Campbell & Kautz

A determination of

the comparative values of

cross-ties of different materials

Railway Civil Engineering

Civil Engineering

B. S.

1910

A DETERMINATION OF THE COMPARATIVE VALUES OF CROSS-TIES OF DIFFERENT MATERIALS

BY

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PAUL KAUTZ

THESIS

FOR THE

DEGREE OF BACHELOR OF SCIENCE

IN

RAILWAY CIVIL ENGINEERING, NEIL NELSON CAMPBELL

IN

CIVIL ENGINEERING, PAUL KAUTZ

COLLEGE OF ENGINEERING

UNIVERSITY OF ILLINOIS

PRESENTED JUNE, 1910

UNIVERSITY OF ILLINOIS

May 26, 1910

THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

Neil Nelson Campbell

ENTITLED A DETERMINATION OF THE COMPARATIVE VALUES OF CROSS-TIES OF DIFFERENT MATERIALS

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF Bachelor of Science

Railway Civil Engineering

Shelby S. Roberts
Instructor in Charge

APPROVED: Edward C. Schmidt

HEAD OF DEPARTMENT OF Railway Engineering

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Contents.

Introduction.

In order to supply the increasing demand for timber, an enormous amount of it has to be cut.Most of this is used for building material,cross ties,fence posts,telegraph poles,etc. In 1906,the railroads of the United States alone purchased 102,834,042 ties,at a total cost of $48,819,124-an average of 47 cents per tie.In 1905,the number of ties purchased amounted to about 15,000,000 less than in 1906,but this does not necessarily mean that the demand for ties is increasing at the rate of 15,000,000 per year.From these figures we see that the amount of timber cut from our forests each year is enormous,and at the rate at which railroads are now being built and new industries introduced,the demand for timber is bound to increase even faster than it has in past years.

Most of the timber in the past came chiefly from sources along the lines of railroads already built,and as this became exhausted the forests farther back were tapped.In the early period of railroad construction,the principal source of supply of white oak ties was Pennsylvania,Ohio,Indiana,and Wisconsin,but at present these states furnish very little,the supply now coming from Missouri,Arkansas,Kentucky and Tennessee.

Fifteen years ago,the railroads purchased,for the most part,the very best white oak ties,of which nearly all were obtained from forests adjacent to their lines.Now the Eastern roads draw the larger part of their tie supply from the

pine forests of the South and from points in Canada,those of the North and Central West from the Pacific Coast,while those of the Central States are drawing from the forests in the lower Mississippi valley.Although the points of supply change slowly, it is evident that unless something is done to protect our forests the timber proposition will be a serious one in the near future.

Both the Department of Agriculture of the Unites States, and the tie and timber departments of the various railroads,are paying a great deal of attention to the preservation of our forests and the planting of treeless areas for future use.Much attention is also being paid to the methods of preserving the timber used,thus not only making it cheaper on account of its greater life,but also by decreasing the quantity used.In the past,the high grade timbers have always been cut and used first while the inferior woods were left standing.One of the great problems that confronts the railroads of today is to devise means whereby the inferior woods,such as swamp-oak,tanarack, lodgepole pines,loblolly pine,gum,etc.,can be treated so as to make them valuable for ties,leaving the white oak and other superior woods for higher grade structural purposes.

In the following pages some attention will be given to the causes of decay in timber,together with a brief outline of the present methods of preservation used in this and other countries.The cutting and seasoning will also be considered, together with the value and necessity of tie plates and better methods of fastening the rail to the ties.In conclusion,we will make an economic comparison of cross ties of different materials

from data received from represented railroads all over the United States, and show the relative value of the different timbers used for cross ties; also the effect which treatment has on their total capitalization and annual cost.

The subject will be considered under the following heads;

1. The structure of timber.
2. Factors which cause decay and how they work.
3. Methods of preserving timber.
4. Cutting and seasoning ties.
5. Tie plates.
6. Rail fastenings.
7. Steel and concrete ties.
8. An economic comparison of cross ties of different materials.
9. Conclusions and recommendations.

The Structure of Timber.

In order to fully comprehend the problems which have to be solved in impregnating timber, it is necessary to have a general understanding of the structure and composition of the wood itself.

Wood is composed of a series of closed tubes extending parallel with the trunk of the tree and fitting into one another endwise so as to form a splice. These tubes vary in size, those formed in the spring when growth is most active being of larger diameter and lighter in color than those formed in the

summer.A group of spring tubes,together with the corresponding summer tubes,form what is know as an annual ring and represents one year's growth.

The young cells are filled with a semi-liquid mass called protoplasm,but as they grow older they lose their protoplasm and become filled with air and various substances, such as gums and resins.In most woods,a series of tubes extend radially outward from the center of the tree;these are known as pith,or medullary rays.They are especially noticeable in oak wood and on this account the quarter-sawed oak is in great demand as a finishing lumber.The medullary rays are composed of short,thin-walled cells and serve to conduct water and food supplies to the inner portions of the tree.

The outermost rings of the tree constitute the living elements.In them the circulation of water takes place, especially the transfer of the same from the roots to the upper branches.The wood cells are filled with various food substances such as starches,sugar,and oils;but as one goes toward the center of the trunk he finds that the cells gradually lose these contents and are partly filled with air. They are then mature,their walls having reached their maximum thickness and strength become reservoirs for the deposit of gums and resins which remain in the tree but take no active part in its life.The depth to which the living elemnts in a tree go depends on the kind of tree.In the maple and beech, for example,the living elements extend through as many as thirty rings,while in the locust and red cedar not more than

fourteen.This is probaly the cause of the early decay in the maple and beech and of the long life in the locust and red cedar.

From the above we see that the outer or living part (commonly known as sapwood)differs materially from the inner or dead part(known as heartwood)in the presence of large quantities of food materials and in the readiness to transmit water.In general,the purpose of the sapwood is to allow the free passage of water and food supplies from the roots through the trunk to the upper branches,while the heartwood serves to support the crown and living parts.In most trees the heartwood is easily distinguished from the sapwood,being of a darker color due to the presence of certain coloring substances.The change from sapwood to heartwood is apparantly sudden and does not always take place in one full ring each year.It has been noticed that on one side of a tree more rings are heartwood than on the other.What ever the cause of the change from sapwood to heartwood may be,for practical purposes the difference is sufficiently well marked.The heartwood lasts longer than the sapwood and is stronger.In some trees,such as the giants of our Western forests the heartwood resists decay for hundreds of years while in others,such as the willow and maple, apparently offer no resistance.

Factors which cause decay and how they work.

The principal causes of the decay of timber are insects,bacteria,and fungi.The insects,such as white ants and termites,which are so destructive to timber in warmer climates, bore holes in the wood and often riddle it completely. In structural timber,however,decay is more generally caused by fungi or bacteria."Fungi are low plants consisting of colorless threads called hyphae,many hyphae making up the mycelium." The fungi may grow on either the dead or the living parts of the tree, from which they extract certain food materials and finally destroy the tissues.The fungi obtain access to the tree through wounds in the bark,or where large branches are broken off,the latter being the principal source of evil.The spores of the fungi,which are floating around in the air,lodge in the cavaties of the dead branch and there germinate.They finally make their way down the branch until they reach the trunk of the tree,when with deadly effect they work both up and down.

Many trees have numerous natural resources for protecting themselves against these invading parasites,such as thick bark and the exudation of gums and resins which close up the wounds made on the tree.During the early life of the tree,these means are more effective than later.The living portion is quickly covered with gum or resin and finally heals entirely,while on the other hand the dead part, has no means in itself of excluding the spores of the fungi.

Its sole protection lies in the living layer which surrounds it on all sides.The wood of some trees,however,such as the cypress,red cedar,and red wood contains a peculiar chemical compound which protects it against the attacks of the fungi.

After sufficient food has been absorbed,the hyphae form fruiting bodies on the outside of the tree.These fruiting bodies are commonly known as punks,conchs,toad stools, frog stools,etc.,and when ripe they discharge their spores in clouds which float off through the air to find lodgment in other trees.The cells of the trees thus infected are first destroyed and finally the tree itself.

For the development and rapid growth of the bacteria and fungi there must be an abundant supply of food and a certain amount of heat and moisture.Some require a large supply of oxygen,others grow best without it;some require startches and sugars,while others do not;but <u>all</u> require moisture. Even the socalled "dry rot" fungi require a certain amount of moisture for its growth.If this simple principle were adhered to more closely,"That without water there can be no rot," much of the decay of timber could be prevented.We find that the ties in a well drained ballast will last longer than their neighbors in a poor ballast. This is also one of the principal reasons why sap wood decays more rapidly than heartwood.The cells of the sapwood afford free passage of water and contain starches, sugar,oils,etc.,thus forming an ideal place for the

invading fungi to germinate.On the other hand,the heartwood does not admit of a ready circulation of water,and contains certain gums and resins which protect it against the fungi.

It has been found that dry wood will resist the attacks of fungi for an indefinite period of time.The timbers of old buildings have been found perfectly sound after being in service for hundreds of years,Wood completely immersed in water will also resist decay,as the supply of oxygen necessary for the growth of the fungi is cut off. Piles are a good example of this,the portion completely and continuously submerged in water remaining sound indefinitely.

The opinion is common among many railraod men that a hewn tie will last longer than a sawn tie,and for this reason many railroads specify that their ties shall be hewn from young trees.It is claimed by some that in the sawing,a straight line is cut and that more of the cells are opened,thus allowing a freer passage of water into the tie.Also the surface of the sawn tie is rougher and holds moisture more readily,while in the hewn tie the chips are split off along the lines of the grain of the tree and thus a smoother cut is made.Whatever the real or imaginary advantages of the hewn tie over the sawn tie may be,it is a matter of small importance when the ties are treated;but on the other hand,hewing is an extremely wasteful process. It is slow and uneconomical and requires the use of young timber,while older and more mature timber is left standing.

We have seen from the foregoing that the older and more mature trees have less power within themselves to resist the attacks of fungi and bacteria and that much of the timber is affected by these parasites after it reaches a certain age, differing with different trees.It therefore should become the practice of all roads to cut the older and more mature timber and reserve the young trees for future needs,thus saving the timber which is likely to be destroyed by fungi and allowing the young trees to continue to grow.

The qualities of timber which determine its resistance to the attacks of fungi are as yet undefined. The physical qualities,such as hardness,density,and tensile strength seem to have no influence.We find that the hard, strong white oak will decay more rapidly than the cypress. The tamarack and hemlock decay more rapidly than the cedar and the locust.Some of the trees which resist decay more than others are the red cedar,cypress,red wood,locust, catalpa,and arbor vitae,the reason for this increased resistance to decay is probaly due to the presence to some chemical compound which protects them against the invading fungi and bacteria.

Methods of preserving timber.

To get the greatest value out of ties of different kinds,especially those most susceptible to decay it is necessary

to use some preservative which will prevent the work of the destructive fungi and bacteria.The principal materials used in impregnating timber at present are;zinc chloride,zinc sulphate,mercuric chloride,tannic acid,and the products of coal tar distilation.These salts when injected into the timber act as poisons,killing the fungi and bacteria which destroy the wood.According to some authorities the amount necessary to kill these parasites is very small,but the general practice in treating ties is too inject as much of the salts as the tie will hold,because the salts,being soluble in water,leak out when the tie comes in contact with water,and of course,the more salt injected the longer it will take to leak out.It is important here to note that "It is the presence of the injected salts which prevent decay", and that it is impossible for the destructive fungi to work and destroy the wood tissues so long as there is sufficuent of these poisonious salts in the tie.

In order to perfectly protect a tie against the attacks of destructive organisms,it is necessary that the preservative used fulfill the following requirements;

1. It must be poisonous to all destroying agents.
2. It must be capable of comparatively easy injection.
3. It must remain in the wood after being injected.
4. It must protect all parts of the wood.
5. It must be so cheap that its cost will not prevent its use.

At present, the principal methods of treatment used in this and other countries are (1) Creosoting, (2) Rueping process, (3) Lowry process, (4) Card process, (5) Wellhouse or zinc tannin process, (6) Burnett izing or zinc chloride process.

The full cell creosote process is considered the best and most lasting of all the processes in use today. It consists of impregnating the wood cells and fibres of the tie with from 6 to 12 pounds of creosote oil per cubic foot. The wood is first seasoned, preferably in the open, or if not in the open, in steaming retorts-often both. After the steaming, a vacuum is produced and maintained until the oil is introduced. The wood is completely submerged in oil, after which it is put under a pressure of from 100 to 125 pounds per square inch until the desired impregnation is secured. The creosote oil is then drained off, and a vacuum is produced to assist in draining off the surplus oil from the exterior of the tie. The complete process requires in the neighborhood of 6 or 7 hours.

Creosoting is used on all English and most French lines, also extensively in Belgium. In these countries, especially in Franch, marked results have been obtained, due to the unlimited amount of high grade creosote oil injected. In England it was found that the Scotch pine tie, which untreated will decay in five or six years, lasts twenty five years or more when treated with creosote. In France, it is claimed that they get thirty years life out of a beech tie treated with creosote, while untreated it will last only from

three to four years.

The Rueping process, often referred to as a partial cell treatment, is used principally with creosote oil. It consists of forcing conpressed air into the cells of the wood and at a higher pressure creosote oil without relieving the air pressure; then, upon relieving the combined pressure, the air expands and forces out the surplus oil, leaving only the wood fibres impregnated.

The Lowry process, also referred to as a partial cell treatment, is very similar to the Rueping process in that it is used in connection with creosote oil, and the results obtained are the same. It consists in forcing creosote oil into the tie and then drawing out, by means of a vacuum, the surplus oil, leaving only the wood fibres impregnated.

The Card process consists of impregnating the wood cells with a mixture of zinc chloride and creosote oil, about one half pound of dry zinc and from one and a half to four pounds of creosote oil per cubic foot being injected.

In this process, it is necessary to keep the mixture agitated so as to prevent a separation of the zinc and the creosote.

The Wellhouse, or zinc tannin process, as it is commonly called, consists of impregnating the tie with a hot solution containing about one half pound of dry zinc chloride and one half percent of glue per cubic foot of wood; also a second solution containing one half percent of tannic acid. The purpose of the tannic acid is to solidify the first

injection and prevent its leaking out.

Burnettizing or zinc chloride process, is very similar to the zinc tannin process, except that the glue and the injection of tannic acid are omitted. The process consists of impregnating the tie with a solution containing one half pound of dry zinc chloride per cubic foot of tie.

The average costs of the treatments per tie, 7" x 9" x 8'0", are about as follows;

1.	Full cell creosote process	$0.46
2.	Rueping process	$0.31
3.	Lowry process	$0.31
4.	Card process	$0.26
5.	Zinc tannin process	$0.22
6.	Zinc chloride process	$0.15

The success attending any and all of these different treatments depends upon the thoroughness with which it is done, the length of time the tie is allowed to season before and after being treated, the kind of timber treated, etc. In Austria, it was found that pine ties having an average life of about six years, untreated, would last about twenty years when treated with zinc chloride, while an oak tie lasting fifteen years, untreated, would decay in seventeen years after being treated with zinc chloride. Again, a beech tie untreated which last three and a half years in the track will give twelve years service when treated with zinc chloride, and seventeen years when treated with creosote. A fir tie lasting four and a half years untreated will last about nine years

treated with zinc chloride and thirteen years treated with creosote.

These examples illustrate the great variation in the increased life of different ties when treated with the same treatments.The life of the oak tie is increased only two yearsby treating it with zinc chloride,while the life of the pine tie is increased fourteen years.The reason for this is not quite certain but probaly is due to the cell structure of the different woods.

We find that ties impregnated with salts soluble in water soon leak out if placed in the track immediately after treatment,where they come in contact with water at frequent intervals;but,on the other hand,if the tie is thoroughly seasoned after treatment the water from without the tie must first force an entrance into the dry wood before it can dissolve the salts which are in the wood fibre and cause them to leak out.Most of the cells are filled with air also and for this reason the entrance of water from without is a very slow process,thus delaying the time when there is not sufficient of the poisonous salts in the wood to destroy the invading fungi.

Cutting and Seasoning of Ties.

With the greater demand for ties and the increase in price comes the question of the more economic use of our

forests trees.The present method of hewing ties is extremely wasteful and must be improved if we would reserve our forests for future generations.In Europe,we find that all ties are sawn,and that specifications have been adopted which allow the greatest utilization of the material from one tree. Belgium leads in this respect,using ties which are left half round,thus getting two ties out of a tree which otherwise would produce only one.In each case they make use of all the sapwood,and impregnate it so that it will last as long as the heartwood.In hewing ties,a tree ten inches in diameter breast high is large enough to get 6" x 8" tie,

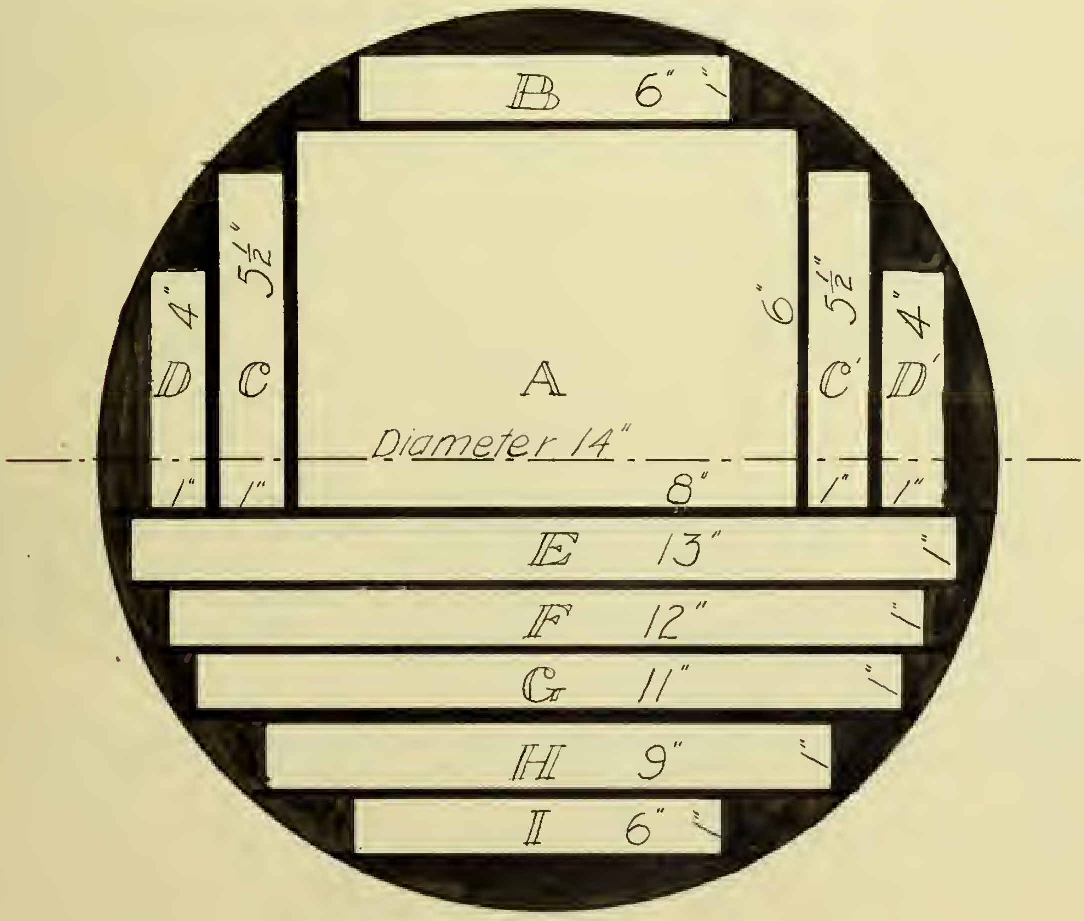


Fig. 1

but we find from the records of the forestry department that about sixty percent of the hewn ties are cut from trees thirteen and fourteen inches in diameter. This waste of timber is wholly unnecessary and with proper methods of sawing we obtain the greatest possible number of ties from each tree and have a considerable amount of lumber left as a by-product.

Fig 1. shows the possibility of cutting A a tie 6" x 8", B board 6" wide, C and C' boards 5½ " wide, D and D' boards 4" wide, E board 13" wide, F board 12" wide, G board 11" wide, H board 9" wide, and I board 6" wide from a log 14" in diameter. Although it is not always possible to get this amount of lumber out of a 14" log yet it shows the possibilty of getting considerable.

By consulting Table 1 we see the gain in lumber resulting when ties are sawn instead of being hewn. Furthermore by a comparison of Figures 2 and 3 we see the advantage of the method of cutting ties used in England over and above

Table 1.

Gain in lumber brought about by sawing instead of hewing ties.

Diameter of Log at small end inside of bark in inches.	Yield of a 16 ft. log.			Percentage of Volume of hewn tie gained by sawing.
	In hewn ties 6" x 8" bd, ft.	In sawn ties & Lumber.		
		Ties 6"x8" Bd, Ft.	Lumber Bd. ft.	
10	64	64	14.8	23
11	64	64	27.0	42
12	64	64	52.4	82
13	64	64	70.8	112
14	64	64	101.3	158
15	64	128	57.6	191

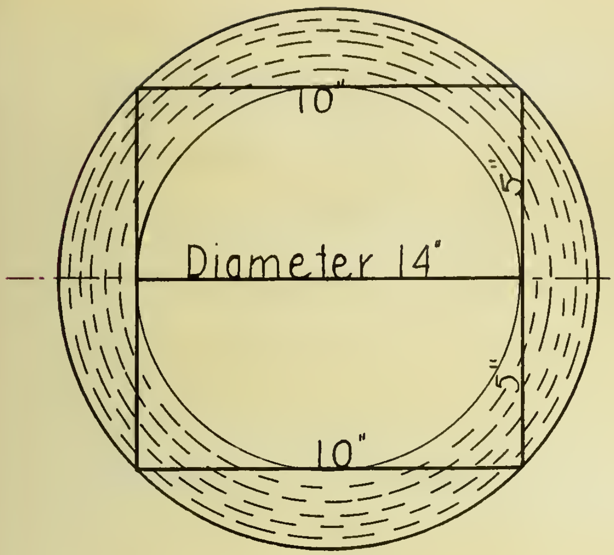


Fig. 2
English method of cutting two ties from a tree 14" in diameter.

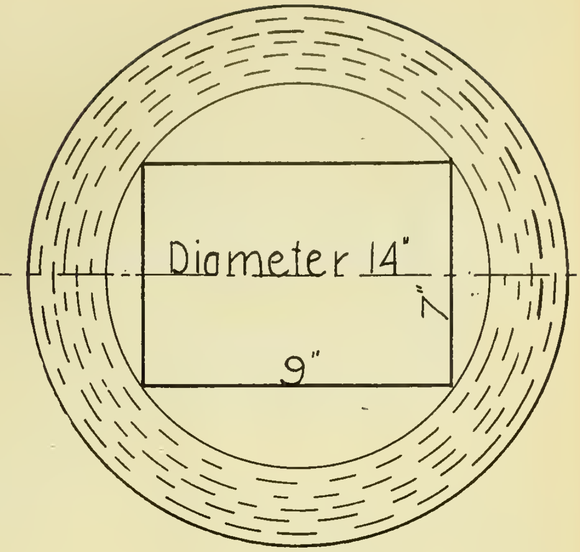


Fig. 3
American method of cutting one heartwood tie from a tree 14" in diameter.

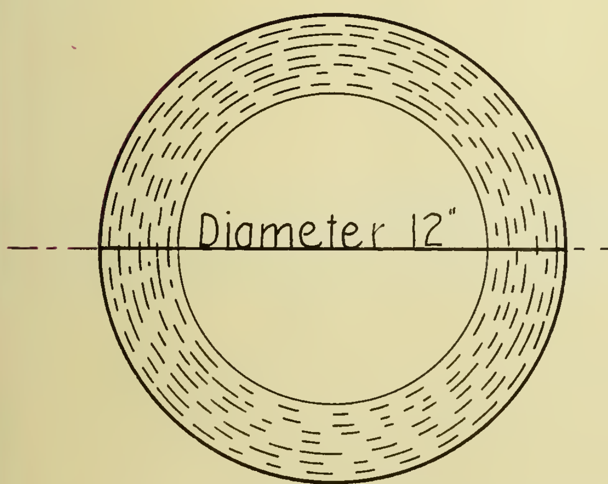


Fig. 4.
Belgium method of cutting two ties from a tree 12" in diameter.

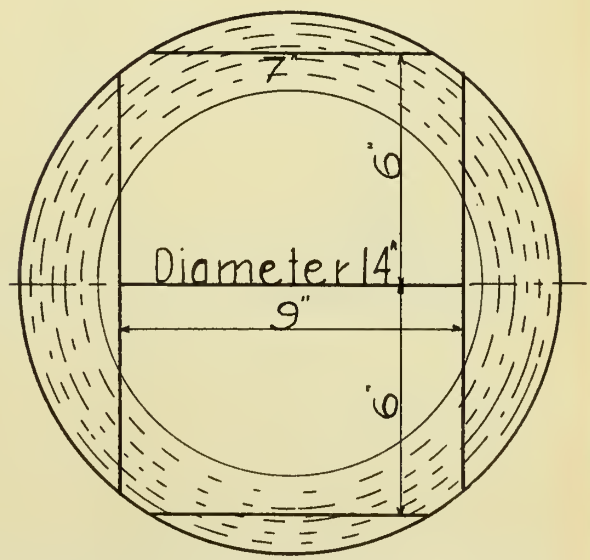


Fig 5
Proposed method of cutting two ties from a tree 14" in diameter.

that used in America,whereby they obtain two ties from a tree which in this country would yield only one heartwood tie. The Belgium practice is illustrated by Fig.4,whereby they utilize the entire tree,thus getting two ties from a tree which with present methods of cutting used in America only one is obtained.Fig.5 shows a proposed method of cutting two ties from a tree fourteen inches in diameter,thus utilizing considerable of the sapwood.

Assuming three cuts to a tree certain diameter trees will make ties as follows;-

16	inches Diameter	4 ties	6" x 8"
18	" "	6 "	" " "
20	" "	10 "	" "
22	" "	12 "	" "
24	" "	20 "	" "
30	" "	28 "	" "
33	" "	34 "	" "

The importance of seasoning ties before placing in the track does not seem to have impressed itself upon our American lumberman;at least,they do not practice it systematically,except in comparatively few cases.In European countries,where timber is scarce and therefore very expensive, all ties are seasoned before being used.The Russian railroad authorities found that a well seasoned oak tie will last practically as long as one treated with zinc chloride,and for that reason they do not treat their oak ties.In all cases treated ties are thoroughly seasoned before and after treatment.

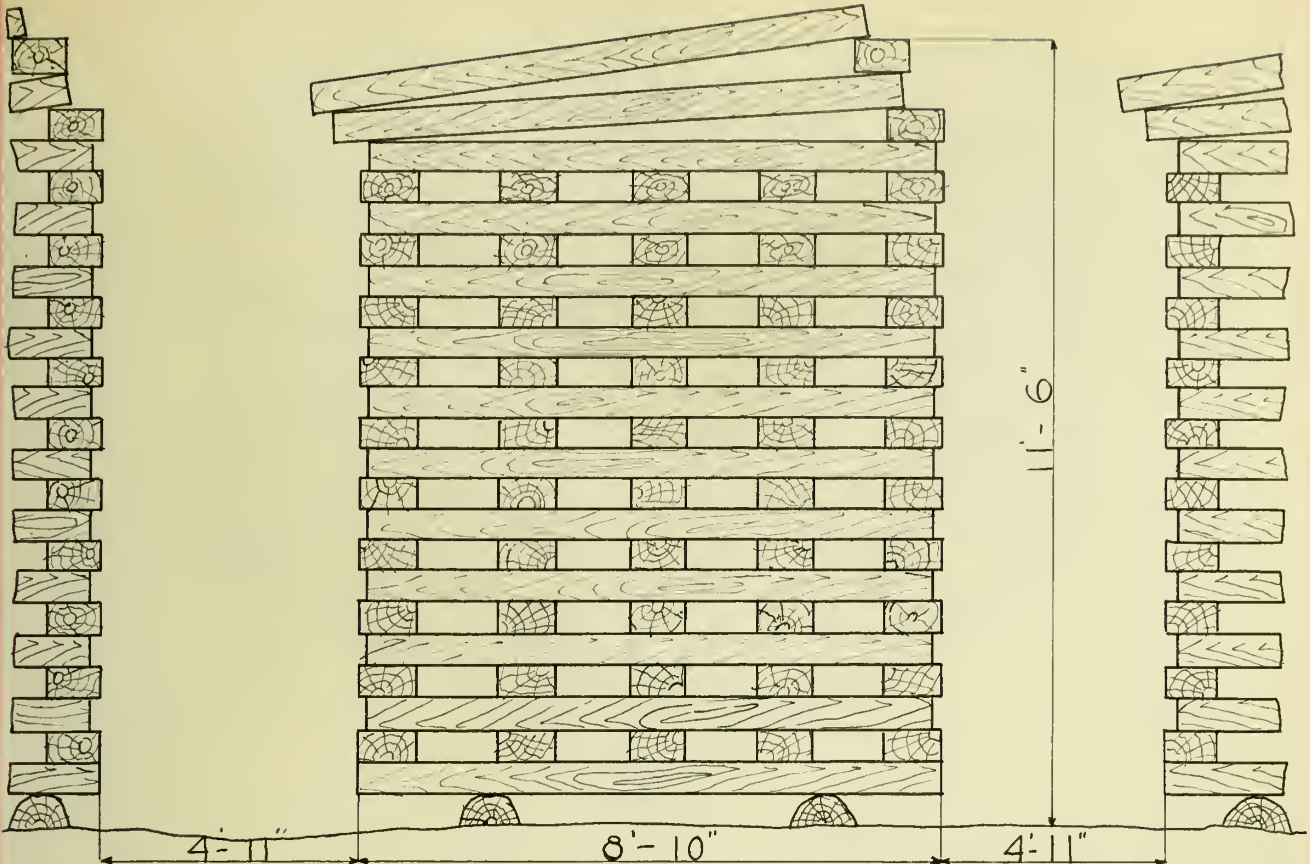
Table 2.

Percentage of ties removed after twelve years.

Kind of timber.	Untreated		Treated. Zinc Chloride	
	seasoned, percent.	Not seasoned, percent	Seasoned, percent	Not seasoned, percent.
Oak	4.9	9.0	-----	2.4
Pine	81.8	109.9	9.0	19.8
Spruce	162.8	203.3	51.2	64.4
Beech	205.7	279.3	18.1	43.8

The oak ties are allowed from 6 to 20 months to season,the time of seasoning depending upon the demand for ties,from four to six months being allowed for beech.An experiment conducted in Germany brings out very clearly the advantage of seasoning ties.In 1888,a number of ties of different materials were laid in the track,some treated,others untreated. In each case one hundred and twenty one ties were laid.

By consulting Table 2,which shows the percentage of ties removed after twleve years,we see that seasoning ties before they are laid materially increases their life in the track.Of the untreated oak nine percent of the seasoned ties were removed against four and nine tenths percent of the seasoned,representing a little over half as many.In the case of the unseasoned pine tie treated with zinc chloride, nineteen and eight tenths percent were removed in twelve years while only nine percent of the seasoned ties had to be taken out-considerably less than half the former number.The beech



Pile of ties on Eastern Railroad of France. Fig. 6.

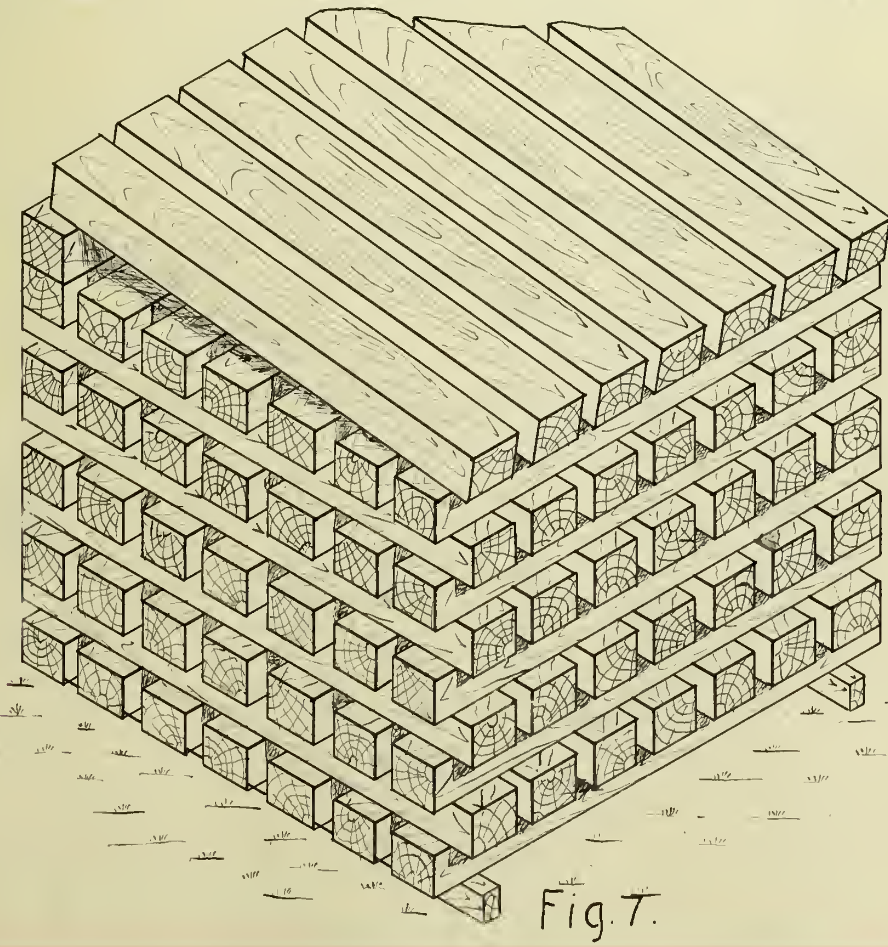


Fig. 7.

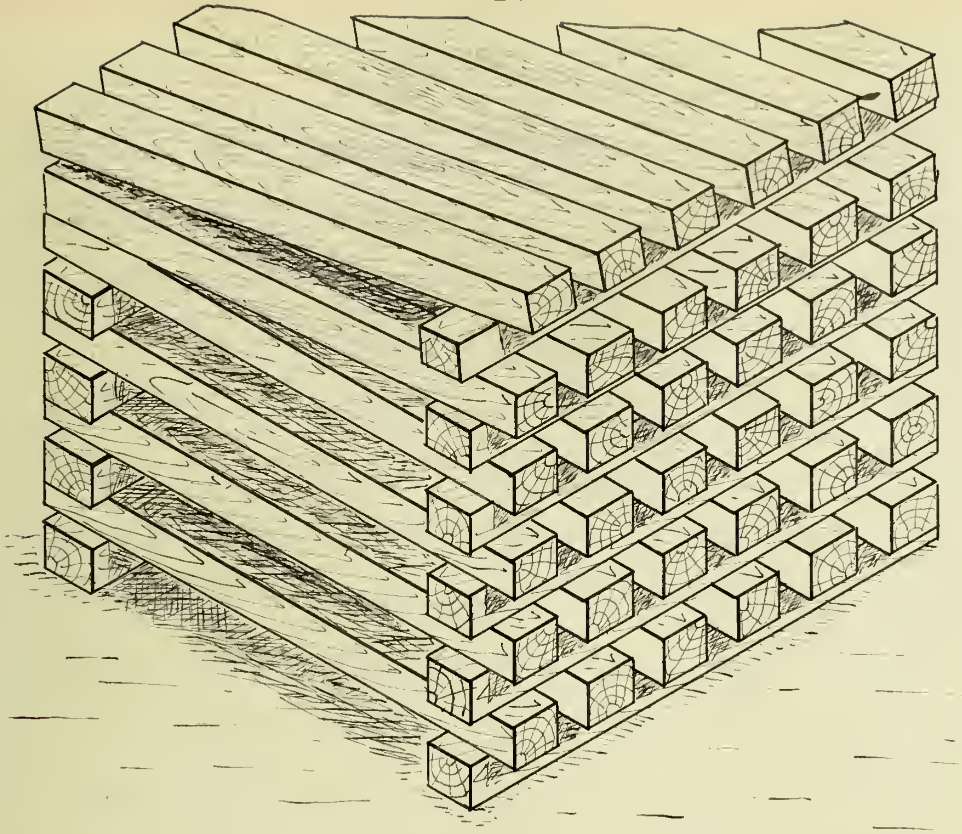


Fig. 8.

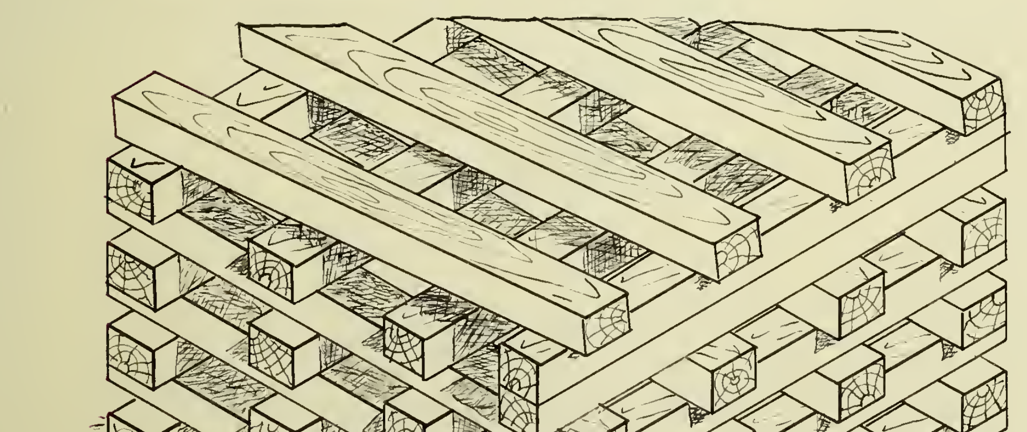


Fig 9

ties treated with zinc chloride show still greater results, forty three and eight tenths percents of the unseasoned ties being removed and only eighteen and one tenth of the seasoned.

In seasoning ties, special attention must be paid to the method of stacking, so as to allow the greatest amount of surface exposed to the sun and wind. Fig. 6 shows the method of piling ties used by the Eastern railroad of France, a method which is the outgrowth of long years of experience, and represents about the best that can be used. In Figures 7, 8, &9 we see some of the methods of stacking ties used in America, which have proven very satisfactory. The pile should always rest upon poles or blocking so as to prevent the lower row from being attacked by fungi, and should have the top row piled close together and inclined so as to shed water.

Tie Plates.

On account of the increasing scarcity of hard wood timbers it has been found necessary to use some means of preserving the softer treated timbers against mechanical wear until they fail by decay. Most of the principal railroads in the United States have found by the use of steel plates on curves and portions of the track where the traffic is very heavy that they have been able to prevent, to a great extent, the cutting of ties by rails and spikes, so that from seventy five to ninety five per cent of the ties fail by decay.

Some use tie plates altogether,with the result that practically all the ties fail be decay.

In Europe,and also in this country,it has become almost the universal practice to use a flat plate with a shoulder on the outer side to prevent the rails from spreading.This type of plate has almost entirely replaced the rail brace,because it was found to be more efficient in keeping the track in line on curves.Several years ago the Pennsylvania railroad adopted a flat tie plade exclusively,with no ridges of any kind on the bottom,as they claimed that these ridges cut into the tie so badly that a large part of its usefulness was lost.Since that time,however,they have made a series of experiments with heavy engines at high speed on curves,and found that this tie plate is not as efficient in holding the track to line as a tie plate with a cutting edge on the outer side.

On straight track,where the primary object of the tie plate is to prevent the rail from cutting into the tie, wooden tie plates have been found to be economical in a few cases.The Eastern railroad of France imploys a popular tie plate one eight of an inch thick impregnated with creosote. The principal objection to these plates is that they have to be renewed at frequent intervals,but this is not a great expense, as the tie plates cost only three dollars per thousand.The Frisco lines also use a wooden tie plate of red gum or creosoted black gum,but it is their purpose to replace these with steel tie plates as soon as the finances of the road will permit. Each plate is fastened to the tie with four 4-penny wire nails,

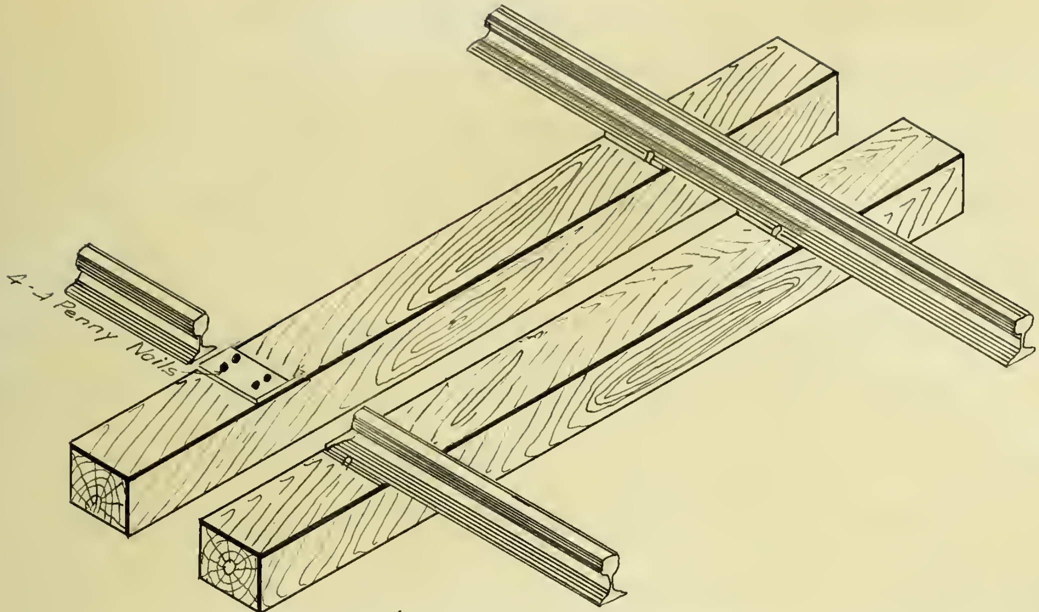


Fig.10.

Showing method of applying wooden tie plates used by the St.Louis and San Francisco R.R.Co.

and is so located as to be exactly covered by the base of the rail,as is illustrated in Fig.10.

Rail Fastenings.

The dertermination of a proper fastening between the rail and the tie has become a matter of considerable importance.During the period when the supply of suitable hard wood timber was sufficient,the ordinary spike satisfactorily fulfilled the requirements;but with the heavier weights of cars and locomotives and also with the use of softer woods for ties the common spike has proved deficient.Variations in the

form of the ordinary spikes have been developed and new forms devised, in an effort to overcome the loss of efficiency attendant upon the use of inferior timbers. In Europe, screw spikes have been used extensibly, a hole being bored in the tie for the spike, before treatment, at the treating plant. But in this country on account of the different sections of rail used it would not always be practical to drill these holes at the treating plant.

Table 3 containing the results of tests made at the University of Illinois*, shows the pulling strengths of common and screw spikes in different kinds of wood. All the values, except those for white oak, have been taken from treated ties. Treated ties offer a greater resistance to pulling than

Table 3

Showing the pulling strengths of common and screw spikes.

Kind of wood	Ordinary spike	Screw spike	Remarks
White Oak	7870 lbs.	12630 lbs.	Untreated
Red Oak	7730 "	13560 "	Treated
Ash	7730 "	12760 "	"
Beech	8840 "	16230 "	"
Elm	7500 "	13690 "	"
Poplar	5670 "	7490 "	"
Chestnut	5200 "	8700 "	"
Gum	5300 "	8280 "	"
Lobloly Pine	4300 "	10620 "	"

Based upon a penetration of five inches.

* Bulletin No. 6. Engineering Experiment Station, University of Illinois.

untreated ties.This probaly duo to two causes.(1) The presence of the preservative in the cells,thus reducing the space into which the fibres can crowd as the spike is withdrawn. (2) The hardening of the fibres by steaming preparatory to treatment, which renders them less pliable.

Tests* have also been made to dertermine the effect of a side blow such as comes on the spike from the rail in service.A five hundred pound weight was dropped three inches on the head of a rail turned sidewise.For the ordinary spike two blows of the hammer pulled the inside spike far enough to allow the rail to drop out.For the screw spike seven blows did not start the inside spike perceptibly,but the head of the outside spike was gradually bent over until the rail fell out .

On account of the comparative ease with which the ordinary spike is withdrawn, rails require frequent respiking.The original hole that is made by the spike is soon enlarged to such an extent that the spike will no longer hold and therefore must be driven in a new place.These holes not only weaken the tie,but they form an entrance through which water can get into the heart of the tie and cause decay.This is the principal way treated ties fail. If no protection against this spike-cutting is made by the use of tie plates or screw spikes the soft wood ties that have been treated to last fifteen years will not last more than five or six. It has been found in Europe, where screw spikes are used in connection with tie plates that this evil has been over-

* Bulletin No 50 Forestry Division of Department of Agriculture

come all together. Tests have shown that the screw spike is not perceptibly loosened by the pressure on the inside of the rail and so does not need to be redriven.

In driving the screw spike, it is necessary to bore a hole in the tie, in order to get the spike in place and thus the wood fibre around the spike is not injured to any appreciable extent, while in the case of the common spike the fibres, especially in soft wood ties, are broken to such an extent that they do not withstand the lateral pressure of the rail.

There are two principal objections to the screw spike. (1) Its first cost is greater than the ordinary spike, (2) It takes longer and costs more to put it in the track; but these objections are more than ofset by the added life thus given to the tie.

Steel and Concrete Ties.

It has been pointed in numerable times that some substitute must be found for the wooden ties, and many are working in the hope of evolving the ideal equivalent. It must be borne in mind that such a substitute must not be the equivalent only, but, the superior, of the wood tie, affording by form, dimension, material, and mass, a better and more permanent bearing surface and greater stability in the road bed. A 7" x 8" x 8' wooden tie has been found to give insufficient bearing surface for the modern high speed track and a larger tie has been recomended,

but wood has become so scarce that the size of the tie is governed largely by the supply and it is evident that these conditions will not improve with time.

Steel ties have been used in Europe for the last forty years and have given very good service,but when the engineers of this country began experimenting with the steel tie they realized the differance in conditions between the two countries and made little attempts to follow the design that had proved most efficient in Europe.The designs used most sucessfully there was practically a half circular shell made of steel or wrought iron,while the earlier designers in this country tried to make use of the standard shapes of channels and "T" bars.The design used in Europe was followed in Mexico with very good results but the conditions are much the same in the two countries.In Mexico,however,they have demonstrated that the steel tie can be protected from rust by dipping in hot tar before it is laid.

The only tie in this country that followed the European design very closely is known as the "Snyder steel tie", which consists of a half circular shell filled with asphalt and broken stone .These ties failed by being bent out of shape by heavy traffic,and thus could not be used where speed was one of the principal objects in view.The asphalt and stone did not add materially to the strength,so these ties were not a success, except on unimportant lines where high speed was not attained, and where the traffic was not heavy.

In the design of a substitute for wood ties three

elements must be considered:(1) an efficient method of fastening the rail to the tie;(2) the requirement of a considerable measure of elasticity;(3) a satisfactory method of insulation. There is always a tendency for the ballast to become unstable and for the track to become center bound.This condition has been largely met by the wood tie because of its elasticity,but in the case of the steel and the concrete tie,which are not as elastic,greater care will be required in track surfacing and maintenance.The question of insulating the steel tie is a serious objection to its adoption,in view of the rapid increase in the insulation of block signals.It has been found necessary to use fibre as an insulating material,and this wears so rapidly that it will be a source of considerable trouble and expense to maintain insulating pieces on each tie.Concrete is almost an insulating material and it will probaly be practical to design a concrete tie that will overcome this difficulty. On the other hand,the construction of such a tie will require a great deal of care to prevent contact through the metal reinforcement.

In addition to these three difficulties in design, there is another which,although it does not affect the efficiency of the tie,nevertheless will prevent its general acceptance for some time at least.This is its first cost.A steel tie costing two dollars and a half might show greater economy than a white oak tie costing sixty-eight cents,but most roads would not have sufficient capital to invest in steel ties.

Of the concrete ties placed upon the market none

have proven satisfactory,their life ranging from two weeks to two years.In most cases they failed by crushing under a heavy traffic,but there are several designs which might be found economical in places where the speed is slow and conditions are especially adverse to the life of wood or metal.

Of the steel ties,one seems to be very promising. This is the improved Carnegie tie with a metal plate over the insulating fibre and with the wedge clip rail fastenings.The fibre used for insulating has a life of about two years and gives very good results.This tie has an "I" beam section and has several advantages over the wood tie.The Bessemer and Lake Erie railroad,which has a very heavy traffic,principally of ore and coal,amounting to 1,000,000 tons a month,these ties have undergone a severe test and have been found to give better alignment on curves than wooden ties.They were first put in the track in 1904 and apparantly are in as good shape as when laid.

An Economic Comparison of Cross Ties of Different Materials.

The principal elements that must always be considered in determining the relative merits of different materials used as cross ties are;(1) the first cost,which should include the cost in forest,the freightage,handling and distributing,and the cost of placing the tie in the track; (2) the life,that is,the time elapsing from the date when the

tie is laid to the time when it becomes necessary to renew it; (3) cost of renewals;(4) rate of interest on money;(5) maintenance,or cost of repairs;(6) salvage,or the scrap value of the tie at the close of its life of usefulness.Since the cost of maintenance on ties is practically the same for all kinds,it will be omitted in this consideration.The item of salvage is also extremely small and in most cases is zero or negative;therefore this also will be omitted,leaving only four elements to be considered.(1) The first cost,(2) life,(3) cost of renewals,(4) rate of interest.

For example,let us consider two ties-a white oak tie which costs sixty-eight cents in the track and lasts nine years,and a pine tie which costs sixty-one and a half cents in the track and lasts six years.

On the basis of capitalization,that tie is considered cheapest which under present conditions will require the least amount to install and to be set aside at compound interest to reproduce it forever,the capitalization is made up of;

(a) The first cost = C

(b) The amount at compound interest necessary to in interest during the life of a tie its first cost.$=C' = \frac{C}{(1+R)^N-1}$

Total capitalization equals.

$$C + C' = \frac{C(1+R)^N}{(1+R)^N -1} \quad \text{------------------(1)}$$

in which N equals the years of life of the tie,and R equals the rate of interest on money,taken in this consideration as 4%.

Total capitilization of white oak tie,

$$= \frac{0.68(1+.04)^9}{(1+.04)^9 -1} = \$2.286$$

Total capitilazation of pine tie.

$$= \frac{0.615(1+.04)^6}{(1+04)^6 -1} = \$2.933$$

On the basis of annual cost that tie is considered cheapest which under present conditions shows the least annual cost. The annual cost being made up of;

(a) The interest on first cost $= I = CR$.

(b) The amount that must be set aside annually at compound interest to provide for renewal at the expiration of the life of the tie. $= A = \frac{CR}{(1+R)^N -1}$

$$\text{Total annual cost} = I+A = \frac{CR(1+R)^N}{(1+R)^N -1} \qquad \text{------------------(2)}$$

Annual cost of white oak tie

$$= \frac{0.68 \times .04(1+.04)^9}{(1+04)^9 -1} = \$0.091$$

Annual cost of the pine tie

$$= \frac{0.615 \times .04(1+.04)^6}{(1+.04)^6 - 1} = \$0.117.$$

On the basis of equivalent cost one tie is considered to cost the same as another when the capitalization or annual cost of the one is equal to the capitalization or annual cost of the other, or

$$C' = \frac{C(1+R)^N}{(1+R)^N - 1} \times \frac{(1+R)^{N'}-1}{(1+R)^{N'}} \qquad \text{--------------------(3)}$$

where C is the cost of a tie of N years life and C' is the cost of a tie of N' years life.

Assuming a white oak tie that costs sixty-eight cents in the track and last nine years to find what can be paid for a pine tie lasting six years to show the same morit.

$$C' = \frac{0.68(1+.04)^9}{(1+.04)^9 - 1} \times \frac{(1+.04)^6 - 1}{(1+.04)^6} = \$0.479.$$

From the above consideration, we see that on the basis of capitalization the white oak tie is the more economical, requiring only \$2.286 total capitalization while the pine tie requires \$2.933, showing an advantage in favor of the white oak tie of \$0.647. On the basis of annual cost the same is true. The annual cost of the white oak tie being \$0.091 while that of the pine tie is \$0.117, showing an advantage in favor of the white oak tie of \$0.026. Again, on the basis of equivalent cost we see that we can pay only \$0.479 for a pine tie lasting six years to show the same merit as a white oak tie lasting nine years and costing \$0.68, while we actually pay \$0.615.

Table 4 shows the average life and cost in track of the ties used on representative railroads all over the United States having a total milage of 62,309 miles. We regret that we were unable to get data representing a larger milage, but we present in tabular form the data as received showing the kind of ties used, their average life, their average cost in track together with the comparative value of each on the basis of capitalization, annual cost, and equivalent cost using as a basis for comparison a live white oak tie costing \$0.68 in the track and lasting nine years. Ties which show an average life of a fraction of a year in the computations were considered to

TABLE 4

Table Showing the Comparative Value of Different Cross-ties

Kind of Material	Treatment if any	Average Life in yrs.	Cost in Track	Capitalization	Annual Cost	Equivalent Cost
White Oak	None	9.0	$ 0.680	$ 2.286	$ 0.091	$ 0.680
Other Oaks	None	6.0	0.625	2.981	0.119	0.479
" "	Zinc Chloride	11.0	0.730	2.083	0.083	0.801
" "	Creosote	15.0	0.827	1.860	0.074	1.017
Pine	None	6.0	0.615	2.933	0.117	0.479
"	Creosote	15.0	0.750	1.687	0.067	1.017
"	Zinc Chloride	8.0	0.710	2.636	0.106	0.616
Cypress	None	10.0	0.540	1.664	0.066	0.742
"	Creosote	17.5	0.950	1.952	0.078	1.112
"	Rueping	15.0	0.810	1.822	0.073	1.017
Chestnut	None	9.0	0.655	2.202	0.088	0.680
Gum	None	5.0	0.550	3.089	0.124	0.407
"	Rueping	15.0	0.810	1.822	0.073	1.017
"	Creosote	17.5	0.855	1.757	0.070	1.112
Hemlock	Rueping	15.0	0.810	1.822	0.073	1.017
"	Creosote	17.5	0.950	1.952	0.078	1.112
Locust	None	12.0	0.700	1.865	0.075	0.858
"	Rueping	17.0	0.860	1.767	0.071	1.112
"	Creosote	20.0	1.000	1.840	0.074	1.243
Hickory	Rueping	15.0	0.810	1.822	0.073	1.017
"	Creosote	17.5	0.950	1.952	0.078	1.112

TABLE 4 (Continued)

Kind of Material	Treatment if any	Average Life. In yrs	Cost in Track	Capitalization	Annual Cost	Equivalent Cost
Beech	None	4.0	$ 0.550	$ 3.787	$ 0.151	$ 0.330
"	Rueping	15.0	0.840	1.889	0.076	1.017
"	Creosote	17.5	0.950	1.952	0.078	1.112
Tamarack	Rueping	15.0	0.810	1.822	0.073	1.017
Maple	None	4.0	0.550	3.787	0.151	0.330
"	Rueping	15.0	0.810	1.822	0.073	1.017
Birch	None	4.0	0.550	3.787	0.151	0.330
"	Rueping	15.0	0.810	1.822	0.073	1.017
Catalpa	None	20.0	0.600	1.104	0.044	1.243
Redwood	None	10.0	0.850	2.620	0.105	0.742
Elm	Rueping	15.0	0.810	1.822	0.073	1.017
Fir	None	7.0	0.620	2.582	0.104	0.549
"	Zinc Chloride	15.0	0.830	1.867	0.075	1.017

TABLE 4a.

Table Showing Data of Table 4 Arranged in Order of Merit.

№	Kind of Material	Treatment if any	Average Life	Cost in Track	Capitalization	Annual Cost
1	Catalpa	None	20.0	$0.600	$1.104	$0.044
2	Cypress	None	10.0	0.540	1.664	0.066
3	Pine	Creosote	15.0	0.750	1.687	0.067
4	Gum	Creosote	17.5	0.855	1.757	0.070
5	Locust	Rueping	17.0	0.860	1.767	0.071
6	Cypress	Rueping	15.0	0.810	1.822	0.073
7	Gum	Rueping	15.0	0.810	1.822	0.073
8	Hemlock	Rueping	15.0	0.810	1.822	0.073
9	Hickory	Rueping	15.0	0.810	1.822	0.073
10	Tamarack	Rueping	15.0	0.810	1.822	0.073
11	Maple	Rueping	15.0	0.810	1.822	0.073
12	Birch	Rueping	15.0	0.810	1.822	0.073
13	Elm	Rueping	15.0	0.810	1.822	0.073
14	Locust	Creosote	20.0	1.000	1.840	0.074
15	Other Oaks	Creosote	15.0	0.827	1.860	0.074
16	Locust	None	12.0	0.700	1.865	0.075
17	Fir	Zinc Chloride	15.0	0.830	1.867	0.075
18	Beech	Rueping	15.0	0.840	1.889	0.076
19	Cypress	Creosote	17.5	0.950	1.952	0.078
20	Hemlock	Creosote	17.5	0.950	1.952	0.078
21	Beech	Creosote	17.5	0.950	1.952	0.078
22	Hickory	Creosote	17.5	0.950	1.952	0.078
23	Other Oaks	Zinc Chloride	11.0	0.730	2.083	0.083
24	Chestnut	None	9.0	0.655	2.202	0.088
25	White Oak	None	9.0	0.680	2.286	0.091
26	Fir	None	7.0	0.620	2.582	0.104
27	Redwood	None	10.0	0.850	2.620	0.105
28	Pine	Zinc Chloride	8.0	0.710	2.636	0.106
29	Pine	None	6.0	0.615	2.933	0.117
30	Other Oaks	None	6.0	0.625	2.981	0.119
31	Gum	None	5.0	0.550	3.089	0.124
32	Beech	None	4.0	0.550	3.787	0.151
33	Maple	None	4.0	0.550	3.787	0.151
34	Birch	None	4.0	0.550	3.787	0.151

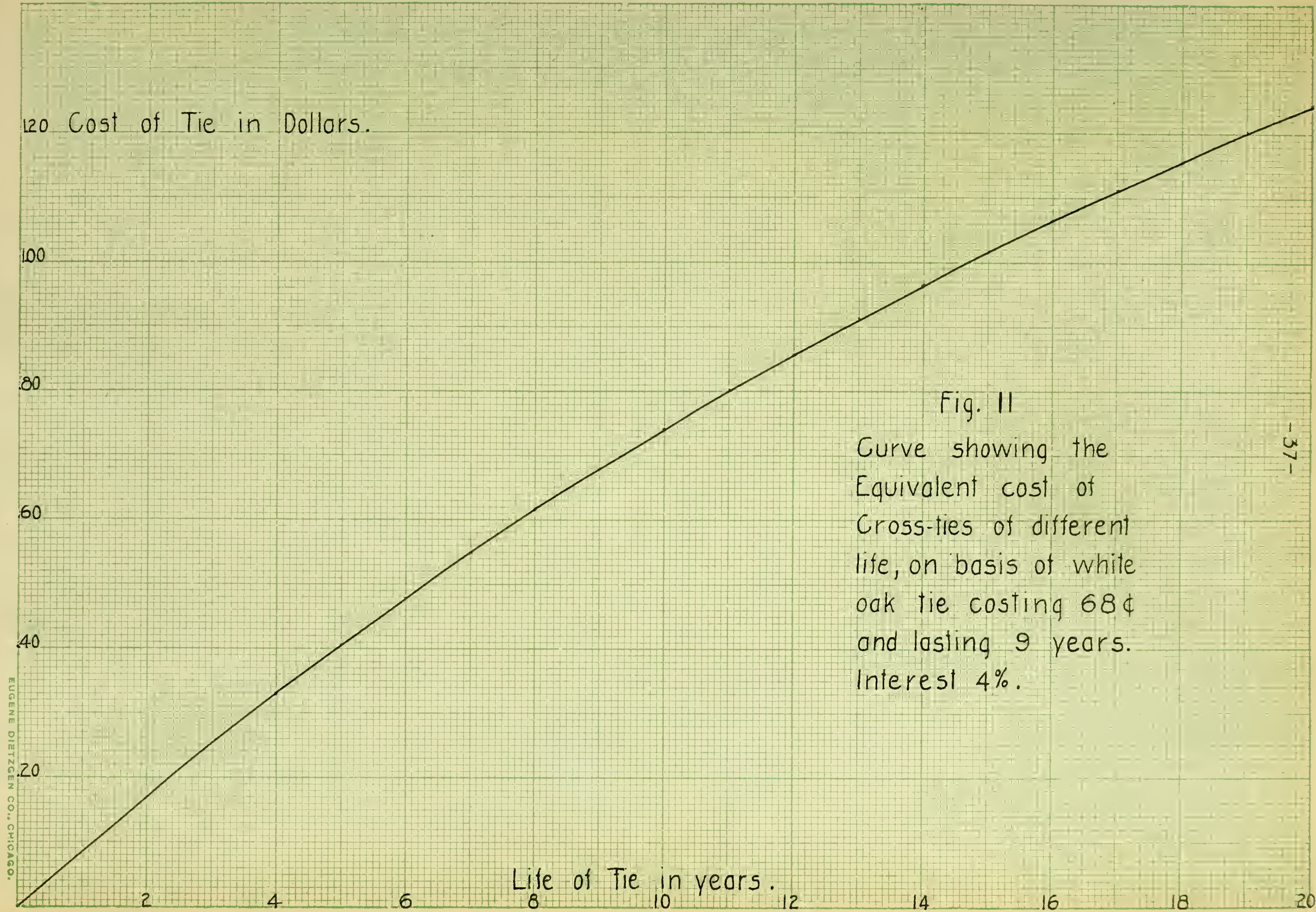


Fig. 11

Curve showing the Equivalent cost of Cross-ties of different life, on basis of white oak tie costing 68¢ and lasting 9 years. Interest 4%.

have a life represented by the nearest whole number of years. Table 4_a shows the same data as is contained in Table 4 excepting the column equivalent cost is omitted. In this table, the ties have been arranged in the order of merit as shown by their capitalization and annual cost regardless of the kind of timber used or whether they were treated or untreated.

Figure 11 represents graphically what we can afford to pay for cross ties of different life to show the same merit as a white oak tie costing $0.68 in the track and lasting nine years.

In Table 4 we have not taken into account the necessity of using tie plates on any of the ties, but with the increase in traffic and heavier rolling stock it becomes necessary to use tie plates on all soft wood ties on curves whether treated or untreated and on hard wood ties which are treated. Best practice also recommends that tie plates should be used on all soft wood treated ties on tangent. If this is not done it is impossible to obtain the full life of the tie. They fail through mechanical wear before they lose their usefulness through decay. Assuming that a live white oak tie will resist mechanical wear as long as it can resist decay, let us compare it with a pine tie on which we have to use a tie plate, the white oak tie with life of nine years to cost $0.68, and the pine tie with life of six years to cost $0.615, tie plates to cost fourteen cents each and last for twenty years.

Total capitalization of white oak tie,

formula---(1)

$$= \frac{C(1+R)^N}{(1+R)^N - 1} = \frac{0.68(1+.04)^9}{(1+.04)^9 - 1} = \$2.286.$$

Total capitalization of pine tie equals.

(a) First cost in track = C =

Cost of pine tie to be renewed every 6 years = $0.615

Cost of 2 tie plates to be renewed every 20 years = $0.280

Total--------------$0.895

(b) The amount at compound interest necessary to produce in interest during the life of the tie its first cost = C_1

$$= \frac{C - T}{(1 + R)^N - 1}$$

(c) The amount at compound interest necessary to produce in interest during the life of the tie plates their first cost.

$$= C_2 = \frac{T}{(1+R)^{N'} - 1}$$

Total capitalization = $C + C_1 + C_2$

$$= \frac{C(1+R)^N}{(1+R)^N - 1} - \frac{T}{(1+R)^N - 1} + \frac{T}{(1+R)^{N'} - 1}$$

Where T = cost of tie plates which last N' years.

N = life of tie.

R = rate of interest on money.

Then total capitalization of pine tie.

$$= \frac{0.895(1+.04)^6}{(1+.04)^6 - 1} - \frac{28}{(1+.04)^6 - 1} + \frac{28}{(1+.04)^{20} - 1} = \$3.448.$$

The annual cost of the live oak tie;formula--------------(2)

$$= \frac{CR\ (1+R)^N}{(1+R)^N - 1} = \frac{0.68 \times .04(1+.04)^9}{(1+.04)^9 - 1} = \$0.091$$

The annual cost of the pine tie equals

(a) The interest on first cost = CR.

(b) The amount that must be set aside annually at compound interest to provide for the renewal of the tie at the expiration of its life $= A = \frac{R(C-T)}{(1+R)^N - 1}$

(c) The amount that must be set aside annually at compound interest to provide for the renewal of the tie plates at the expiration of their life $= A_1 = \frac{RT}{(1+R)^{N'}-1}$

Then total annual cost $= I + A + A_1$.

$$= \frac{CR(1+R)^N}{(1+R)^N-1} - \frac{TR}{(1+R)^N-1} + \frac{TR}{(1+R)^{N'}-1}$$

$$= \frac{0.895 \times .04(1+.04)^6}{(1+.04)^6 - 1} - \frac{0.28 \times .04}{(1+.04)^6-1} + \frac{0.28 \times .04}{(1+.04)^{20}-1} = \$0.138.$$

From these examples we see that the white oak tie shows considerable advantage over the pine tie,requiring only \$2.286 capitalization,while the pine tie with a tie plate requires \$3.448.A similar advantage is shown when the two are considered on the basis of annual cost.The annual cost of the white oak tie being \$0.091 against \$0.138 for the pine tie.

Table 6 shows the same data as is contained in Table 4.excepting that the comparison of the ties on the basis of capitalization and annual cost it was considered necessary to use tie plates on all ties excepting the white oak,other oaks,chestnut,gum,beech,birch,and maple,which are untreated. In the case of these ties it was considered that they would resist mechanical wear as long as they can resist decay.

Table 5_a contains the same data as Table 5 excepting that the column headed "Equivalent Cost" has been omitted.

TABLE 5

Table Showing the Comparative Value of Different Cross-ties Using Tie-Plates

Kind of Material	Treatment if any	Average Life	Cost in Track Including Two Tie-plates	Capitalization	Annual Cost	Equivalent Cost
White Oak	None	9.0	$0.680*	$2.286	$0.091	$0.680
Other Oaks	None	6.0	0.625*	2.981	0.119	0.479
" "	Zinc Chloride	11.0	1.010	2.598	0.104	0.801
" "	Creosote	15.0	1.107	2.375	0.095	1.017
Pine	None	6.0	0.895	3.448	0.138	0.479
"	Zinc Chloride	8.0	0.990	3.151	0.126	0.616
"	Creosote	15.0	1.030	2.202	0.088	1.017
Cypress	None	10.0	0.820	2.179	0.087	0.742
"	Creosote	17.5	1.230	2.467	0.099	1.112
"	Rueping	15.0	1.090	2.337	0.093	1.017
Chestnut	None	9.0	0.655*	2.202	0.088	0.680
Gum	None	5.0	0.550*	3.089	0.124	0.407
"	Rueping	15.0	1.090	2.337	0.093	1.017
"	Creosote	17.5	1.135	2.272	0.091	1.112
Hemlock	Rueping	15.0	1.090	2.337	0.093	1.017
"	Creosote	17.5	1.230	2.467	0.099	1.112
Locust	None	12.0	0.980	2.370	0.095	0.858
"	Rueping	17.0	1.040	2.282	0.091	1.112
"	Creosote	20.0	1.280	2.355	0.094	1.243
Tamarack	Rueping	15.0	1.090	2.337	0.093	1.017

Note: Tie plates assumed to cost 14 cents each.

TABLE 5 (Continued)

Kind of Material	Treatment if any	Average Life	Cost in Track Including Two Tie Plates	Capitalization	Annual Cost	Equivalent Cost
Beech	None	4.0	$0.550*	$3.787	$0.151	$0.330
"	Rueping	15.0	1.120	2.404	0.096	1.017
"	Creosote	17.5	1.230	2.467	0.099	1.112
Hickory	Rueping	15.0	1.090	2.337	0.093	1.017
"	Creosote	17.5	1.230	2.467	0.099	1.112
Maple	None	4.0	0.550*	3.787	0.151	0.330
"	Rueping	15.0	1.090	2.337	0.093	1.017
Birch	None	4.0	0.550*	3.787	0.151	0.330
"	Rueping	15.0	1.090	2.337	0.093	1.017
Catalpa	None	20.0	0.880	1.619	0.065	1.243
Redwood	None	10.0	1.130	3.135	0.125	0.742
Elm	Rueping	15.0	1.090	2.337	0.093	1.017
Fir	None	7.0	0.900	3.097	0.124	0.549
"	Zinc Chloride	15.0	1.110	2.382	0.095	1.017

*Tie plates not used on these ties.

TABLE 5a

Table Showing Data of Table 5 Arranged in Order of Merit.

No	Kind of Material	Treatment if any	Average Life	Total Cost in Track	Capitalization	Annual Cost
1	Catalpa	None	20.0	$0.880	$1.619	$0.065
2	Cypress	None	10.0	0.820	2.179	0.087
3	Chestnut	None	9.0	0.655*	2.202	0.088
4	Pine	Creosote	15.0	1.030	2.202	0.088
5	Gum	Creosote	17.5	1.135	2.272	0.091
6	Locust	Rueping	17.0	1.040	2.282	0.091
7	White Oak	None	9.0	0.680*	2.286	0.091
8	Cypress	Rueping	15.0	1.090	2.337	0.093
9	Gum	Rueping	15.0	1.090	2.337	0.093
10	Hemlock	Rueping	15.0	1.090	2.337	0.093
11	Hickory	Rueping	15.0	1.090	2.337	0.093
12	Tamarack	Rueping	15.0	1.090	2.337	0.093
13	Maple	Rueping	15.0	1.090	2.337	0.093
14	Birch	Rueping	15.0	1.090	2.337	0.093
15	Elm	Rueping	15.0	1.090	2.337	0.093
16	Locust	Creosote	20.0	1.280	2.355	0.094
17	Locust	None	12.0	0.980	2.370	0.095
18	Other Oaks	Creosote	15.0	1.107	2.375	0.095
19	Fir	Zinc Chloride	15.0	1.110	2.382	0.095
20	Beech	Rueping	15.0	1.120	2.404	0.096
21	Cypress	Creosote	17.5	1.230	2.467	0.099
22	Hemlock	Creosote	17.5	1.230	2.467	0.099
23	Beech	Creosote	17.5	1.230	2.467	0.099
24	Hickory	Creosote	17.5	1.230	2.467	0.099
25	Other Oaks	Zinc Chloride	11.0	1.010	2.598	0.104
26	Other Oaks	None	6.0	0.625*	2.981	0.119
27	Gum	None	5.0	0.550*	3.089	0.124
28	Fir	None	7.0	0.900	3.097	0.124
29	Redwood	None	10.0	1.130	3.135	0.125
30	Pine	Zinc Chloride	8.0	0.990	3.151	0.126
31	Pine	None	6.0	0.895	3.448	0.138
32	Beech	None	4.0	0.550*	3.787	0.151
33	Maple	None	4.0	0.550*	3.787	0.151
34	Birch	None	4.0	0.550*	3.787	0.151

*No tie plates used on these ties.

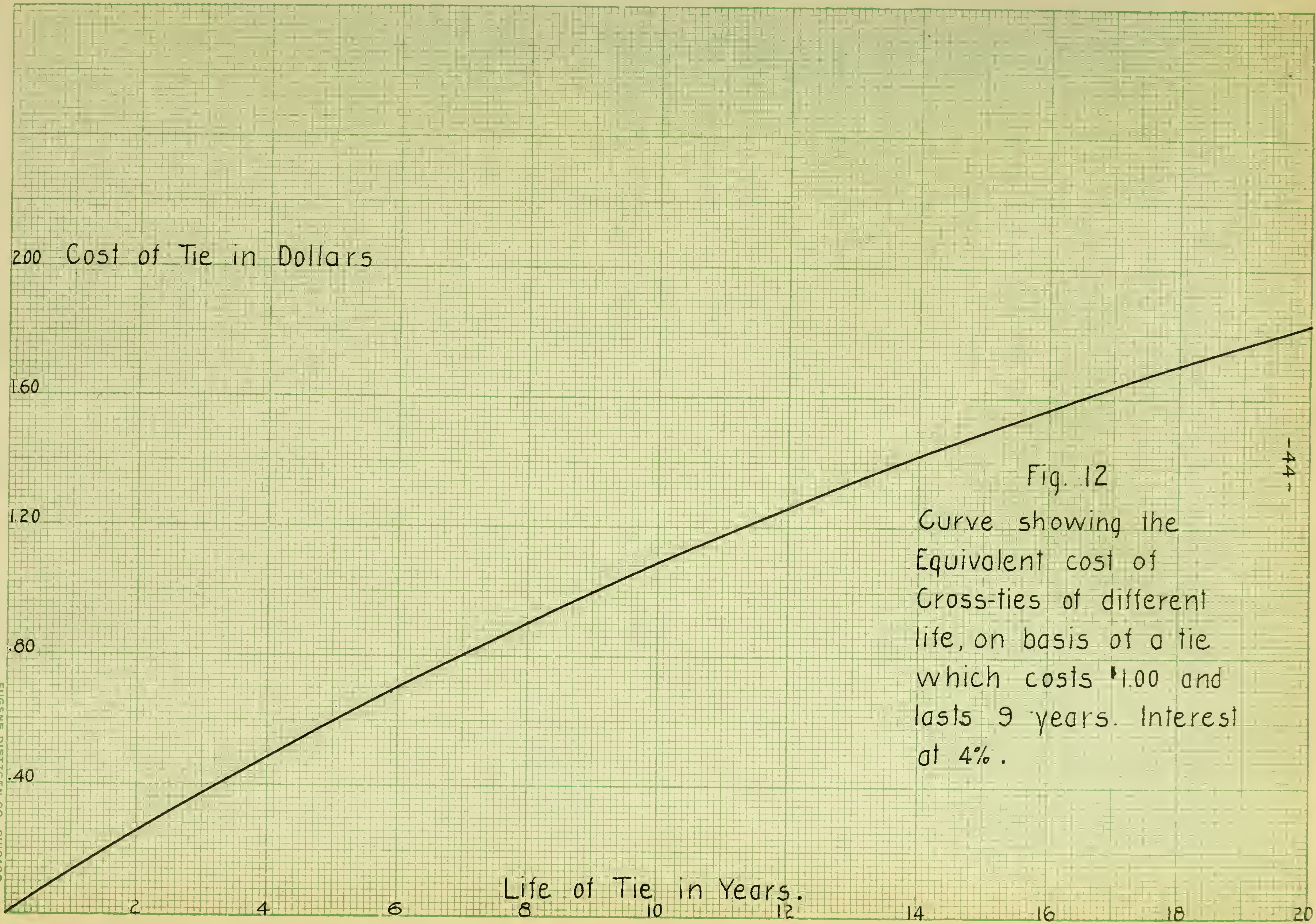


Fig. 12

Curve showing the Equivalent cost of Cross-ties of different life, on basis of a tie which costs $1.00 and lasts 9 years. Interest at 4%.

In this table the ties have been arranged in order of merit, as shown by their capitalization and annual cost. By comparing this table with Table 4_a, we see the effect upon the capitalization and annual cost of the tie, caused by the use of tie plates. In Table 4_a, the white oak tie comes number 25 in order of merit, while in Table 5_a, it jumps to number 7. Again, the untreated pine tie drops from number 29 in Table 4_a to number 31 in Table 5_a, while the chestnut jumps from number 24 to number 3. These tables also show the relative merit of ties of the same kind which are treated with different treatments. For example, in Table 4_a the creosoted pine tie holds 3rd place, the pine tie treated with zinc Chloride the 28th, and the untreated pine tie the 29th. In case of the creosoted gum tie we find it occupies 4th place, the same tie treated with rueping process drops to the 7th place, while the untreated gum falls to the 31st.

Fig. 12 represents graphically what we can afford to pay for ties of different life to show the same merit as a tie costing $1.00 in the track and lasting 9 years. For example, suppose we have a chestnut tie lasting 9 years in the track and costing $0.655 to find what we can afford to pay for a tie which lasts 12 years. From the curve we find that the cost of a tie with life of 12 years is $1.262, multipy this by the cost of the tie of 9 years' life, $0.655 and we have $0.827, or the price we can pay for a tie with life of 12 years to show the same merit as the chestnut tie.

Conclusions and Recommendations.

In considering which is the most economical cross tie so many variable factors must be considered that it is extremely difficult to arrive at any certain result. A few questions, however, have been proven beyond a doubt, and in conclusion we present these, together with a few recommendations.

Methods of Preserving Timber.

Preservatives of different kinds have been used for a century or more, and it is certain that they materially increase the life of the ties. There are, however, several questions which need further investigation, such as the amount of preservative necessary to kill the bacteria and fungi, and the most economical treatment to use with ties cut from different kinds of wood. Experiment has shown that no tie should be treated until it has been thoroughly air dried; and in no case ties freshly treated with preservatives soluble in water should be exposed to weathering influences until they have been carefully seasoned to allow the water in the tie to evaporate. Attention should also be paid to such inferior timbers as the tamarack, swamp oak, loblolly pine, lodge pole pine, hemlock, etc., to see if some method cannot be devised whereby they can be made valuable as timbers for ties, so that the white oak and other superior timbers may be reserved for higher grade of

structural purposes.

Cutting and Seasoning Ties.

Green ties should be placed in open piles as soon as cut, and allowed to remain there until thoroughly seasoned, as this materially increases their life in the track. The questions as to how long a tie should be allowed to season and which are the best methods of stacking are as yet uncertain, and to answer these questions a series of tests on a large scale are recommended. It is also recommended that the practice of sawing all ties should be adopted, as this allows of the most economical use of the timber in one tree.

Tie Plates.

The use of tie plates is recommended on all soft wood treated ties and such other ties as cannot resist mechanical wear as long as they can resist decay. The tie plates not only protect the tie against rail-cutting but also afford a better method of holding the track to line.

Rail Fastenings.

Experiment has shown the superiority of the screw

spike over the common spike in holding power and in resistance to lateral pressure.Furthermore,it does not injure the wood fibre to such an extent in being put in place and seldom has to be redriven.We therefore recommend the use of some form of the screw spike on all soft wood ties and such other ties as are treated.

Steel and Concrete Ties.

It is recommended that further investigation and experiment be made with different designs of steel and concrete ties in order to devise some suitable substitute for the wooden tie as present designs do not fulfill the reauirements.