him. The contractor must furnish all necessary appliances, apparatus, and labor to make tests without charge.

Section 5. In case the contractor does not supply his own ties, the parties furnishing them will be required to deliver f. o. b. cars at the station nearest to the impregnating works, provided they are shipped by rail. Ties delivered by wagon or other conveyance will be delivered loaded at storage yards of the factory without charge.

The hauling of ties from the station to factory will be at the expense of the contractor for impregnation. He has also to provide for unloading, piling, and handling of ties as per regulations. The contractor will be paid for this labor the amount of 8 pfennigs (1.92 cents) for each track tie and 4 pfennigs (0.96 cent) for each switch tie of 1 m. These prices cover the expense of labor and tools required in receiving green ties as well as that of reloading rejected ties, payment for a tie to be made only once.

SECTION 6. The contractor for impregnating is held liable for all damages and loss of ties that may occur from the time they are delivered to him at the railroad station, or at his works, as long as ties remain at his works. This liability includes losses by fire occurring at the impregnation works and by theft committed while ties remain there. The contractor must pay the value of all missing ties or of such as become unserviceable previous to their return after impregnation, but is not liable for splitting. He is, however, required to furnish without charge all necessary S hooks and bolts for drawing together the cracks occurring during storage, and has to drive or put these in according to directions of the supervising official.

When ties are turned over to the contractor for impregnation, they are already supplied with S hooks needed to draw together all existing cracks. Each beech track tie is also fitted with two iron bolts running through it about 10 cm. (4 ins.) from each end in the direction of its breadth. It is his duty, therefore, to supply without charge only such S hooks and bolts as may be needed thereafter, and of the same kind, and to fasten them.

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BULLETINS OF THE BUREAU OF PLANT INDUSTRY.

The Bureau of Plant Industry, which was organized July 1, 1901, includes Vegetable Pathological and Physiological Investigations, Botanical Investigations and Experiments, Grass and Forage Plant Investigations, Pomological Investigations, and Gardens and Grounds, all of which were formerly separate divisions, and also Seed and Plant Introduction, The Arlington Experimental Farm, Tea Investigations and Experiments, and the Congressional Seed Distribution. Beginning with the date of organization of the Bureau, the independent series of bulletins of each division was discontinued, and all are now published as one series of the Bureau.

The bulletins published in the Bureau series are:

No. 1. The Relation of Lime and Magnesia to Plant Growth. 1901.
2. Spermatogenesis and Fecundation of Zamia. 1901.
3. Macaroni Wheats. 1901.
4. Range Improvement in Arizona. 1901.
5. Seeds and Plants Imported through the Section of Seed and Plant Introduction, etc. Inventory No. 9. 1902.
6. A List of American Varieties of Peppers. 1902.
7. The Algerian Durum Wheats. 1902.
8. A Collection of Economic and other Fungi prepared for distribution. 1902.
9. The North American Species of Spartina. 1902.
10. Record of Seed Distribution and Cooperative Experiments with Grasses and Forage Plants. 1902.
11. Johnson Grass: Report on Investigations Made during the Season of 1901. 1902.
12. Notes on the Grasses and Forage Plants and the Forage Conditions. 1902.
13. Experiments in Range Improvement in Central Texas. 1902.