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INTRODUCTORY.

We have been practically engaged in the business of timber preservation for more than 7 years past, and during that time have confined ourselves almost exclusively to treating by the Creosote Process. During that period of time we have made every endeavor to obtain all the reliable information which was available upon the general subject of timber preservation, and we will place before our readers only such information as we have gained by our own experience and that quoted from the most reliable authorities which we could obtain. While our works are of a very extensive character, and so arranged that we can treat timber by any of the known processes, our investigations and experience in that direction would prohibit us from recommending any other but the Creosote Process, to give our patrons the most profitable results. While the first cost of many of the other processes is very much cheaper than the Creosote treatment, the general satisfactory results have at all times proven favorable to the Creosote process. As well as our own experience in this direction, we will quote from the AMERICAN SOCIETY OF CIVIL ENGINEERS; THE ASSOCIATED INSTITUTION OF CIVIL ENGINEERS OF ENGLAND; THOMAS WILLIAM BRITTON, late Surveyor of the Metropolitan Board of Works and Silver Medallist of the Royal Institute of British Architects 1854-56-70, in his work entitled: "A Treatise on the Origin, Progress, Prevention and Cure of Dry Rot in Timber," with remarks on the means of preserving woods from destruction by Sea Worms; also, H. Ward, M. A., F. R. S., F. L. S., Professor of Botany at the Royal Indian College, Cooper Hill, in his work on "Timber and Some of Its Diseases," also Mr. E. Christian, General Manager of the Norfolk Creosoting Co., Norfolk, Virginia, U. S. A., who has had many years' experience in the treating of timber. Also, Samuel Bagster Boulton, member of the INSTITUTION OF CIVIL ENGINEERS OF ENGLAND, who has given this subject a study a great part of his life; Mr. E. R. Andrews of the AMERICAN SOCIETY OF CIVIL ENGINEERS, who has devoted many years, in company with other members of his society, to the investigations on the subject of timber preservation; Octave Chanute, Chairman of Committee on Wood Preservation, AMERICAN SOCIETY OF CIVIL ENGINEERS, who has investigated most fully the above subject; J. W. Putnam, member of the AMERICAN SOCIETY OF CIVIL ENGINEERS; Howard C. Holmes, late CHIEF ENGINEER OF THE BOARD OF STATE HARBOR COMMISSIONERS, San Francisco, California, U. S. A.; also, the late W. G. Curtis of the ASSOCIATION OF ENGINEERING SOCIETIES and John D. Isaacs, both of whom have had extensive experience with timber preservation.

The weight of opinion of all the authorities that we have found on this subject, as well as our own experience, leads us to say most unhesitatingly that Creosoting is by far the most economic method of treating piles and timber for structural or submerged work, notwithstanding its high first cost.

The SAN FRANCISCO TIMBER PRESERVING CO. has a capacity of 3,000 lineal feet of piling in 24 hours, or 30,000 feet B. M. of lumber. We treat piles and lumber of all dimensions up to 120 feet in length with an injection of 20 pounds of Creosote per cubic foot if desired.

We are at the present time installing an addition to our plant for treating structural timber and paving blocks by a patented process in which crude petroleum and asphalt will be the principal commodities.

We will be pleased at all times to convey such information to our patrons as they may desire if at our command.

San Francisco Timber Preserving Co.

CREOSOTED PILES AND LUMBER.

Unless all saps and water are thoroughly extracted from the piles and timber before creosote is injected, the value of the treatment is greatly diminished.

All the lumber for structural purposes should have all fitting and trimming done before treating, otherwise the value of the treatment is greatly diminished. If in case trimming is unavoidable, or if holes are bored for bolts or other purposes, swab the parts thoroughly with hot creosote.

In wharf and trestle construction, workmen usually bore holes in piles for staging to cut off piles; these holes should be filled with creosoted plugs driven in.

Creosote should be kept in hot solution by submerging a can containing it in boiling water.

Don't allow dogs or cant hooks to puncture holes in piles except near ends which will go below ground line or above high water line.

Insist on having tight fitting rings used in driving piles.

It is a common custom with raftsmen to dog creosoted piles carelessly at any point in their length, the same as raw piles. If this is not avoided, serious damage will be done by producing holes in the pile between high and low water line.

If piles are driven without rings checks are likely to be developed by which the Teredo can enter.

To maintain the full value of creosoting in piles or timber, the TREATED SURFACE SHOULD BE PROTECTED UNTIL FASTENED IN PLACE. After that it is perfectly safe from worms or rot for an indefinite time, IF WELL TREATED.

Many years of experiment have proved that no process, calculated for the preservation of timber, can hope for success unless it replaces the liquid and semi-liquid portions of the wood with a substance that is insoluble and non-volatile, and under the conditions which obtain in each particular case.

Extract from "Creosoted Timber, Its Preparation and Uses," by Edmund Christian, General Manager of the Norfolk Creosoting Co., Norfolk, Virginia, U. S. A.

PRESERVING TIMBER BY PATENT PROCESSES, ETC.

(Extract from "A Treatise on Dry Rot in Timber," by T. A. Britton.)

Long years of practical experience has shown that timber, however prone to dry or wet rot, may be preserved from both by the use of certain metallic solutions, or other suitable protective matters.

All the various processes may be said somewhat to reduce the transverse strength of the timber when dry, and the metallic salts are affected at the iron bolts or fastenings. The natural juices of some woods do this; and bolts which have united beams of elm and pitch pine will often corrode entirely away at the junction.

The processes adopted for resisting the chemical changes in the tissues of the wood are all founded on the principle that it is essential to inject some material which shall at once precipitate the coagulable portion of the albumen retained in the tissues of the wood in a permanent insoluble form, so that it will not hereafter be susceptible of putrefactive decomposition. For this purpose, many substances, many solutions, have been employed with variable success, but materials have been sometimes introduced for this purpose which produced an effect just the opposite to what was anticipated.

Experience has shown that timber is permeable, at least by aqueous solutions, only so long as the sap channels are free from incrustation.

Such in general is the case with beech, elm, poplar, and hornbeam, the capillary tubes of which are always open, or, at least, close very slowly. At the same time it may be said that there must remain ever in these species some parts impervious to injection, whilst it is almost impossible but that a certain portion of the fibres will be more or less incrusted. The sap woods, on the other hand, of every species appear quite pervious.

Very little is known of any preservative process adopted in ancient times. Pliny observes that the ancients used garlic boiled in vinegar with considerable success, especially with reference to preserving timber from worms: he also states that the oil of cedar will protect any timber anointed with it from worm and rottenness. Oil of cedar was used by the ancient Egyptians for preserving their mummies. Tar and linseed oil were also recommended by him. The image of the goddess Diana, at Ephesus, was saturated with olive and cedar oils; also the image of Jupiter, at Rome; and the statues of Minerva and Bacchus were impregnated with oil of spikenard.

The idea of preserving wood by the action of oil is therefore by no means new; but it is somewhat curious that the earliest modern processes should also be by means of oil. The *oils most proper* to be used are *linseed, rapeseed,* or almost any of the vegetable fixed oils. Oak wood, rendered entirely free from moisture, and then immersed in linseed oil, is said to be thus prevented from splitting: the time of immersion depending on the size, &c. Palm oil is preferable to whale oil, because impregnation with the latter, although in many instances eligible, causes wood to become brittle. It is, however, probable that whale oil, when combined with other substances, such as litharge, coal pitch, or charcoal, may lose much of that effect. As cocoa-nut oil, which is, under low temperature, like the oil expressed from the nuts of the palm tree, is known to be highly preservative of timber and metallic fastenings, we may expect the same result from the latter, and thereby avoid that extreme dryness and brittleness of the timber which Mr. Strange complained of in the Venetian ships that had been seasoned for many years in frame under cover. Cocoa-nut oil beat up with shell lime or *chunam,* so as to become putty, and afterwards diluted with more oil, is used at Bombay and elsewhere as a preservative coat or varnish to plank. It cannot become a varnish without the addition of some essential oil; and the oil of mustard is used, which, of course, will produce the desired effect. In the first volume of the Abbé Raynal, on the European settlements in the East and West Indies, he mentions that an oil was exported from Pegu for the preservation of ships; but as he does not say what oil, no conclusion can be drawn further than as to the probability of its being one of those already noticed.

Experience has proved that even *animal oils* are so far injurious to timber as to *render it brittle,* whilst they preserve it from rottenness; and that, on the other hand, a mineral salt more or less combined with fatty substances does not produce that effect. The staves of whale-oil casks become quite brittle, whilst those of beef, pork, and tallow barrels remain tough and sound. Ships *constantly* in the Greenland trade have their timbers and planks preserved so far as they have become impregnated with whale oil.

Experiments with fish oil prove that of itself, unless exposed to sun and air, it may be injurious; that it loosens the cohesion of timber; but that *animal fat,* combined *with saline matter, is preservative.*

Fish oil used alone is ineligible, because capable of running into the putrefactive process, unless as a thin outside varnish. In hard, sound timber, it will hardly enter at all; and if poured into bore-holes in the heads of timbers, it will insinuate itself into the smallest rents or cracks, and waste through them. Used alone, or with any admixture, it is absorbed and dried quickly on wood in a decomposing state or commencing to be dry rotten. Used with litharge, it dries after some days; but with lamp-black it has scarcely so much tendency to dry as when used alone. Paint of fish oil and charcoal drys very quickly where there is absorption, and the charcoal extends its oxidating or drying effect to the fish oil in its vicinity.

We give the following to prove that we have written, and also to serve as an example for those who wish to try experiments:—

EXPERIMENTS ON FISH OIL.

June 9.—Upon a piece of old oak scantling, with its alburnam on one side in a state of decay, fish oil was poured several times, viz. on this day, on June 25, and July 3, which it rapidly absorbed in the decayed part.

July 26.—It was payed (or mopped) with fish oil and charcoal powder, and the following day it was put under an inverted cask.

October 1.—The end of this piece was covered with a greenish mould. *This proves that fish oil must be injurious, except where exposed to sun and air to dry it.*

A compound of fixed oils and charcoal is liable to inflame, but as a thin covering or pigment it may not be so.

The *petroleum* oil-wells, near Prome, in Burmah, have been in use from time immemorial. Wood, both for ship-building and house-building, is invariably saturated or coated with the product of those wells; and it is stated that the result is *entire immunity from decay* and the ravages of the white ant. At Marseilles, and some other ports in the

Mediterranean, it used to be the practice to run the petroleum, which is obtained near the banks of the Rhone, into the vacancies between the timbers of the vessels to give them durability. It was sometimes for the conjoint purpose of giving stability and duration to vessels, mixed with coarse sand or other extraneous matters, and run in whilst hot between the ceiling and bottom plank, where it filled up the vacancies between the timbers in the round of their bottoms, excepting where necessary to be prevented. The great objection to the use of petroleum is its imflammability. *Creosote,* its great rival for wood preserving, is also inflammable, and not so agreeable in colour; but it is *considerably cheaper,* which is an important matter.

As we are now about to enter upon the subject of patent processes, &c., it appears desirable to lay down certain principles at the commencement, in order to assist the reader as much as possible.

Almost every chemical principle or compound of any plausibility has been suggested in the course of the last hundred and fifty years; but the multiplicity and contradiction of opinions form nearly an inextricable labyrinth. To commence.

1st. It seems obvious that *the sooner the sap is wholly removed from the wood the better, provided the woody fibre solidifies without injury.*

2nd. That *the wood should be impregnated with any strongly antiseptic and non-deliquescent matter which must necessarily be in solution when it enters the wood.* No deliquescent remedy is eligible, because moisture is injurious to metallic fastenings.

3rd. *The wood should be first dried, and its pores then closed with any substance impervious to air and moisture, and at the same time highly repellant to putrescency.* The most essential requisites in a preservative of timber being a disposition to *dryness,* and a tendency to resist *combustion* as far as consistently obtainable.

4th. *Any process to be successful ought not to be tedious, very difficult, or too expensive.* These are important elements in the success of any patent.

Very little is known of any preservative process previous to the year 1717, when directions were given by the Navy authorities to *boil* treenails, and dry them before they were used. But whether the custom had prevailed before this time, or whether their strength and durability were increased by it, there are no means of ascertaining. It does not appear that any substance was put into the water to decompose the juices; but as they are soluble in warm water, perhaps the power of vegetation might have been destroyed without it.

In 1737 Mr. Emerson patented a process of saturating timber with *boiled oil,* mixed with poisonous substances; but his process was very little used. This, we believe, was the *first* patent on wood preserving.

About 1740, Mr. Reid proposed to arrest decay by means of a certain *vegetable acid* (probably pyroligneous acid). The method of using it was by simple immersion.

In 1756, Dr. Hales recommended that the planks at the water-line of ships should be soaked in *linseed oil,* to prevent the injury to which wood is subject when alternately exposed to wet and dry; and indeed, many ships were built in which a hollow place was cut in one end of each beam or sternpost, which might constantly be kept filled with *train oil.* Amongst other ships so constructed, the 'Fame,' 74, may be mentioned. When, after some years, this ship was repaired, it was found that as far as the oil had penetrated, namely, from 12 to 18 inches from the end, the wood was quite sound, whilst the other parts were more or less decayed. The Americans used to hollow out the tops of their masts in the form of cups or basins; bore holes from the end a considerable way down the masts; pour oil into these; cover them over with lead; and leave the oil to find its way down the capillary vessel to the interior of the timber.

In 1769, Mr. Jackson, a London chemist, with a view to the prevention of decay, obtained permission to prepare some timber to be used in the national yards, by immersing it in a solution of *salt water, lime, muriate of soda, potash, salts,* &c., the result of which dose was, that several frigates in the Navy subjected to the process were rendered more perishable than if they had been constructed of unprepared timber. The solution was filtered into the wood partly by means of holes made in it. Chapman proposed a similar method of preserving the frames of ships, viz. by boring holes in the timbers, and pumping a *solution of copperas* in water into them. He believed every part of the vessel would thus be impregnated.

Mr. Jackson also prepared the frame of the ship 'Intrepid' with another solution. The ship lasted many years. Bowden thought it was a *solution of glue.* Chapman suggested *slaked lime,* thinned with a weak *solution of glue* for mopping the timbers of a ship.

Shortly after Mr. Jackson's process was started, Mr. Lewis attempted to accomplish the preservation of timber by placing it surrounded by pounded lime, in spaces below the "surface of the earth." The use of lime has also been advocated by Mr. Knowles, Secretary of the Committee of Surveyors of the Navy, who has written an able work on the 'Means to be Taken to Preserve the British Navy from Dry Rot' (1821).

Between 1768 and 1773 a practice prevailed of saturating ships with common salt; but this was found to cause a rapid corrosion of the iron fastenings, and to fill the vessels between decks with a constant damp vapour. In 'Nicholson's Journal,' No. 30, there is an article signed *Nauticus* on this subject. Vessel owners had long ago observed that those ships which have early sailed with cargoes of salt are not attacked by dry rot. Indeed, several instances are attested of vessels whose interiors were lined with fungi having all traces of the plant destroyed by accidental or intentional sinking in the sea. Acting on such hints, a trader of Boston, U. S., salted his ships with 500 bushels of the chloride, disposed as an interior lining, adding 100 bushels at the end of two years. Such an addition of dead weight is sufficient objection to a procedure which has other great disadvantages. Salt should never be applied as an antidote against the dry rot, on account of its natural powers of attracting moisture from the atmosphere, which would render apartments almost uninhabitable, from their continual dampness. Those who have lived for any length of time in a house at the sea-side, the mortar of which has been partly composed of sea sand, will have observed the moist state of the paper, plastering, &c., in wet weather. Bricks made with sea sand are objectionable.

Salt water seasoning has already been referred to, but as it is so closely connected with salt seasoning, the further and final consideration of salt water seasoning may be fitly dealt with here. Salt water will not extract the juices from the timber like fresh water. It is only by destroying the vegetation that salt water can be advantageous, but it would require a very long time to impregnate large timber to the heart so as to destroy vegetation. It is well known that wood is softened, and in time decomposed, by extreme moisture. Fifty years since, the master builder at Cronstadt complained that the oak from Casan, which was frequently wet from different causes in its passage of three years to Cronstadt, was so water-soaked as never to dry; and also from the information of Mr. Strange, it appears "that the practice at Venice of the fresh-cut timber being thrown into salt water, prevents its ever becoming dry in the ships, and that the salt water rusted and corroded the iron bolts." In fine, vessels built with salt water seasoned wood are perfect hygrometers, being as sensible to the changes of the moisture of the atmosphere as lumps of rock salt, or the plaster of inside walls where sea sand has been used.

In Ceylon, the timber of the female palm tree is much harder and blacker than that of the male, inasmuch as its brings nearly triple its price. The natives are so well aware of the difference that they resort to the devise of immersing the male tree in *salt water* to deepen its colour, as well as add to its weight.

Vessels impregnated with *bay salt,* or the large grained salt of Leamington or of Liverpool (pure muriate of soda), will possess decided advantages; as also will vessels that have been laden with *saltpetre,* if it has been dispersed amongst their timbers.

Ships (the timbers of which have been previously immersed in salt water) have been broken up after a few years' service, and the floor timbers taken out quite sound: but when exposed to the sun and rain in the summer months, their albumen has been in a decomposed or friable state.

By the answers to queries given to Mr. Strange, the British Minister at Venice, in or about 1792, it appears that several of the Venetian ships of war had then lain under sheds for fifty-nine years; some in bare frames, and others planked and caulked: that these ships show no outward marks of decay; but their timbers have shrunk much, and *become brittle;* that some of the most intelligent ship builders were of opinion that great prejudice had arisen from the prevalent custom of throwing the timber fresh cut into salt water, and letting it lie there until wanted; that afterwards it dried, and withered on the outside, under the sheds, while the inside, being soaked with salt water, rotted before it became dry; and this was one reason, amongst others, why Venetian ships, though built of good timber, lasted so short a time; for the salt moisture not only rots the inside of the beams and timbers, but of course rusts and corrodes the iron bolts.

Salt water, sea-sand, and *sea-weed* are now used for seasoning "jarrah" wood in Western Australia. This wood is considered a first-class wood for ship-building, but it is somewhat slow to season, and if exposed before being seasoned it is apt to "fly" and cast. The method adopted is as follows: The logs are thrown into the sea, and left there for a few weeks; they are then drawn up through the sand, and after being covered with sea-weed a few inches deep, are left to lie on the beach, care being taken to prevent the sun getting at their ends. The logs are then left for many months to season. When taken up they are cut into boards 7 inches wide, and stacked, so as to admit of a free circulation of air around them, for five or six months before using them. Sea-weed or sea-ware, cast upon the shores, contains a small quantity of carbonate of soda, and a large proportion of nitrogenous and saline matters, with earthy salts, in a readily decomposable state. They also contain much soluble mucilage. The practice of seasoning timber by heating it in a *sand bath* was formerly adopted by the Dutch, and by the Russians in building boats. Mr. Thomas Nichols (in a letter to Lord Chatham, when First Lord of the Admiralty) states "that the same end, viz. preservation of timber from decay, might probably be acquired by burying the timber in sand, which acts as an artificial sap," in the same manner as mentioned in Townsend's 'Travels through Spain,' to be used with the masts of ships of war at Cadiz.

Peat moss has been recommended (because the sulphates of iron, soda, and magnesia are found in it), but it failed when tried.

With reference to Mr. Lewis's proposal to preserve wood by means of lime, it must be remembered that *quicklime,* with damp, has been found to accelerate putrefaction, in consequence of its extracting carbon; but when dry, and in such large quantities as to absorb all moisture from the wood, *the wood is preserved, and the sap hardened.* Vessels *long* in the lime trade have afforded proof of this fact; and we have also examples in plastering-laths, which are generally found sound and good in places where they have been dry. Whitewash or *lime-water* has been strongly recommended for use between the decks of ships, as being unfavourable to vegetation: it should be renewed at intervals of time, according to circumstances. It has been applied with good effect to the joists and sleepers of kitchen floors; but to be effectual it should be occasionally renewed. Effete, or re-carbonated lime, is injurious to timber, like other absorbent earths; so also are calcareous incrustations formed by the solution of lime in water, as appears from Von Buch's 'Travels in Norway,' in which he says, "that in the fishing country (near Lofodden, beyond the Arctic circle) the calcareous incrustations brought by water, filtering through a bed of shells, soon cause the vessels and wood to be covered with and destroyed by green fungi." The ends of joists of timber inserted in walls are frequently found rotten; and where not so, it may probably be owing to the mortar having been made with hot lime, and used immediately, or to the absence of moisture. It does not appear practicable to use limewater to any extent for preserving timber, because water holds in solution only about 1-500th part of lime, which quantity would be too inconsiderable; it, however, renders timber more durable, but at the same time very hard and difficult to be worked.

Vessels constantly in the *coal* trade have generally required little repair, and have lasted until in the common course of things they were lost by shipwreck. This must be owing to the martial pyrites which abound in all coals; and also from the sulphuric acid arising from the quantity of coal dust which finds its way through the seams of the ceiling, and adheres to the timber and planks.

In 1779, M. Pallas, in Russia, proposed to steep wood in *sulphate of iron* (green vitriol) until it had penetrated deeply, *and* then in *lime* to precipitate the vitriol. Neumann, in his first volume of 'Chemistry,' on the article green vitriol, says, "That in the Swedish transactions this salt is recommended for preserving wood, particularly the wheels of carriages, from decay.

"When all the pieces are fit for being joined together, they are directed to be boiled in a solution of vitriol for three or four hours, and then kept for some days in a warm place to dry. It is said that the wood by this preparation becomes so hard and compact that moisture cannot penetrate it, and that iron nails are not so apt to be destroyed in this vitriolated wood as might be expected, *but last as long as the wood itself.*"

In 1780 the marcasite termed by the miners *mundic,* found in great abundance in the tin mines in Devonshire and Cornwall, was employed, in a state of fusion, to eradicate present and to prevent the future growth of dry rot; but whether its efficacy was proved by time is not known. A garden walk where there are some pieces of mundic never has any weeds growing; the rain that falls becomes impregnated with its qualities, and in flowing through the walk prevents vegetation.

In 1796 Hales proposed to *creosote* the treenails of ships: this was forty-two years previous to Bethell's patent for creosoting wood.

About the year 1800, the Society of Arts Building in the Adelphi, London, being attacked by dry rot, Dr. Higgins examined the timbers, caused some to be removed and be replaced by new, and the remainder to be scraped and washed with a solution of *caustic ammonia,* so as by burning the surface of the wood to prevent the growth of fungi.

At the commencement of the present century, a member of the Royal Academy of Stockholm called attention to the use of *alum* for preserving wood from fire. He says, in the Memoirs of that Academy, "Having been within these few years to visit the alum mines of Loswers, in the province of Calmar, I took notice of some attempts to burn old staves of tubs and pails that had been used for the alum works. For this purpose they were thrown into the furnace, but those pieces of wood which had been *penetrated* by the alum did not burn, though they remained for a long time in the fire, where they only became red; however, at last they were consumed by the intenseness of the heat, but they yielded no flame." He concludes, from this experiment, that wood or timber for the purpose of building may be secured against the action of fire by letting it remain for some time in water wherein vitriol, alum, or any other salt has been dissolved which contains no inflammable parts.

In Sir John Pringle's Tables of the antiseptic powers of different substances, he states *alum* to be thirty times stronger than sea-salt; and by the experiments of the author of the 'Essai pour servir à l'Histoire de la Putréfaction,' metallic salts are much more antiseptic than those with earthy bases.

In 1815 it occurred to Mr. Wade that it would be a good practice to fill the pores of timber with *alumine* or selenite; but two years after, Chapman observed, "Impregnation of ships' timbers with a *solution of alum* occurred to me about twenty years since, because on immersion in sea-water the alumine would be deposited in the pores of the timber; but I was soon informed of its worse than inutility, by learning that the *experiment had been tried,* and, in place of preserving, had *caused the wood to rot speedily.* Impregnation with *selenite* has been tried in elm water-pipes. On precipitation from its solvent it partially filled the pores, and hardened the wood, but *occasioned speedy rottenness.*" If, by using a *solution of alum* to render wood uninflammable, we at the same time cause it to *rot speedily,* it becomes a question *whether the remedy is not worse than the disease.* Captain E. M. Shaw. of the London Fire Brigade, in his work, 'Fire Surveys' (1872), recommends *alum and water.* Probably he only thought of fire, and not of rotting the wood. The alum question does not appear to be yet satisfactorily settled.

While upon the subject of uninflammable wood, we may state that in 1848, upon Putney Heath (near London), by the roadside, stood an obelisk, to record the success of a discovery made in the last century of the means of building a house which no ordinary application of ignited combustibles could be made to consume: the obelisk was erected in 1786. The inventor was Mr. David Hartley, to whom the House of Commons voted 2500*l.*, to defray the expense of the experimental building, which stood about one hundred yards from the obelisk. The building was three stories high, and two rooms on a floor. In 1774, King George the Third and Queen Charlotte took their breakfast in one of the rooms, while in the apartment beneath fires were lighted on the floor, and various inflammable materials were ignited to attest that the rooms above were fire-proof. Hartley's secret lay in the floors being double, and there being interposed between the two boards sheets of laminated iron and copper, not thicker than stout paper, which rendered the floor air-tight and thereby intercepted the ascent of the heated air; so that, although the inferior boards were actually charred, the metal prevented the combustion taking place in the upper flooring. Six experiments were made by Mr. Hartley in this house in 1776, but we cannot ascertain any particulars about them, or any advantages which accrued to the public from the invention, although the Court of Common Council awarded him the freedom of the City of London for his successful experiments.

In 1805 Mr. Maconochie proposed to saturate with resinous and oily matters inferior woods, and thus render them more lasting. This proposal was practically carried out in 1811 by Mr. Lukin, who constructed a peculiar stove for the purpose of thus impregnating wood under the influence of an increased temperature. The scheme, however, had but very partial success, for either the heat was too low, and the wood was not thoroughly aired and seasoned, or it was too high and the wood was more or less scorched and burnt. Mr. Lukin buried wood in *pulverized charcoal* in a heated oven, but the fibres were afterwards discovered to have started from each other. He next erected a large kiln in Woolwich dockyard, capable of containing 250 loads of timber, but an explosion took place on the first trial, before the process was complete, which proved fatal to six of the workmen, and wounded fourteen, two of whom shortly afterwards died. The explosion was like the shock of an earthquake. It demolished the wall of the dockyard, part of which was thrown to the distance of 250 feet; an iron door weighing 280 lb. was driven to the distance of 230 feet; and other parts of the building were borne in the air upwards of 300 feet. The experiment was not repeated.

Mr. Lukin was not so fortunate in 1811 as in 1808, for in the latter year he received a considerable reward from the Government for what was considered a successful principle of ventilating hospital ships.

In 1815 Mr. Wade recommended the impregnation of timber with resinous and oleaginous matter (preferring linseed oil to whale oil) or with *common resin* dissolved in a lixivium of *caustic alkali,* and that the timber should afterwards be plunged into water acidulated with any cheap acid, or with alum in solution. He considered that timber impregnated with oil would not be disagreeable to rats, worms, cockroaches, &c., and that the contrary was the case with resin. He also recommended the impregnation of timber with *sulphate of copper, zinc, or iron,* rejecting deliquescent salts, as they corrode metals.

In 1815 Mr. Ambrose Boydon, of the Navy Office strongly recommended that the timber, planks, and treenails of ships should be first boiled in *lime-water* to correct the acid, and that they afterwards should be boiled in a *thin solution of glue,* by which means the pores of the wood would be filled with a hard substance insoluble by water, which would not only give the timbers durability, by preventing vegetation, but increase their strength. Glue, he thought, might be used without limewater, or glue and limewater mixed together.

In 1817 Mr. William Chapman published the result of various experiments he had made on wood with *lime, soap,* and *alkaline* and *mineral salts.* He recommended a solution of a pound of *sulphate of copper* or blue vitriol (at that time 7*d*. per pound) dissolved in four ale gallons of rain water, and mopped on hot over all the infected parts, or thrown over them in a plentiful libation. He also recommended one ounce of *corrosive sublimate* (then 6*s*. per pound) to a gallon of rainwater applied in the same manner to the infected parts. For weather-boarded buildings he considered one or more coats of thin *coal tar,* combined with a small portion of *palm oil,* for the purpose of preventing their tendency to rend, to be a good preservative.

Messrs. Wade, Boydon, and Chapman published works on dry rot about this time.

In 1822 Mr. Oxford took out a patent for an improved method of preventing "decay of timber," &c. The process proposed was as follows: "The essential *oil of tar* was first extracted by distillation, and at the same time saturated with *chlorine gas.* Proportions of *oxide of lead, carbonate of lime,* and *carbon of purified coal tar* well ground, were mixed with the oil, and the composition was then applied in thick coatings to the substances intended to be preserved.

On 31st March, 1832, Mr. Kyan patented his process of *corrosive sublimate* (solution of the *bi-chloride of mercury)* for preventing dry rot; which process consisted as follows: A solution of the corrosive sublimate is first made, and the timber is placed in the tank. The wood is held down in such a way, that when immersed on the fluid being pumped in, it cannot rise, but is kept under the surface, there being beams to retain it in its place. There it is left for a week, after which the liquor is pumped off, and the wood is removed. This being done, the timber is dried, and said to be prepared. Sir Robert Smirke was one of the first to use timber prepared by Kyan, in some buildings in the Temple, London; and he made some experiments on timber which had undergone Kyan's process. He says, "I took a certain number of pieces of wood cut from the same log of yellow pine, from poplar, and from the common Scotch fir; these pieces I placed first in a cesspool, into which the waters of the common sewers discharged themselves; they remained there six months; they were then removed from thence, and placed in a hotbed of compost,under a garden-frame; they remained there a second six months; they were afterwards put in a flower border, placed half out of the ground, and I gave my gardener directions to water them whenever he watered the flowers; they remained there a similar period of six months. I put them afterwards in a cellar where there was some dampness, and the air completely excluded; they remained there a fourth period of six months, and were afterwards put into a very wet cellar. Those pieces of wood which underwent Kyan's process are in the same state as when I first had them, and all the others to which the process had not been applied are more or less rotten, and the poplar is wholly destroyed.

"I applied Kyan's process to yellow Canadian pine about three years ago, and exposed that wood to the severest tests I could apply, and it remains uninjured, when any other timber (oak or Baltic wood) would certainly have decayed if exposed to the same trial, and not prepared in that manner.

"As another example of the effect of the process, I may mention that about two years ago, in a basement story of some chambers in the Temple, London, the wood flooring and the wood lining of the walls were entirely decayed from the dampness of the ground and walls, and to repair it under such circumstances was useless. As I found it extremely difficult to prevent the dampness, I recommended lining the walls and the floor with this prepared wood, which was done; and about six weeks ago I took down part of it to examine whether any of the wood was injured, but it was found in as good a state as when first put up. I did not find the nails more liable to rust.

"I have used Kyan's process in a very considerable quantity of paling nearly three years ago; that paling is now in quite as good a state as it was, though it is partly in the ground. It is yellow pine. Some that I put up the year before, without using Kyan's process (yellow pine), not fixed in the ground, but close upon it, is decayed."

This evidence, by such an experienced architect as the late Sir Robert Smirke was, is certainly of great value in favour of Kyan's process.

The recorded evidence upon the efficiency of this mode of treating timber for its preservation is somewhat contradictory. On the Great Western Railway 40,000 loads were prepared, at an expenditure of 1¾ lb. of sublimate to each load, the timber, 7 inch, being immersed for a period of eight days, and the uniformity of the strength of the solution being constantly maintained by pumping. Some samples of this timber, after six years' use as sleepers on the railway, were found "as sound as on the day on which they were first put down." This timber was prepared by simple immersion only, without exhaustion or pressure. Some of the sleepers on the London and Birmingham Railway, on the other hand, which had been Kyanized three years only, were found absolutely rotten, and Kyan's process was there consequently abandoned.

This process is said to cost an additional expense to the owner of from fifteen to twenty shillings per load of timber. Mr. Kyan at first used 1 lb. of the salt in 4 gallons of water, but it was found that the wood absorbed 4 or 5 lb. of this salt per load; more water was added to lessen the expense, until the solution became so weak as in a great measure to lose its effect.

Simple immersion being found imperfect as a means of injecting the sublimate, attempts were afterwards made to improve the efficiency of the solution by *forcing* it into the wood. Closed tanks were substituted for the open ones, and forcing pumps, &c., were added to the apparatus. The pressure applied equalled 100 lb. on the square inch. With this arrangement a solution was made use of having 1 lb. of the sublimate to 2 gallons of water; and it was found that three-fourths of this quantity sufficed for preparing one load of timber. The timber was afterwards tested, and it was ascertained that the solution had penetrated to the heart of the logs. Mr. Thompson, the Secretary to Kyan's Company, stated, in March, 1842, that experience had proved "that the strength of the mixture should not be less than 1 lb. of sublimate to 15 gallons of water; and he had never found any well-authenticated instance of timber decaying when it had been properly prepared at that strength." As much as 1 in 9 was not infrequently used. Kyan's process is now but very rarely used; Messrs. Bethell, of King William Street, London, adopt it when requested by their customers. We have given the statements which have been made for and against this patent, but after a lapse of forty years it is difficult to reconcile conflicting statements.

Although Mr. Kyan invented his process in 1832, Sir Humphrey Davy had previously used and recommended to the Admiralty, and Navy Board, a weak solution of the same thing to be used as a wash where rot made its appearance: on giving his opinion upon Mr. Lukin's process, that eminent chemist observed "that he had found corrosive sublimate highly antiseptic, and preservative of animal and vegetable substances, and therefore recommended rubbing the surface of the timber with a solution of it." In 1821 Mr. Knowles, of the Navy Office,referred to the use of corrosive sublimate for timber. In fact, it was used in 1705, in Provence (France), for preserving wood from beetles. Kyan, however, was the first to apply it to any extent. In the years 1833 to 1836, at the Arsenal, Woolwich, experiments were instituted, having for their object the establishing, or otherwise, the claims of Kyan's system; the results of which were of a satisfactory nature. Dr. Faraday has stated that the combination of the materials used was not simply mechanical but chemical; and Captain Alderson, C.E., having experimented upon some specimens of ash and Christiana deal, found that the rigidity of the timber was enhanced, but its strength was in some measure impared; its specific gravity being also in some degree diminished. Kyan's process is said by some to render the wood brittle.

Mr. Kyan considered that the commencement of rot might be stopped or prevented by the application of corrosive sublimate, in consequence of the chemical combination which takes place between the corrosive sublimate and those albuminous particles which Berzelius and others of the highest authority consider to exist in and form the essence of wood; which, being the first parts to run to decay, cause others to decay with them. By seasoning timber in the ordinary way, the destructive principle is dried, and under common circumstances rendered inert. But when the timber is afterwards exposed to great moisture, &c. (the fermentative principle being soluble when merely dried), it will sometimes again be called into action. Kyan's process is said not only altogether to destroy this principle and render it inert, but, by making it solid and perfectly insoluble, to remove it from the action of moisture altogether. It thus loses its hygrometric properties, and, therefore, prepared or patent seasoned timber is not liable to those changes of atmosphere which affect that which is seasoned in the common way. All woods, including mahogany and the finest and most expensive wood, may be seasoned by Kyan's process in a very short space of time, instead of the months required by the ordinary methods.

The reader will find a great deal about Kyan's system in the 'Quarterly Review,' April, 1833; and about proposals for using chloride of mercury for wood, 'Memoirs of the Academy of Dijon,' 1767; 'Bull. des Sciences tecn.,' v. ii., 1824, Paris; and 'Bull. de Pharm.,' v. 6, 1814, Paris.

It is well known that Canadian timber is much more liable to decay than that grown in the northern parts of Europe, and for this reason is never extensively used in buildings of a superior description. The principle of decay being destroyed by Kyan's process as above described, this objection no longer exists, and this kind of timber may therefore now be employed with as great security as that of a superior quality and higher price. The same observation applies with great force to timber of British growth, particularly to that of Scotland, much of which is considered as of little or no value for durable purposes, on account of its extreme liability to decay, whether in exposed situations or otherwise. The process invented by Kyan might therefore render of considerable value plantations of larch, firs of all kinds, birch, elm, beech, ash, poplar, &c.

Cost of process in 1832, 1*l.* per load of 50 cubic feet of timber.

Mr. W. Inwood, the architect of St. Pancras Church, London, reported favourably of Kyan's process. On 22nd February, 1833, Professor Faraday delivered a lecture at the Royal Institution, London, on Kyanizing timber; and on 17th April, 1837, he reported that Kyan's process had not caused any rusting or oxidation of the iron in the ship 'Samuel Enderby,' after the ship had been subjected to this process, and had been on a three years' voyage to the South Sea fisheries; and in the same year, viz. 1837, Dr. Dickson delivered a lecture at the Royal Institute of British Architects on dry rot, recommending Kyan's process.

Five years after Mr. Kyan's invention, viz. in 1837, a Mr. Flocton invented a process for preventing decay, by saturating timber with *wood-tar* and *acetate of iron,* but little is known of this invention: we believe it was a failure.

During the same year Mr. Flocton's process was made known, a Frenchman named Letellier recommended saturating timber in a solution of *corrosive sublimate,* and when dry, into one of *glue, size,* &c.

During this year Mr. Margary took out his patent for applying *sulphate of copper* to wood. We propose to describe Margary's process further on: we do not think he received any medals for it.

We now arrive at the modern *creosoting* process, which was brought to perfection by the late Mr. John Bethell. Mr. Bethell's process of the creosoting, or the injection of the heavy oil of tar, was first patented by him on July 11th, 1838. It consists in impregnating the wood throughout with oil of tar, and other bituminous matters containing creosote, and also with pyrolignite of iron, which holds more creosote in solution than any other watery menstruum. Creosote, now so extensively used in preserving wood, is obtained from coal tar, which, when submitted to distillation, is found to consist of pitch, essential oil (creosote), naphtha, ammonia, &c. In the application of the oil of tar for this purpose, it is now considered to be indispensable that the ammonia be got rid of; otherwise the wood sometimes becomes brown and decays, as may be constantly seen in wood coated with the common oil tar. The kind of creosote preferred by continental engineers and chemists, and also by the late Mr. John Bethell himself, is *thick,* and rich in *naphthaline.* Some English chemists now seem to prefer the thinnest oil, which contains no naphthaline but a little more carbolic acid; the crude carbolic acid would vary from 5 to 15 per cent.: no engineer has ever required more than 5 per cent. of crude carbolic acid in creosote. The thinner oil appears to be more likely to be drawn out of the wood by the heat of the sun or absorption in powdery soil, and is more readily dissolved out by moisture.

Mummies many thousands of years old have evidently been preserved on the creosoting principle, and from observing the mummies the process of creosoting suggested itself to Mr. Bethell. The ancient Egyptians, whether from the peculiarity of their religious opinions, or from the desire to shun destruction and gain perpetuity even for their dead bodies, prepared the corpses of their deceased friends in a particular way, viz. by coagulating the albumen of the various fluids of the body by means of creosote, cedar oil, salt, and other substances, and also by excluding the air. How perfectly this method has preserved them the occasional opening of a mummy permits us to see. A good account of the operation is given in the chapter on mummies, in the second volume of Egyptian Antiquities in the 'Library of Entertaining Knowledge.'

Creosote has the same effect of coagulating the albumen, whilst it fills the pores of the wood with a bituminous asphaltic substance, which gives a waterproof covering to the fibre, prevents the absorption of water, and is obnoxious to animal life.

In cases where the complete preservation of timber is of vital importance, and expense not a consideration, the wood should be first subjected to Burnett's process, and then creosoted, by which means it would be nearly indestructible; the reason for this combined process being, that the albumen or sap absorbs the creosote more readily than the heart of the timber, which can, however, be penetrated by the solution of chloride of zinc. Mr. John Bethell's patent of 1853 recommends this in a rather improved form. He says the timber should *first* be injected with metallic salts, then dried in a drying-house, then creosoted. By this method, very considerable quantities both of metallic salt and creosote can be injected into timber.

It has been stated that the elasticity of wood is increased by creosoting; the heartwood only decays by oxidation.

The wood should be dried previous to undergoing the process, as the sapwood, otherwise almost useless, can be rendered serviceable, and for piles for marine work whole round timber should be used, because the sapwood is so much more readily saturated with the oil, and this prevents the worms from making an inroad into the heart.

Mr. Bethell uses about 10 lb. of creosote per cubic foot of wood, and he does not allow a piece of timber to be sent from his works without being tested to ascertain if it has absorbed that amount, or an amount previously agreed upon. We mention the latter statement, because it is evident that all descriptions of wood cannot be made to imbibe the same amount. This process is chiefly used for pine timber: yellow pine should absorb about 11 lb. to the cubic foot, and Riga pine about 9 lb. The quantity of oil recommended by the patentee, engineers, and others, is from 8 to 10 lb. for land purposes, and about 12 lb. to the cubic foot for marine. In this country, for marine the quantity does not exceed 12 lb.; but on the Continent, in France, Belgium, and Holland, the quantity used is from 14 to 22 lb. (!) per cubic foot. The specifications frequently issued by engineers for sleepers for foreign railways describe them to be entirely of heartwood, and then to be creosoted to the extent of 10 lb. of the oil per cubic foot: this it is impossible to do, the value of the process being in the retention of the sapwood.

It being ascertained a few years since that the centres of some sleepers were not impregnated with the fluid, after the sleeper had been creosoted to the extent of 10 lb. of creosote per cubic foot, Sir Macdonald Stephenson suggested, as a means of obviating that defect, the boring of two holes, 1 inch in diameter, through each sleeper longitudinally, and impregnating up to 12 lb. or 14 lb. per cubic foot. By that means the creosote would be sent all through the sleeper. The boring by hand would be an expensive process, but by machinery it might be effected at a comparatively small increased cost.

During the last twenty-five years an enormous quantity of creosoted railway sleepers have been sent to India and other hot climates. The native woods are generally too hard for penetration. On the Great Indian Peninsular Railway, the native woods were so hard and close-grained that they could not be impregnated with any preservative substance, sâl wood being principally used, into which creosote would not penetrate more than one quarter of an inch. As regards creosoting wood in India, it is moreover a costly process, owing to the difficulty and expense of conveying creosote from England; iron tanks are necessary to hold the oil when on board ship, and, being unsaleable in India, add to the expense.

English contractors often send piles to be creosoted which have been taken from the timber docks. The large quantity of water they contain resists the entrance of the oil, and the result is that a great deal of timber is badly prepared because the contractors cannot obtain it dry.

In the best creosoting works the tank or cylinder is about 6 feet diameter, and from 20 to 50 feet long. In some instances cylinders are open at both ends, and closed with iron doors, so that sleepers or timber entered at one end, on being treated, can be delivered finished at the opposite end; but for all practical purposes one open end is sufficient, as the oil when heated being of such a searching character it is a difficult matter to get the doors perfectly air-tight, consequently they are apt to leak during the time the pressure is being applied. Pipes are led from the cylinder to the air and force pumps; the air is not only extracted from the interior of the cylinder, but also from the pores of the timber. When a vacuum is made, the oil, which is contained in a tank below the cylinder, is allowed to rush in, and, as soon as the cylinder is full, the inlet pipe is shut and the pressure pumps started to force the oil into the wood; the pressure maintained is from 150 to 200 lb. to the square inch, until the wood has absorbed the required quantity of oil, which is learned by an index gauge fixed to the working tank below. All cylinders are fitted with safety valves, which allow the oil not immediately absorbed to pass again into the tank. The oil is heated by coils of pipe placed in the tank, through which a current of steam is passed from end to end, raising the temperature to 120°.

It is essential to observe that all methods of protecting timber depend for their success upon the skilful and conscientious manner in which they are applied; for, as they involve chemical actions on a large scale, their efficiency must depend upon the observance of the minute practical precautions required to exclude any disturbing causes. In the case of creosoting: to distil the creosote, to draw the sap or other moisture from the wood, and subsequently to inject the creosote in a proper manner, it is necessary that the operations should be carried into effect under the supervision of experienced persons of high character.

Mr. Bethell's process has been and still is being tested on the Indian railways. According to Dr. Cleghorn, it appears that many of the creosoted sleepers have, however, "been found decayed in the centre, the interior portion being scooped out, leaving nothing but a deceptive shell, in some instances not more than ½ inch in thickness," but he does not state whether the sleepers were prepared in England or India; because, if prepared in India, it is probable that some of the hard Indian woods, into which it is not possible to get creosote or any other preservative fluid, had been used. Mr. Burt, who has large timber-preserving works in London for creosoting, stated about eight years since, that after an experience of twenty years, during which time he had sent over one million and a half sleepers to India alone, besides having prepared many thousand loads of timber for other purposes, he could safely assert that the instances of failure had been rare and isolated.

A section of a piece of timber impregnated with creosote presents some curious and very distinctive characteristics, according to the duration of the process of injection and amount of tar injected. In every case the injected tar follows the lines and sinuosities of the longitudinal fibres. When injected in sufficient quantity it fills the pores altogether; when, on the contrary, the process has been incompletely performed, which, however, is generally sufficient, the tar accumulates in the transverse sections, and plugs the channels that give access to deleterious agents.

The experiments made by M. Melseuns on oaken blocks exposed to the fumes of *liquid ammonia* show that the conservating fluids follow the precise course that would be taken by decay. In wood treated with creosote the tar acts on the very parts first exposed to injury, and on the course that would be taken by decay, which is thus rendered impossible. The methods of injection suggested by M. Melseuns in 1845 did not answer equally well with every kind of wood. After trying wooden blocks in every sort of condition, dressed, and in the rough, green and dry, sound and decayed, M. Melseuns found that alder, birch, beech, hornbeam, and willow were easily and completely impregnated; deal sometimes resisted the process, the innermost layers remaining white; poplar and oak offered a very great resistance—indeed, with poplar it was found necessary to repeat the process.

The decay of sleepers, prepared and unprepared, will often depend on their form. Three forms have been used: 1st, the half-round sleeper, 10 inches by 5 inches; these are now almost universally used; 2nd, the triangular sleeper, about 12 inches wide on each side, used by Mr. Cubitt on the Dover line, but since abandoned; and 3rd, the half square, 14 inches by 7 inches, used by Mr. Brunel and still in use. Mr. G. O. Maun, in reporting on the state of the sleepers of the Pernambuco Railway, states that fair average samples taken out on the 1st December, 1863 (laid in 1857), show that the half-round intermediate sleeper is in the most perfect state of preservation; in fact, nearly as good as on the day it was put down; while the square-sawn or joint sleeper has not withstood the effects of the climate so well.

The kind of ballast in which it will be most advisable to lay the sleeper is another important point to be attended to. About 12 miles of the Pernambuco Railway are entirely laid with creosoted sleepers, principally in white sand. In this description of ballast the half-round sleepers have suffered, since the opening of the first section of the line in 1858 up to 1866, a depreciation of not more than 1 per cent., whilst the square-sawn sleepers have experienced a depreciation of not less than 50 per cent. Had the latter been placed in wet cuttings with ballast retentive of moisture, no doubt the whole of them would have required to be renewed. Hence it is evident that fine open sand ballast, which allows a free drainage during the rains, is best adapted for the preservation of sleepers in the tropics: it has also been found to be the best in most countries.

The number of testimonials given in favour of creosote is very large, and are from the most eminent engineers of all countries, in addition to which Mr. Bethell has received several medals at international exhibitions. The English engineers include Messrs. Brunel, Gregory, Abernethy, Ure, Hemans, Hawkshaw, and Cudworth; the French, MM. Molinos and Forestier; the Dutch, Messrs. Waldorp, Freem, and Von Baumhauer; and the Belgian, M. Crepin. The late Mr. Brunel expressly stated that, in his opinion, well creosoted timbers would be found in a sound and serviceable condition at the expiration of forty years. M. Forestier, French engineer of La Vendée department, reporting to the juries of the French Exhibition of 1867, cites a number of experiments he has lately tried upon many pieces of creosoted and uncreosoted oak, elm, ash, Swedish, Norwegian, and Dantzic red fir, Norway white fir, plane, and poplar, and shows that in each case, except that of the poplar, the resistance of the wood both to bending and crushing weight was much increased by creosoting.

Drs. Brande, Ure, and Letheby, also bear testimony to the efficacy of this mode of preserving timber.

Creosoting has been extensively employed upon all the principal railways in Great Britain. In England, upon the London and North Western, North Eastern, South Eastern, Great Western, &c. In Scotland, on the Caledonian, Great Northern, &c. In Ireland, on the Great Southern and Western, Midland, &c. It has also been and is being employed in Belgium, Holland, France, Prussia, India, and America.

Between the years 1838 and 1840, Sir William Burnett's (formerly Director-General of the Medical Department of the Navy) process was first made known to the public.

This process consists of an injection of *chloride of zinc* into timber, in the proportion of about 1 lb. of the salt to about 9 or 10 gallons of water, forced into the wood under a pressure of 150 lb. per square inch.

The late Professor Graham thus wrote of its efficiency: "After making several experiments on wood prepared by the solution of chloride of zinc for the purpose of preservation, and having given the subject my best consideration, I have come to the following conclusions:

"The wood appears to be fully and deeply penetrated by the metallic salt. I have found it in the centre of a large prepared block.

"The salt, although very soluble, does not leave the wood easily when exposed to the weather, or buried in dry or damp earth. It does not come to the surface of the wood like the crystallizable salts. I have no doubt, indeed, that the greater part of the salts will remain in the wood for years, when employed for railway sleepers or such purposes. This may be of material consequence when the wood is exposed to the attacks of insects, such as the white ant in India, which, I believe, would be repelled by the poisonous metallic salt. After being long macerated in cold water, or even boiled in water, thin chips of the prepared wood retain a sensible quantity of the oxide of zinc; which I confirmed by Mr. Toplis' test, and observed that the wood can be permanently dyed from being charged with a metallic mordant.

"I have no doubt, from repeated observations made during several years, of the valuable preservative qualities of the solution of chloride of zinc, as applied in Sir W. Burnett's process; and would refer its beneficial action chiefly to the small quantity of the metallic salt, which is permanently retained by the ligneous fibre in all circumstances of exposure. The oxide of zinc appears to alter and harden the fibre of the wood, and destroy the solubility, and prevent the tendency to decomposition of the azotised principles it contains by entering into chemical combination with them."

The Report of the Jury, which was drawn up by the Count of Westphalia, at the Cologne International Agricultural Exhibition, in 1865, upon prepared specimens of timber, has the following remarks on the chloride of zinc process:

1st. That chloride of zinc is the only substance which thoroughly penetrates the timber, and is at the same time the best adapted for its preservation.

2nd. That the process of impregnating the wood after cutting is more useful and rational than doing so while the tree is growing.

3rd. That red beech is the only wood which has been impregnated in an uniform and thorough manner.

It should, however, be stated that the Jury had very slender evidence presented to it respecting the creosoting process. The creosoted specimens had been impregnated under the pressure of 60 lb. to 65 lb. per square inch for three or four hours, and were consequently inefficiently done; in England the pressure per square inch would have been at least 140 lb.

Drs. Brande and Cooper, of England, and Dr. Cleghorn, of India, also wrote favorably of Sir W. Burnett's process.

In 1847 a powerful cylinder, of Burnett's construction, hermetically closed, was laid down adjoining the sawmills in Woolwich dockyard. It was found to admit the largest description of timber for the purpose of having the moisture extracted, and the pores filled with chloride of zinc. Three specimens of wood—English oak, English elm, and Dantzic fir—remained uninjured in the fungus pit at Woolwich for five years; while similar, but unprepared specimens were all found more or less decayed.

Although among the many attempts to preserve wood those in England have proved the most successful, it should be mentioned that France, Germany, and America have given much attention to the subject.

At the end of the last century Du Hamel and Buffon pointed out the possibility of preserving wood, as well as the means of rendering it unalterable. As early as 1758 Du Hamel made experiments on the vital suction of plants, and made some curious observations on the different rings of vegetable matter which absorb most liquid in different plants. He also tried the effect of vital suction and pressure (of gravitation) acting at the same time. His process was reviewed by Barral in 1842.

About 1784 M. Migneron invented a process about which little is known, but the wood was covered with certain fatty substances. Wood nine years exposed to deterioration was improved by this process. M. Migneron had the approval of Buffon, Franklin, and the Academies. His invention was again brought into notice in 1807, when it was found that timber which had been prepared by it in 1784, and exposed more than twenty years, was quite sound.

In 1811 Cadet de Gassicourt made different kinds of wood imbibe vegetable and mineral substances, and certain unguents: he used metallic salts (iron, tin, &c.).

In 1813 M. Champy plunged wood into a bath of *tallow* at 334°, and kept it there two or three hours. His experiments were afterwards repeated by Mr. Payne.

About the year 1832 it was proposed in America to apply *pyroligneous acid* to the surface of wood, or introduce it by fumigation.

Biot (who has written an excellent life of Sir Isaac Newton) remarked, in 1834, that wood could be soaked by pressure; but his process of penetrating it with liquids was imperfect, and his discovery remains unapplied.

A Frenchman, of the name of Bréant, made about this time a discovery which preceded Boucherie's method, which is adopted to a great extent in France. Bréant's apparatus consisted of a very ingenious machine, which, acting by pressure, caused liquids to penetrate to all points of a mass of wood of great diameter and considerable length. He may therefore be regarded as having solved the problem of penetration in a scientific, though not in a practically applied, point of view. Dr. Boucherie testified before the Académie des Sciences, in 1840, to the merit of Bréant's invention, which, with modifications by Payne, Brochard, and Gemini, has been worked in France and England. This process was recommended by Payne in 1840 and 1844, and imitated by him in France, and later on by Vengat and Bauner, who used both *an air pump and a forcing pump*. Bréant obtained three patents, viz. 1st, in 1831, to act by pressure; 2nd, in 1837, by vital suction; and 3rd, in 1838, vacuum by steam. A mixture of linseed oil and resin succeeded best with him. He attached more importance to the thorough penetration of the wood than to the choice of the penetrating substances. He borrowed his process from Du Hamel, but to make the necessary suction in the pores he produces a partial vacuum in the impregnating cylinder by filling it with steam, and condensing the steam.

Previous to Boucherie's method, a German, Frantz Moll, in 1835, proposed to introduce into wood *creosote in a state of vapour*, but the process was found to be too expensive. This was a modification of Maconochie and Lukin's trials in 1805 and 1811. A similar process has since arisen in New York: we believe Mr. Renwick, of that place, suggested it.

Such were the known labours when Dr. Boucherie, in December, 1837, devoted his time to a series of experiments upon timber, with a view to discover some preservative process which should answer the following requirements: First, for protecting wood from dry rot or wet rot; second, for increasing its hardness; third, for preserving and developing its flexibility and elasticity; fourth, for preventing its decay, and the fissures that result from it, when, after having been used in construction, it is left exposed to the variations of the atmosphere; fifth, for giving it various and enduring colours and odours; and sixth and last, for greatly reducing its inflammability.

It is a curious coincidence that at Bordeaux, in 1733, the Academy received a memoir relative to the circulation of the sap and coloured liquids in plants; and it was at Bordeaux, a century afterwards, viz. 1837, that M. Boucherie first mentioned his method.

M. Boucherie's process was first discussed in Paris in June, 1840. It consists in causing a solution of *sulphate of copper* to penetrate to the interior of freshly cut woods, to preserve them from decay; he occasionally used the chloride of calcium, the *pyrolignite of iron (pyrolignite brut de fer), prussiate of iron, prussiate of copper,* and various other metallic salts. As a general rule sulphate of copper is used; but when the hardness of the wood is desired to be increased, pyrolignite of iron is taken (1 gallon of iron to 6 gallons of water); and when the object is to render the wood flexible, elastic, and at the same time uninflammable, chloride of calcium is used. The liquid is taken up by the tree either whilst growing in the earth or immediately after it has been felled. Not more than two or three months should be allowed to elapse before the timber is operated upon, but the sooner it undergoes the process after being felled the better.

Sulphate of copper is said to be superior to corrosive sublimate. Dr. Boucherie's process of the injection of the wood with the salts of copper is as simple as it is easy. For those woods intended for poles it consists in plunging the base of a branch, furnished with leaves, into a tub containing the solution. The liquid ascends into the branches by the action of the leaves, and the wood is impregnated with the preservative salt. As for logs, the operation consists in cutting down the tree to be operated upon; fixing at its base a plank, which is fixed by means of a screw placed in the centre, and which can be tightened at will when placed in the centre of the tree. This plank has, on the side to be applied to the bottom of the tree, a rather thick shield of leather, cloth, pasteboard, or some other substance, intended to establish a space between it and the wood, sufficient for the preserving fluid to keep in contact with the freshly cut surface of the tree. The liquid is brought there from a tub or other reservoir, by the help of a slanting pole made on the upper surface of the tree, and in which is put a tube, adapted at its other extremity to a spigot in the upper reservoir which contains the solution. A pressure of 5 mètres suffices; so that the instant the sap of the tree is drawn away it escapes, and is replaced by the liquid saturated with sulphate of copper. The proportion of sulphate of copper in the solution should be 1 lb. of the salt to 12½ gallons of water. As soon as the operation terminates (and it lasts for some hours for the most difficult logs), the wood is ready for use.

For various practical reasons, the first invention of impregnating the wood of the tree whilst still in a growing state, causing it to suck up various solutions by means of the absorbing power of the leaves themselves, was subsequently abandoned; and at the present time a cheap, simple, and effective process is adopted for impregnating the felled timbers with the preserving liquid, designated in France "trait de scie, et la cuisse foulante." The trunk of a newly felled tree is cut into a length suitable for two railway sleepers; a cross cut is made on the prostrate timber to nearly nine-tenths of its diameter; a wedge is then inserted, and a cord is wound round on the cut surface, leaving a shallow chamber in the centre, when it is then closed by withdrawing the wedge. A tube is then inserted through an auger hole into this chamber, and to this tube is attached an elastic connecting tube from a reservoir placed some 20 or 30 feet above the level on which the wood lies, and a stream of the saturating fluid with this pressure passes into the chamber, presses on the sap in the sap tubes, expels it at each end of the tree, and itself supplies its place. The fluid used is a solution of copper in water, in the proportion of 10 or 12 per cent., and a chemical test that ascertains the pressure of the copper solution is applied at each end of the tree from which the sap exudes, by which the operator ascertains when the process is completed.

A full account of this process may be found in the number for June, 1840, of 'Les Annales de Chimie et de Physique.' Messrs. de Mirbel, Arago, Poucelet, Andouin, Gambey, Boussingault, and Dumas, on the part of l'Académie des Sciences, made a report upon Dr. Boucherie's process, confirming the value of the invention. In France, Dr. Boucherie, some years since, relinquished his brevet, and threw the process open to the public, in consideration of a national reward; whilst in England he has obtained two patents (1838 and 1841), which, however, are similar to Bethell's patent, obtained by him on July 11, 1838: *which is the same day and year of Boucherie's patent.* A prize medal was awarded for Dr. Boucherie's process at the Great Exhibition in London, in 1851, and a grande médaille d'honneur, at the Paris Exhibition of 1855. Many thousands of railway sleepers have been prepared by this process, and laid down on the Great Northern Railway of France, and are at present perfectly sound, whilst others not prepared, on the same line, have rotted. Boucherie's process was used on Belgium railways up to 1859; and it is to be regretted that the reasons which led to its abandonment have not been given in the reports of the railway administration, as such reasons would have afforded reliable data for future experimentalists to go upon.

Messrs. Légé and Fleury-Pironnet's patent for the injection of sulphate of copper into beech and poplar is as follows: After the wood is placed, and the opening hermetically sealed, a jet of steam is introduced, intended at first to enter the timber and open its pores for the purpose of obtaining a sudden vacuum, so as to establish at any time a communication between the interior of the cylinder and the cold water condenser; at the same time the air pump is put in action. The vacuum caused is very powerful, and is equal to 25½ ins. of the barometer. Under the double influence of the heat and the vacuum the sap is quickly evaporated from the wood as steam, and ejected from the cylinder by the air pump, so that in a very short time the wood is fully prepared to admit the preserving liquid through the entire bulk.

The use of sulphate of copper for preserving timber has not been, however, confined to France, for about the time Dr. Boucherie brought forward his process, a Mr. Margary took out a patent in England for the use of the same material. His method consists in steeping the substances to be preserved in a solution of sulphate of copper, of the strength of 1 lb. of the sulphate to 8 gallons of water, and leaving them in it till thoroughly saturated. The timber is allowed to remain in the tank two days for every inch of its thickness. Another method is to place the timber in a closed iron vessel of great strength, and it is made to imbibe the solution by exhaustion and pressure, the operation occupying but a short time.

Sulphate of copper is sold in quantities at 4*d.* per lb.; so that 100*l.* would buy 6000 lb., and each pound weight is sufficient for 7 or 8 gallons of water, according to Margary; or 12 gallons of water, according to Boucherie.

To preserve railway sleepers, the French railway engineers require ¼ lb. of sulphate of copper per cubic foot, say at least 12 lbs. to the load of 50 feet, to be used in a 2 per cent. solution; so that a load of timber can be rendered imperishable for the sum of four shillings, exclusive of labour, if sulphate of copper be reckoned at 4*d.* per lb.

With respect to the use of pyrolignite of iron, Mr.

Bethell considers it an expensive process, the pyrolignite costing 6*d.* to 9*d.* per gallon, whilst the oil of tar can be delivered at from 2*d.* to 3*d.* per gallon: the cost of these materials is constantly varying.

A great many sleepers were prepared on the Great Western Railway by pyrolignite of iron, and all have *decayed.* Their black colour makes them exactly resemble creosoted sleepers, and *many mistakes* have arisen from this resemblance.

Messrs. Dorsett and Blythé's (of Bordeaux) patent process of preparing wood by the injection of heated solutions of sulphate of copper is said to have been adopted by French, Spanish, and Italian, as well as other continental railway companies, by the French Government for their navy and other constructions, and by telegraph companies for poles on continental lines. It is as cheap as creosote, and is employed in places where creosote cannot be had. Wood prepared by it is rendered incombustible. Wood for outdoor purposes so prepared has a clean yellowish surface, without odour; it requires no painting, remains unchangeable for any length of time, and can be employed for any purpose, the same as unprepared material, and carried with other cargo without hindrance. Messrs. Dorsett and Blythé's process is similar to that of Mr. Knab, which consisted of a solution of sulphate of copper, heated to nearly boiling point, and placed in a lead cylinder, protected by wood.

In 1846, 80,000 sleepers, treated with sulphate of copper, were laid down on French railways, and after nine years' exposure were found to be as perfect as when first laid.

Mr. H. W. Lewis, University of Michigan, U. S., thus writes in the 'Journal' of the Franklin Institute, in 1866, with reference to the decay of American railway sleepers: "Allowing 2112 sleepers per mile, at 50 cents each, 1056 dols. per mile of American railroad decay every seven years. Thoroughly impregnate those sleepers with sulphate of copper, at a cost of 5 cents each, and they would last twice as long. Thus would be effected a saving of 880 dols. per mile in the seven years on sleepers alone. In the United States, there are 33,906.6 miles of railroad. The whole saving on these lines would be 29,389,-568 dols., or upwards of 4,262,795 dols. per annum."

With reference to the decay of unprepared wooden sleepers, it may be here stated that the renewal of wooden sleepers on the Calcutta and Delhi Indian line alone costs annually 130,000*l.*

The preservative action of sulphate of copper on wood has long been known, but there are several things in its action which require explanation. The 'London Review' says that Kœnig has lately investigated the chemical reactions which occur when wood is impregnated with a preservative solution of blue vitriol. He finds, as a general rule, that a certain quantity of basic sulphate of copper remains combined in the pores of the wood in such a manner that it cannot be washed out with water. The copper salt may be seen by its green colour in the spaces between the yearly rings in the less compact portions of the wood, that is to say, in those portions which contain the sap. Those varieties of wood which contain the most resin retain the largest amount of the copper salt—oak, for example, retaining but little of it. The ligneous fibre itself appears to have little or nothing to do with the fluxation of the copper salt, and indeed none whatever is retained in chemical combination, so that it cannot be washed out with water by pure cellulose. When wood, from which all resin has been extracted by boiling alcohol, is impregnated with sulphate of copper, it does not become coloured like the original resinous wood, and the copper salt contained in it may be readily washed out with water. In like manner, from impregnated resinous wood all the copper salt may be removed with the resin, by means of alcohol. The constituents of the blue vitriol are consequently fixed in the wood by means of the resin which this contains. Further, it is found that the impregnated wood contains less nitrogen than that which is unimpregnated, and that it is even possible to remove all the nitrogenous components of the wood by long-continued treatment with the solution of sulphate of copper; the nitrogenous matters being soluble in an excess of this solution, just as the precipitate which forms when aqueous solutions of albumen and sulphate of copper are mixed is soluble in excess of the latter. Since the nitrogenous matters are well known to be promoters of putrefaction, their removal readily accounts for the increased durability of the impregnated wood. The utility of blue vitriol as a preservative may also depend on a measure upon the resinous copper salt which is formed, by which the pores of the wood are more or less filled up, and the ligneous fibre covered, so that contact with the air is prevented, and the attack of insects hindered. It is suggested that those cases in which the anticipated benefits have not been realized in practice, by impregnating wood with a solution of blue vitriol, may probably be referred to the use of an insufficient amount of this agent; that is, where the wood was not immersed in the solution for a sufficient length of time. The action should be one of lixiviation, not merely of absorption.

In 1841, a German, named Müenzing, a chemist of Heibronn, proposed *chloride of manganese* (waste liquor in the manufacture of bleaching powder) as a preservative against dry rot in timber; but his process has not been adopted in England, and very little noticed abroad.

In July, 1841, Mr. Payne patented his invention for *sulphate of iron* in London; and in June and November, 1846, in France; and in 1846 in London, for *carbonate of soda.* The materials employed in Payne's process are sulphate of iron and sulphate of lime, both being held in solution with water. The timber is placed in a cylinder in which a vacuum is formed by the condensation of steam, assisted by air pumps; a solution of sulphate of iron is then admitted into the vessel, which instantly insinuates itself into all the pores of the wood, previously freed from air by the vacuum, and, after about a minute's exposure, impregnates its entire substance; the *sulphate of iron* is then withdrawn, and another solution of *sulphate of lime* thrown in, which enters the substance of the wood in the same manner as the former solution, and the two salts react upon each other, and form two new combinations within the substance of the wood—muriate of iron, and muriate of lime. One of the most valuable properties of timber thus prepared is its perfect incombustibility; when exposed to the action of flame or strong heat, it simply smoulders and emits no flame. We may also reasonably infer that with such a compound in its pores, decay must be greatly retarded, and the liability to worms lessened, if not prevented. The greatest drawback consists in the increased difficulty of working. This invention has been approved by the Commissioners of Woods and Forests, and has received much approbation from the architectural profession. Mr. Hawkshaw, C.E., considers that this process renders wood brittle. It was employed for rendering wood uninflammable in the Houses of Parliament (we presume, in the carcase, for *steaming* was used for the joiner's work), British Museum, and other public buildings; and also for the Royal Stables at Claremont.

In 1842, Mr. Bethell stated before the Institute of Civil Engineers, London, that *silicate of potash,* or *soluble glass,* rendered wood uninflammable.

In 1842, Professor Brande proposed *corrosive sublimate* in *turpentine,* or *oil of tar,* as a preservative solution.

In 1845, Mr. Ransome suggested the application of *silicate of soda,* to be afterwards decomposed by an acid in the fibre of the wood; and in 1846, Mr. Payne proposed soluble sulphides of the earth *(barium sulphide,* &c.*)*, to be also afterward decomposed in the woods by acids.

In 1855, a writer in the 'Builder' suggested an equal mixture of alum and borax (biborate of soda) to be used for making wood uninflammable. We have no objection to the use of alum and borax to render wood uninflammable, providing it does not *hurt the wood.*

Such are the *principal* patents, suggestions, and inventions, up to the year 1856; but there are many more which have been brought before the public, some of which we will now describe.

Dr. Darwin, some years since, proposed absorption, first, of *lime water* then of a weak solution of *sulphuric acid,* drying between the two, so as to to form a gypsum (sulphate of lime) in the pores of the wood, the latter to be previously well seasoned, and when prepared to be used in a dry situation.

Dr. Parry has recommended a preparation composed of *bees-wax, roll brimstone,* and *oil,* in the proportion of 1, 2, and 3 ounces to ¾ gallon of water; to be boiled together and laid on hot.

Mr. Pritchard, C.E., of Shoreham, succeeded in establishing *pyrolignite of iron* and *oil of tar* as a preventive of dry rot; the pyrolignite to be used very pure, the oil applied afterwards, and to be perfectly free from any particle of ammonia.

Mr. Toplis recommends the introduction into the pores of the timber of a solution of sulphate or muriate of iron; the solution may be in the proportion of about 2 lb. of salt to 4 or 5 gallons of water.

An invention has been lately patented by Mr. John Cullen, of the North London Railway, Bow, for preserving wood from decay. The inventor proposes to use a composition of *coal-tar, lime,* and *charcoal;* the charcoal to be reduced to a fine powder, and also the lime. These materials are to be well mixed, and subjected to heat, and the wood immersed therein. The impregnation of the wood with the composition may be materially aided by means of exhaustion and pressure. Wood thus prepared is considered to be proof against the attacks of the white ant.

The process of preserving wood from decay invented by Mr. L. S. Robins, of New York, was proposed to be worked extensively by the "British Patent Wood Preserving Company." It consists in first removing the surface moisture, and then charging and saturating the wood with hot *oleaginous vapours* and compounds. As the Robins' process applies the preserving material in the form of vapour, the wood is left clean, and after a few hours' exposure to the air it is said to be fit to be handled for any purposes in which elegant workmanship is required. Neither science nor extraordinary skill is required in conducting the process, and the treatment under the patent is said to involve only a trifling expense.

Reference has already been made to the use of *petroleum.* The almost unlimited supply of it within the last few years has opened out a new and almost boundless source of wealth. An invention has been patented in the name of Mr. A. Prince, which purports to be an improvement in the mode of preserving timber by the aid of petroleum. The invention consists, first, in the immersion of the timber in a suitable vessel or receptacle, and to exhaust the air therefrom, by the ordinary means of preserving wood by saturation. The crude petroleum is next conveyed into the vessel, and thereby caused to penetrate into every pore or interstice of the woody fibre, the effect being, it is said, to thoroughly preserve the wood from decay. He also proposes to mix any cheap mineral paint or pigment with crude petroleum to be used as a coating for the bottom of ships before the application of the sheathing, and also to all timber for building or other purposes. The composition is considered to render the timber indestructible, and to repel the attacks of insects. Without expressing any opinion on this patent as applied to wood for building purposes, we must again draw attention to the high inflammability of petroleum.

The 'Journal' of the Board of Arts and Manufactures for Upper Canada considers the following to be the cheapest and the best mode of preserving timber in Canada: Let the timbers be placed in a drying chamber for a few hours, where they would be exposed to a temperature of about 200°, so as to drive out all moisture, and by heat, coagulate the albuminous substance, which is so productive of decay. Immediately upon being taken out of the drying chamber, they should be thrown into a tank containing crude petroleum. As the wood cools, the air in the pores will contract, and the petroleum occupy the place it filled. Such is the extraordinary attraction shown by this substance for dry surfaces, that by the process called capillary attraction, it would gradually find its way into the interior of the largest pieces of timber, and effectually coat the walls and cells, and interstitial spaces. During the lapse of time, the petroleum would absorb oxygen, and become inspissated, and finally converted into bituminous substance, which would effectually shield the wood from destruction by the ordinary processes of decay. The process commends itself on account of its cheapness. A drying chamber might easily be constructed of sheet iron properly strengthened, and petroleum is very abundant and accessible. Immediately after the pieces of timber have been taken out of the petroleum vat, they should be sprinkled with wood ashes in order that a coating of this substance may adhere to the surface, and carbonate of potash be absorbed to a small depth. The object of this is to render the surface incombustible; and dusting with wood ashes until quite dry will destroy this property to a certain extent.

The woodwork of farm buildings in this country is sometimes subjected to the following: Take two parts of *gas-tar,* one part of *pitch,* one part *half caustic lime* and *half common resin;* mix and boil these well together, and put them on the wood quite hot. Apply two or three coats, and while the last coat is still warm, dash on it a quantity of well-washed sharp sand, previously prepared by being sifted through a sieve. The surface of the wood will then have a complete stone appearance, and may be durable. It is, of course, necessary, that the wood be perfectly dry, and one coat should be well hardened before the next coat is put on. It is necessary, by the use of lime and long boiling, to get quit of the ammonia of the tar, as it is considered to injure the wood.

Mr. Abel, the eminent chemist to the War Department, recommends the application of *silicate of soda* in solution, for giving to wood, when applied to it like paint, a hard coating, which is durable for several years, and is also a considerable protection against fire. The silicate of soda, which is prepared for use in the form of a thick syrup, is diluted in water in the proportion of 1 part by measure of the syrup to 4 parts of water, which is added slowly, until a perfect mixture is obtained by constant stirring. The wood is then washed over *two* or *three* times with this liquid by means of an ordinary whitewash brush, so as to absorb as much of it as possible. When this first coating is nearly dry, the wood is painted over with *another* wash made by slaking good fat lime, diluted to the consistency of thick cream. Then, after the lime-wash has become moderately dry, *another* solution of the silicate of soda, in the proportion of 1 of soda to 2 of water, is applied in the same manner as the first coating. The preparation of the wood is then complete; but if the lime coating has been applied too quickly, the surface of the wood may be found, when quite dry, after the last coating of the silicate, to give off a little lime when rubbed with the hand; in which case it should be *once more* coated over with a solution of the silicate of the same strength as in the first operation. If Mr. Abel had been an architect or builder, he would never have invented this process. What would the cost be? and would not a special clerk of the works be necessary to carry out this method in practice?

The following coating for piles and posts, to prevent them from rotting, has been recommended on account of its being economical, impermeable to water, and nearly as hard as stone: Take 50 parts of *resin,* 40 of finely powdered *chalk,* 300 parts of *fine white sharp sand,* 4 parts of *linseed oil,* 1 part of native *red oxide of copper,* and 1 part of *sulphuric acid.* First, heat the resin, chalk, sand, and oil, in an iron boiler; then add the oxide, and, with care, the acid; stir the composition carefully, and apply the coat while it is still hot. If it be not liquid enough, add a little more oil. This coating, when it is cold and dry, forms a varnish which is as hard as stone.

Another method for fencing, gate-posts, garden stakes, and timber which is to be buried in the earth, may be mentioned. Take 11 lb. of *blue vitriol* (sulphate of copper) and 20 quarts of water; dissolve the vitriol with boiling water, and then add the remainder of the water. The end of the wood is then to be put into the solution, and left to stand four or five days; for shingle, three days will answer, and for posts, 6 inches square, ten days. Care should be taken that the saturation takes place in a well-pitched tank or keyed box, for the reason that any barrel will be shrunk by the operation so as to leak. Instead of expanding an old cask, as other liquids do, this shrinks it. This solution has also been used in dry rot cases, when the wood is only slightly affected.

It will sometimes be found that when oak fencing is put up new, and tarred or painted, a fungus will vegetate through the dressing, and the interior of the wood be rapidly destroyed; but when undressed it seems that the weather desiccates the gum or sap, and leaves only the woody fibre, and the fence lasts for many years.

About fifteen years ago, Professor Crace Calvert, F.R.S., made an investigation for the Admiralty, of the qualities of the different woods used in shipbuilding. He found the goodness of teak to consist in the fact that it is highly charged with *caoutchouc;* and he considered that if the tannin be soaked out of a block of oak, it may then be interpenetrated by a *solution of caoutchouc,* and thereby rendered as lasting as teak.

We can only spare the space for a few words about this method.

1st. We have seen lead which has formed part of the gutter of a building previous to its being burnt down: lead melts at 612° F.; caoutchouc at 248° F.; therefore caoutchouc would not prevent wood from being destroyed by fire. At 248° caoutchouc is highly inflammable, burns with a white flame and much smoke.

2nd. We are informed by a surgical bandage-maker of high repute, that caoutchouc, when used in elastic knee-caps, &c., *will perish,* if the articles are left in a drawer for two or three years. When hard, caoutchouc is brittle.

Would it be advisable to interpenetrate oak with a solution of caoutchouc? In 1825, Mr. Hancock proposed a solution of 1½ lb. of caoutchouc in 3 lb. of essential oil, to which was to be added 9 lb. of tar. Mr. Parkes, in 1843, and M. Passez, in 1845, proposed to dissolve caoutchouc in sulphur: painting or immersing the wood. Maconochie, in 1805, after his return from India, proposed distilled *teak* chips to be injected into fir woods.

Although England has been active in endeavouring to discover the best and cheapest remedy for dry rot, France has also been active in the same direction.

M. le Comte de Chassloup Lambat, Member of the late Imperial Senate of France, considers that, as *sulphur* is most prejudicial to all species of fungi, there might, perhaps, be some means of making it serviceable in the preservation of timber. We know with what success it is used in medicine. It is also known that coopers burn a sulphur match in old casks before using them—a practice which has evidently for its object the prevention of mustiness, often microscopic, which would impart a bad flavour to the wine.

M. de Lapparent, late Inspector-General of Timber for the French Navy, proposed to prevent the growth of fungi by the use of a paint having flour of sulphur as a basis, and linseed oil as an amalgamater. In 1862 he proposed charring wood; we have referred to this process in our last chapter (p. 96).

The paint was to be composed of:

Flour of sulphur	200 grammes	3,088 grains.
Common linseed oil	135 grammes	2,084 grains.
Prepared oil of manganese	30 grammes	463 grains.

He considered that by smearing here and there either the surfaces of the ribs of a ship, or below the ceiling, with this paint a slightly sulphurous atmosphere will be developed in the hold, which will purify the air by destroying, at least in part, the sporules of the fungi. He has since stated that his anticipations have been fully realized. M. de Lapparent also proposes to prevent the decay of timber by subjecting it to a skilful carbonization with common inflammable coal gas. An experiment was made at Cherbourg, which was stated to be completely successful. The cost is only about 10 cents per square yard of framing and planking. M. de Lapparent's gas method is useful for burning off old paint. We saw it in practice (April, 1875) at Waterloo Railway Station, London, and it appeared to be effective.

At the suggestion of MM. Le Châtelier (Engineer-in-chief of mines) and Flachat, C.E.'s, M. Rance, a few years since, injected in a Légé and Fleury cylinder certain pieces of white fir, red fir, and pitch pine with *chloride of sodium*, which had been deprived of the manganesian salts it contained, to destroy its deliquescent property. Some pieces were injected four times, but the greatest amount of solution injected into pitch pine heartwood was from 3 to 4 per cent., and very little more was injected into the white and red fir heartwood. It was also noticed that sapwood, after being injected four times, only gained 8 per cent. in weight in the last three operations. The experiments made to test the relative incombustibility of the injected wood showed that the process was a complete failure; the prepared wood burning as quickly as the unprepared wood.

M. Paschal le Gros, of Paris, has patented his system for preserving all kinds of wood, by means of a *double salt of manganese* and of *zinc*, used either alone or with an admixture of *creosote*. The solution, obtained in either of the two ways, is poured into a trough, and the immersion of the logs or pieces of wood is effected by placing them vertically in the trough in such a manner that they are steeped in the liquid to about three-quarters of their length. The wood is thus subjected to the action of the solution during a length of time varying from twelve to forty-eight hours. The solution rises in the fibres of the wood, and impregnates them by the capillary force alone, without requiring any mechanical action. The timber is said to become incombustible, hard, and very lasting.

M. Fontenay, C.E., in 1832, proposed to act upon the wood with what he designated *metallic soap*, which could be obtained from the residue in greasing boxes of carriages; also from the acid remains of *oil, suet, iron*, and *brass dust;* all being melted together. In 1816 Chapman tried experiments with *yellow soap;* but to render it sufficiently fluid it required forty times its weight of water, in which the quantity of resinous matter and tallow would scarcely exceed 1-80th; therefore no greater portion of these substances could be left in the pores of the wood, which could produce little effect.

M. Letellier, in 1837, proposed to use *deuto-chloride of mercury* as a preservative for wood.

M. Dondeine's process was formerly used in France and Germany. It is a paint, consisting of many ingredients, the principal being *linseed oil, resin, white lead, vermilion, lard, and oxide of iron.* All these are to be well mixed, and reduced by boiling to one-tenth, and then applied with a brush. If applied cold, a little varnish or turpentine to be added.

Little is known in England of the inventions which have arisen in foreign countries not already mentioned.

M. Szerelmey, a Hungarian, proposed, in 1868, *potassa, lime, sulphuric acid, petroleum,* &c., to preserve wood.

In Germany, the following method is sometimes used for the preservation of wood: Mix 40 parts of *chalk,* 40 parts of *resin,* 4 of *linseed oil;* melting them together in an iron pot; then add 1 part of native *oxide of copper,* and afterwards, carefully, 1 part of *sulphuric acid.* This mixture is applied while hot to the wood by means of a brush, and it soon becomes very hard.

Mr. Cobley, of Meerholz, Hesse, has patented the following preparation: A strong solution of *potash, baryta, lime, strontia,* or any of their salts, are forced into the pores of timber in a close iron vessel by a pump. After this operation, the liquid is run off from the timber, and *hydro-fluo-silicic acid* is forced in, which, uniting with the salts in the timber, forms an insoluble compound capable of rendering the wood uninflammable.

About the year 1800, Neils Nystrom, chemist, Norkopping, recommended a solution of *sea salt and copperas,* to be laid upon timber as hot as possible, to prevent rottenness or combustion. He also proposed a solution of *sulphate of iron, potash, alum,* &c., to extinguish fires.

M. Louis Vernet, Buenos Ayres, proposed to preserve timber from fire by the use of the following mixture: Take 1 lb. of *arsenic,* 6 lb. of *alum,* and 10 lb. of *potash,* in 40 gallons of water, and mix with *oil,* or any suitable tarry matters, and paint the timber with the solution. We have already referred to the conflicting evidence respecting alum and water for wood: we can now state that Chapman's experiments proved that *arsenic* afforded no protection against dry rot. Experiments in Cornwall have proved that where arsenical ores have lain on the ground, vegetation will ensue in two or three years after the removal of the ore. If, therefore, alum or arsenic have no good effect on timber with respect to the dry rot, we think the use of both of them together would certainly be objectionable.

The last we intend referring to is a composition frequently used in China, for preserving wood. Many buildings in the capital are painted with it. It is called *Schoicao,* and is made with 3 parts of blood deprived of its febrine, 4 parts of lime and a little alum, and 2 parts of liquid silicate of soda. It is sometimes used in Japan.

It would be practically useless to quote any further remedies, and the reader is recommended to carefully study those quoted in this chapter, and of their utility to judge for himself, bearing in mind those principles which we have referred to before commencing to describe the patent processes. A large number of patents have been taken out in England for the preservation of wood by preservative processes, but only two are now in use,—that is, to any extent,—viz. Bethell's and Burnett's. Messrs. Bethell and Co. now impregnate timber with *copper,* *zinc, corrosive sublimate, or creosote;* the four best patents.

For the *non-professional* reader we find we have *three* facts:

1st. The most successful patentees have been Bethell and Burnett, in England; and Boucherie, in France: all B's.

2nd. The most successful patents have been *knighted.* Payne's patent was, we believe, used by Sirs R. Smirke and C. Barry; Kyan's, by Sir R. Smirke; Burnett's, by Sirs M. Peto, P. Roney, and H. Dryden; while Bethell's patent can claim Sir I. Brunel, and many other knights. We believe Dr. Boucherie received the Legion of Honour in France.

3rd. There are only at the present time three timber-preserving works in London, and they are owned by Messrs. Bethell and Co., Sir F. Burnett and Co., and Messrs. Burt, Boulton, and Co.—all names commencing with the letter B.

For the *professional* reader we find we have *three hard* facts:

The most successful patents may be placed in three classes, and we give the key-note of their success.

1st. ONE MATERIAL AND ONE APPLICATION.—Creosote, Petroleum. *Order*—Ancient Egyptians, or Bethell's Burmese.

2nd. TWO MATERIALS AND ONE APPLICATION.—Chloride of zinc and water; sulphate of copper and water; corrosive sublimate and water. *Order*—Burnett, Boucherie, Kyan.

3rd. TWO MATERIALS AND TWO APPLICATIONS.—Sulphate of iron and water; afterwards sulphate of lime and water. Payne.

We thus observe there are *twice three* successful patent processes.

Any inventions which cannot be brought under these three classes have had a short life; at least, we think so.

The same remarks will apply to *external* applications for wood—for instance, coal-tar, *one application,* is more used for fencing than any other material.

We are much in want of a valuable series of experiments on the application of various chemicals on wood to resist *burning to pieces;* without causing it to *rot speedily.*

HEADQUARTERS DEPARTMENT OF CALIFORNIA, OFFICE OF THE CHIEF QUARTERMASTER, SAN FRANCISCO, CAL., June 26, 1896.

P. F. Dundon, Esq.,

Dear Sir: In December, 1891, we repaired the Presidio wharf with standard piles which had been treated with 12 pounds of creosote to the cubic foot, at the works of the Pacific Improvement Company, at Oakland Point, in November of the same year. On the reconstruction of this wharf with wrought iron piles this spring (1896) these piles were pulled, and have since been cut up and used in repairs to the wharf at Alcatraz Island. A careful examination of the piles failed to show any signs of destruction from worms or other causes, except one pile which had been slightly attacked by the limnoria. In the same wharf fender piles unprotected failed to last to exceed three years.

Very respectfully yours,

JAMES H. HUMPHREYS, C. E.,
Quartermaster's Dept., U. S. A.

SAN FRANCISCO, CAL., April 20, 1896.

To the San Francisco Timber Preserving Co.,
225 Folsom Street, San Francisco, Cal.

Gentlemen: The U. S. Life Saving Station has made use of creosoted lumber and piles on this Coast for a period extending over six years and the creosoted lumber for ways, and creosoted piles for foundation of same have resisted the teredo and limnoria, and have given perfect satisfaction, and we anticipate using creosoted lumber still further. The foundation and ways for the Life Saving Station at Baker's Beach, this city, were creosoted, and built in 1890. Yours truly,

(Signed) T. J. BLAKENEY,
Supt. 12th Life Saving District.

THOMSON BRIDGE COMPANY, SAN FRANCISCO,
August 5, 1896.

P. F. Dundon, Esq.,

Dear Sir: In reply to yours regarding creosoted piles, I would state that my experience with the same justifies me in earnestly recommending the use of the process to any party who desires to build a wharf where the teredo or limnoria exists. In July, 1892, I commenced to build the Santa Monica wharf for the Pacific Improvement Co., and drove in that structure over 5,000 creosoted piles. A few months ago some 5 or 6 piles, broken from time to time, were replaced with new ones. Those broken piles were thoroughly examined, and all, with the exception of one, were found to be entirely free from any worm—the one exception had evidently been broken when being driven, and it showed that the teredo had entered in the heart of the pile at the break and worked up about 6 or 8 inches, but had never touched or penetrated the outside, which had been impregnated with creosote. This examination I consider good of a very severe four years' test, as the locality is known to be one of the very worst on the Pacific Coast for the ravages of the teredo and limnoria.

Respectfully,

THOS. THOMSON.

P. S.—All of the original piles are still in this structure and sound at this date, Dec., 1902.

HOWARD C. HOLMES, Chief Engineer of the Board of State Harbor Commissioners, in his report for the two years, ending June 30, 1896, states: "Without doubt the creosoting process is the most valuable and efficient of all processes known for prolonging the life of timber. The process was invented in England about the time Kyanizing and the other metallic salt antiseptics came into use; it has survived all other processes, and is used to a greater extent than any other method, both in Europe and in this country."

Transactions American Society of C. E., Vol. XIV., Jan.-Dec., 1885, Page 265.

The American Society of Civil Engineers held an annual convention June 25, 1885. The following are extracts of reports from a committee of its members who had been previously appointed to determine which methods of preserving timber against decay were most successful, and which were best adapted to the needs and current practice in this country. The subject had been most thoroughly investigated by this committee, and the reports, as presented, are based on the most reliable information which it has been possible to receive on this subject. They report that the process of creosoting timber for preservative purposes was invented and brought into use in 1838 by Mr. John Bethell, of England, and in 1853, in a discussion of a paper (by Mr. H. P. Burt) before the British Institution of Civil Engineers, he made the following among other remarks: "Experiment proved that oil of tar, or creosote, was perhaps the most powerful coagulator of albumen (of wood), while it at the same time furnished a water-proof covering for the fiber, and its antiseptic properties prevented putrefaction. If, then, the operation of injection was well performed, there was every reason to anticipate the perfect success of the system. He found that by forcing at least seven pounds of creosote oil into each cubic foot of timber the process was perfect for railway work, but for marine work it was better not to have less than ten pounds per cubic foot." Further on it states: "The best known engineers, such as Messrs. Brunel, Hawkshaw, Rendell and others, also gave on that occasion the results of their experience, which was in every case satisfactory when the work was thoroughly done, and creosoting has now become the standard mode of timber preservation in England. There is no question about its efficacy and economy when well done, as evidenced by the fact that out of twelve of the leading railways of Great Britain to whom M. Bogard, Secretary of this Society, addressed circulars of inquiry in 1878, 10 used creosoted sleepers, and some of them forwarded with their answers sleepers taken from their tracks, which were yet sound and in use after 22 years of exposure. As a protection against marine worms (the teredo navalis and limnoria terebrans) creosote is the *only known preservative* and if there be enough of it injected it is thoroughly efficient. All other substances which have been tried have failed, but the success of creosote has been established by abundant evidence all the world over. The treatment of timber by antiseptic methods has been acknowledged by some of the greatest engineers of this country to have been useful to the art of constructive engineering. It may be made even more useful in the future than it has been in the past. All that the advocates for its still more extended development can desire to claim will be that their methods and investigations may be seriously examined, and from time to time decided upon, in accordance with the results which science and experience may bring to light."

Extract from "The Preservation of Timber by the Use of Antiseptics," by Samuel Bagster Boulton, Assoc. Inst. C. E., London, England.

In 1848 a line of poles was erected from Fareham to Portsmouth, a distance of about 20 miles, and all the poles, three hundred and eighteen in number, were creosoted by Mr. Bethell. In 1861, he examined all of them in the situ, and only two showed the slightest trace of decay, and they had begun to decay at the top. In 1874, he had them again examined, and every pole was sound. Last year (1884) owing to the requirements of the service and the necessity of increasing the number of wires, the line of poles had to be taken down, and although they had been put up in 1848, they were as sound as when they were first erected. About the year 1861 the question of the proper mode of preserving timber was one of great consequence. The authorities were not satisfied as to which was the best, boucherizing or creosoting, and consequently on the Yeoril and Exeter line of the London and Southwestern Railway Co., the poles were put up alternately; first, a plain pole, next a boucherized pole, and next a creosoted pole, the line extending about 40 miles. In 1870 he had them carefully examined, and it was found that of the plain poles that had been up 10 years, not one existed all having decayed, while of the boucherized poles 30 per cent had gone, and of the creosoted poles not one had decayed. The result was that the Government has decided for years past to creosote all their poles.

Extract from "The Preservation of Timber by the Use of Antiseptics," by Samuel Bagster Boulton, Assoc. Inst. C. E., London, England.

In 1867, Mr. Coisne obtained some creosoted sleepers which had successfully resisted decay during periods of from 18 to 20 years. The wood was crushed and the substances obtained therefrom tested. He found no tar acids; if they had ever been there they were no longer present. He found, however, a quantity of naphthaline, also a quantity of oil which did not commence to distil until 230 degs. Centrigrade (446 degs. Fahrenheit). In 1882 the author caused some similar experiments to be made. Through the kindness of the authorities of the London and Northwestern Railway Co., 11 pieces of old creosoted sleepers were sent from their permanent way. They had been in use for the following periods:

1 specimen 16 years.
1 specimen 17 years.
2 specimens 20 years.
2 specimens 22 years.
1 specimen 28 years.
2 specimens 29 years.
1 specimen 30 years.
1 specimen 32 years.

Sleepers were also received from the Taff Vale Railway, the Southeastern Railway, and the Great Eastern Railway, which had been in use periods varying from fourteen to twenty-three years. A portion was also taken from a creosoted pale fence which had been fixed in the Victoria docks in 1855, and which is still in place, perfectly sound and strong after 29 years of use.

Extract from "The Preservation of Timber by the Use of Antiseptics," by Samuel Bagster Boulton, Assoc. Inst. C. E., London, Eng. Transactions American Society of C. E., Vol. XIV., Jan.-Dec., 1885, Pages 274-75.

Experiments Nos. 22, 23 and 24 illustrate the difference between good and bad work. Creosoting works at Galveston, Texas, creosoted in 1874 some 10,000 superficial feet of long leaf yellow pine paving blocks. The result was not satisfactory. The blocks upon being examined in 1881 showed that the creosote had penetrated the wood for about ⅛ of an inch only, and the center was dozy. Some other blocks, however, furnished for a stable yard (Experiment No. 23) were of bastard, or loblolly pine, which in its ordinary condition is very perishable wood. These, when examined in 1885, proved to be perfectly sound, and upon being split open were found to be creosoted to the center. The works above alluded to were principally established to creosote the piles for the railroad bridge over Galveston Bay, which is some two miles long. This was in 1875 (Experiment No. 24). In 1882, Mr. Temple, the chief engineer, wrote:

"About half of the piles have been renewed having been eaten by the teredo, caused evidently by dishonest creosoting for last year, upon taking out the foundation of the drawbridge for the purpose of replacing it with brick, it was discovered that only two piles had been attacked out of a selected lot of 74. The piles were loblolly pine, known in most Southern States as 'fox tail' or 'old field' pine, the life of which, not treated, is about two years here."

Transactions American Society of C. E., Vol. XIV., Jan.-Dec., 1885, Pages 267-69.

COMMENTS ON CREOSOTING EXPERIMENTS.

The first experiment on the list, that on the Philadelphia and Reading R. R. in 1854, was not made with creosote at all, but with the coal tar from which it is extracted. Some 70,000 ties were prepared by first placing them in a large drying chamber for 76 hours, at a temperature of 120 degrees, then placing them for two hours in a bath of coal tar at a temperature of 150 degrees. Subsequently this was changed to the dipping of 2 feet at each end of the tie into the tar, so as to give the center a chance to part with any remaining moisture. The cost was eight cents a tie, but it was discontinued because it was not found to prolong their life. The committee has heard, in a somewhat vague way, of a good many other experiments with coal tar. None of them proved successful, except where seasoned fence posts or paving blocks had their lower ends dipped. This kept out the ground moisture while the wood could still dry out through the top. Whenever the whole stick was covered with coal tar, and the sap and moisture confined, the result was fermentation and failure, especially in those cases where the ammonia was not previously removed from the tar by boiling. The second experiment (in 1865) was true creosoting. It was conducted under the instruction of Isaac Hinkley, Esq., then of Massachusetts, in the preparation of 700 piles for the construction of a bridge over the Taunton River, on the Old Colony Railroad. Creosoting works were erected for the purpose of treating these piles, and these works are still in use at Somerset, Mass. In 1878, the Chief Engineer of the Old Colony Railroad, the late E. N. Winslow, wrote as follows about these piles:

"We have removed about 200 of the 700. The work was generally done with a rush, and in a careless manner; many of the piles were fitted, knots trimmed up, etc., after they were creosoted. I find they are eaten in patches and spots commencing apparently where the trimming was done. Upon examination, I find the outer portion of the piles, from ¼ to ½ inch in thickness, filled with creosote, today as limpid and odorous as when applied. Hence, I infer the attack has been made in almost every instance where the trimming or fitting was done." The experiment was considered a success, and has been continued, but all trimming of timber after treatment destined to be exposed to sea water is now recognized here, and abroad, as fatal to success, inasmuch as the teredo will attack any point unprotected by sufficient creosote, and will speedily make his way to the heartwood, which, in consequence of its density, can absorb but a small portion of this preservative."

Transactions American Society of C. E., Vol. XIV., Jan.-Dec., 1885, Page 289.

SELECTION OF PRESERVING PROCESS.

In view of the differing cost of the various antiseptics used, and of the price of timber in this country, where it is still much cheaper than in Europe, we believe that the method to be selected for preserving wood (if any) depends almost wholly upon its proposed subsequent exposure, and that it has been a mistake hitherto to look to a single process for all purposes. If the timber is to be exposed, in sea water, to the attacks of the teredo navilis and limnoria terebrans, there is but one antiseptic which can be used with our present knowledge. This is creosote, or "dead oil," and the amount of it necessary depends upon the activity of the teredo, or rather upon the length of time during the year when the temperature of the water renders them active.

Transactions American Society of C. E., Vol. XIV., Jan.-Dec., 1885, Pages 293-96.

WILL IT PAY?

The question whether it will pay to preserve timber against decay seems to have been answered very positively in the affirmative in Europe. There seems to be indeed, no longer any question there about it; preservation is looked upon as quite a matter of course, and public works, which fail to avail of it, are alluded to as neglecting an important economy. In this country preservation of wood (except in an experimental way) has been the rare exception, but the time has probably arrived when in many sections an economy of 20 to 50 per cent a year can be obtained in the maintenance of timber structures and cross-ties by preparing them artificially to resist decay, while in other sections timber is still too cheap to warrant spending money to preserve it. This depends upon the price. Thus where a white oak tie costs 25c. and lasts eight years, if we spend 25c. more in preparing it so that it will last 16 years, we but double the life as well as the cost, and save only the expense of taking the old tie out and placing the new tie in the track at the end of the first 8 years, if the price of ties in the meanwhile continues the same. If, however, the oak tie costs 75c. and we can substitute a hemlock tie, which would, unprepared last three and a half years, and cost 30c. and by preparing it extend its life to 12 years at an additional cost of 25c. or even more, we then have a notable economy, both in first cost and in duration. In the case of piles which are cut off by the teredo in 1 or 2 years, as occurs in our Southern harbors, the case is plain. They must be creosoted, or great waste and increased expense will result. In cases where they last 8 to 10 years, as in some Northern sections, it will depend partly upon the value of the structure which the piles sustain whether it will pay to creosote them or not. In case of bridges and trestles, much will depend upon the exposure and cost of maintenance, as well as upon the proximate exhaustion of suitable timber in the vicinity and upon contemplated permanent renewals, while in the case of buildings, platforms, floors, etc., the ordinary wear from traffic will also have to be taken into account. The most important factor will be the exposure (wet or dry) and consequent rate of decay. Thus all brewers find it economical to preserve their floors; and mills, bleacheries, dye-houses, etc., largely resort to artificial preparation of timber because of their exposure to stopping of water and consequent moisture in heated apartments. The engineers and managers of the several works, therefore, will have to figure up for themselves, in view of the local circumstances of their case and the present and prospective price of timber, whether the economy or artificial treatment is sufficiently attractive to induce them to resort to it. The great consumers of timber are the railroads, and the managers of such enterprises have to be governed by a good many considerations, both of finance and of expediency, besides those of eventual economy. Hitherto, aside from the past cheapness of timber, the principal objections to its preparation against decay have been the lack of information as to what results could be confidently expected and the conflicting claims of the promoters of various modes of treatment, each of whom represented his process as absolutely the best under all circumstances. The committee hopes that this report of the result of its investigations during the past five years will have done something toward removing the above-mentioned obstacles to an important economy, but there still remains the objection that the results to be accomplished are somewhat remote, while the expenditure must be immediate. Railroad managers naturally want to obtain immediate returns. They do not like to burden the revenues of the current year for the benefit of future administrations, and they are with reason jealous of every dollar that goes out now, even if it promises to save 2 or 3 dollars in the future; yet, now that close competition requires every possible economy to be availed of, that railroads must more largely depend upon saving money in their maintenance, in order to continue or to resume their dividend, and that companies in good standing can obtain new capital for expense saving appliances at four and one-half or five per cent a year, the time has probably arrived, in view of advancing prices and scarcity of timber, when some leading railroads will take steps to preserve it. Computations of the money saving to be effected will be found in Appendix No. 6, and in Appendix No. 17. In the former, Privy Councillor Funk estimates that in 1878, out of sixty millions of sleepers on the German railroads, twenty-five millions were impregnated, and that even with the extraordinary length of life stated for unprepared ties (13.6 years for oak and 6.1 for fir and pine) had the remaining thirty-five millions of ties been impregnated, there would have been a resulting economy of about one million dollars a year, or some thirty-three per cent. on the cost of renewals. This estimate is understood as having resulted in a material extension of tie-preserving in Germany, notwithstanding the fact that metallic ties have already been largely introduced in that country. As regards the latter, a simple calculation shows that the time has not yet arrived when they can profitably be introduced in this country. They will cost, laid in track, about $2.50 each, and were they to last forever (the estimated life in Germany is 20 to 40 years) the interest on the cost at 5 per cent. would be 12½ c. a year a tie, or more than the annual charge of an unprepared white oak tie, costing 77 c. in the track, and lasting seven years. If, instead of 13.6 years for oak, and 6.1 for fir and pine unprepared, which life is said to obtain in Germany (probably in consequence of more thoroughly drained and ballasted roadbeds than our own), we assume a life of eight years for oak, and four for mountain pine and hemlock, as in better accord with experience in this country, we shall have the following computations of economy upon the basis of Councillor Funk's paper, when oak sells at 50 c. and hemlock at 25c.:

UNPREPARED TIES.

			Annual Charge
15,000,000 oak @ 50 c.	$7,500,000	÷ 8	$ 937,500
20,000,000 hemlock @ 25 c.	5,000,000	÷ 4	1,250,000
			$2,187,500

If it costs 25 c. each to impregnate them, we then have for lives of sixteen and twelve years:

PRESERVED TIES.

			Annual Charge
15,000,000 oak @ 75 c.	$11,250,000	÷ 16	$703,125
20,000,000 hemlock @ 50 c.	10,000,000	÷ 12	833,333
			$1,536,458

Annual economy, $651,042.

When, however, the prices have advanced to 75 c. for the oak, and 30 c. for the hemlock, we have, with the same life and cost of preparation, the following comparison:

UNPREPARED TIES.

		Annual Charge
15,000,000 oak @ 75 c.	$11,250,000 ÷ 8	$1,406,250
20,000,000 hemlock @ 30 c.	6,000,000 ÷ 4	1,500,000
		$2,906,250

PRESERVED TIES.

		Annual Charge
15,000,000 oak @ $1	$15,000,000 ÷ 16	$937,500
20,000,000 hemlock @ 55 c.	11,000,000 ÷ 12	916,667
		$1,854,167

Annual economy, $1,052,083.

This illustrates how the economy of preservation increases as the price of ties advances. The above mode of calculation is not strictly accurate. It omits the interest account, which would increase the cost as against the prepared ties, and it also omits the cost of periodical renewals, which would increase the cost of the unprepared ties. Various methods have been employed for computing the economy of renewable structures. Local conditions and considerations vary so much, and there are so many circumstances which will force themselves into account that it is, perhaps, not wise to state any very definite rule in the premises. Your committee submits, however, three methods for such calculations in the appendix. Appendix No. 18 is an estimate of the economy of creosoting ties by M. E. R. Andrews of this committee. Appendix No. 19 is an estimate of what increased life is necessary in order to justify a certain rate of expenditure in preserving timber, by Mr. B. M. Harrod, also of this committee, and Appendix No. 20 contains a formula for estimating the economy of various kinds of ties, furnished to your committee by an expert in such matters, the late

Mr. Ashbel Welch, then president of this society, and who thus renders a last service to the society which regrets him still.

Respectfully submitted,

O. CHANUTE,
B. M. HARROD,
G. BOUSCAREN,
E. A. ANDREWS,
E. W. BOWDITCH,
C. S. SMITH,
J. W. PUTNAM,
G. H. MENDEL,
FREDRIC GRAFF, *ex officio*,
Committee on the Preservation of Timber.

Extract Transactions American Society C. E., Vol. XIV., Jan.-Dec., 1885, Page 303. Appendix No. 4. Burnettizing on Central Vermont R. R.

ST. ALBANS, VT., April 28, 1882.

O. Chanute, Esq.,
127 East Twenty-third Street, New York, N. Y.

Dear Sir: In reply to your favor of the 25th inst. I would say that in 1856 this road erected works for the purpose of extracting sap from wood and of infusing chemicals for the purpose of preservation. It was in use some four years, but it was so much work to get through with such large quantities of timber as are used upon a railroad that it was thought best to abandon the work; therefore, the boilers and fixtures were removed and sold, and nothing more was thought of the "Burnettizing" process until some three years since, when an old side-track was removed, which had not been in use for several years, and which was nearly covered with earth and grass; still the hemlock ties were then found to be nearly sound, having laid there for nearly twenty-five years. I did not keep watch of other prepared timber put in at that early time and as repairs are constantly going on upon a railroad, I am unable to say whether there are any similar cases upon our line or not, but there is no doubt that the preservation of these ties was due to the process above named. The reason for abandoning the "Burnettizing" works upon this road would seem to be that the officers in charge at the time lost faith in the theory, and as it was an experiment, they did not learn of its value until recently discovered in the matter referred to. There is no question, in my opinion, regarding the value of the process.

Yours very truly,

J. W. Hobart,
General Superintendent.

Extract Transactions American Society C. E., Vol. XIV., Jan.-Dec., 1885, Page 318.

SUMMARY OF SUNDRY TESTS AND INVESTIGATIONS.

From the statements furnished above, as well as from other sources of information respecting the durability of the ties, we will gather in concise form the most important conclusions.

1. The average life of unimpregnated ties on the German and Austrian railroads has been the following up to the present time:

For oak ties	13.6 years.
For fir ties	7.2 years.
For pine ties	5.1 years.
For beech ties	3.0 years.

2. The average life of ties impregnated in a rational manner with creosote or chloride of zinc, under a powerful pressure, reaches:

For oak ties ....19.5 years.
For fir ties ....14 to 16 years.
For pine ties .... 8 to 10 years.
For beech ties ....15 to 18 years.

3. The average life of 831,341 pine ties on 13 German railroads, impregnated on various systems, is calculated at 14.0 years.

Extract Transactions American Society C. E., Vol. XIV., Jan.-Dec., 1885, Pages 323-324. Appendix No. 8.

BURNETTIZING ON LEHIGH AND SUSQUEHANNA RAILROAD.

BROOKLYN, April 24th, 1883.

O. Chanute, Esq., Chairman Committee on Preservation of Timber.

Dear Sir: Soon after receiving your circular asking for information regarding "preservation of timber," I went to Mauch Chunk, and calling upon Mr. Twining, Roadmaster of the L. & S. Division of the C. R. R. of New Jersey, he very kindly accompanied me to a portion of his track in which were a quantity of burnettized ties which had been in the track since 1867 and 1868. The track on which these ties are laid runs along the river bank, and is in a side-cutting, in rock principally. The ties in question consist of maple, beech and hemlock. They were mixed indiscriminately with untreated ties, at the same time of laying, with one, two, and three in a place. With a few exceptions they have resisted decay almost perfectly. The rails have worn into them from ¼ to ⅝ of an inch. The beech ties that were treated had stood well, showing very little, if any decay, but being straight-grained they had in some cases split through the heart, beginning at one end, which was open one to three inches and extending half or two-thirds of the length of the stick. The effect of treatment upon the hemlock ties appeared to be the best of all. They were very hard to cut, dulling the knife, and where cut presented a glassy appearance. They were generally much harder and consequently less worn by the rail than any of the other woods. Most of the treated ties in the track appeared good for seven or eight years longer. A few of the treated ties had been taken out of the track and piled alongside but many of them apparently removed unnecessarily. In nearly all cases the under sides of these ties appeared like new timber. As an experiment, the value of the operation was greatly vitated by mixing these ties with the untreated ones in such a manner as to render it difficult to ascertain the effect of the treatment in promoting resistance to wear under the rail. I also examined some creosoted cypress ties which were laid in the track of the C. R. R. of N. J., near Round Brook Station, in the year 1876, several hundred feet of track being laid exclusively with ties thus treated. They are sound, very slightly worn, and will no doubt serve a good purpose for several years longer, probably 10 or 12 years. These ties can easily be found in the track, both from their blackened appearance and by the odor. The Burnettized ties can be picked out from among the others by the somewhat weatherbeaten appearance of the surface, as well as from the fact that an end of each was stamped with figures showing at which date they were laid in the track.

Respectfully yours,

L. L. Buck.

Extract Transactions American Society C. E., Vol. XIV., Jan.-Dec., 1885, Pages 333-339. Appendix No. 13.

CREOSOTING ON NEW ORLEANS AND MOBILE R. R.

NEW ORLEANS, LA., June 20, '85.

O. Chanute, Esq., Chairman Committee on Preservation of Timber.

Dear Sir: The line of railroad between New Orleans and Mobile runs parellel to and near the Coast, crossing various arms of the sea, and so near the mouths of rivers that the tide ebbs and flows a considerable distance above the railroad crossings. The salt water flows over the bar at high tide, and at the ebb, the fresh water being lightest, flows over the top, leaving a basin of salt water in which the teredo navalis finds some of his choicest feeding grounds. As the tidal rise is only a foot or two the tidal currents are not very strong. It often happens that piles driven for these bridges will be honey-combed from 5 to 40 feet below the surface of the water, while not a sign of the teredo can be found at the surface. In the construction of the road the bridges over these waters were built of unpreserved piles and timber. Before the road had been fairly completed it was found that the piles were being rapidly destroyed by the teredo, and before trains had been running 6 mos. a part of the bridge over Bay Biloxi gave away, precipitating the locomotive and part of the train of freight cars into the bay. Realizing that something must be done to protect the piles, and knowing of no methods of reliably treating them, it was decided to sheath them with metal. Between 4 and 5 thousand piles were sheathed, part with yellow metal, such as is used for covering ships' bottoms, and part with zinc with a layer of felt underneath. Four or five hundred were charred and oiled, and as this was less costly than covering with metal, more piles were thus treated subsequently. The zinc corroded rapidly, and in about 3 years there were many small holes through it. It served as a partial protection until the bridge was rebuilt with creosoted piles, eight years later. The felt underneath did good service after holes came in the zinc. The yellow metal was more durable and did not show many holes for six years. When taken off in eight years many sheets had lost all toughness and broke like plates of glass. The charred and oiled piles were about as durable as zinc. In charring timber, there are narrow lines or strips of clear wood between the coals, and into these as well as in the places where the coal gets chafed off, the marine animals enter. It appears that there is great difference in the durability of metals in different waters, owing to the ingredients leached out of the earth and brought down by the streams. In some harbors sheet copper is reported good after 40 years' service, while in others it will be destroyed in 5 years. An outline history of the use of timber on the New Orleans and Mobile Railroad will apply to most roads in the South that have used the same kinds of timber. A large amount of long-leafed yellow pine and quite a quantity of cypress was used in the construction of the road in the years 1869-70. In the year 1874 extensive renewals were required. In 1875-76 still more extensive renewals were demanded. The decay was so rapid, especially with the horizontal timber, that in the last bridges, rebuilt in 1879, probably not more than 5 per cent of the original pine stringers and caps remained. But some of these were sound and would probably have lasted 2 or 3 years longer. Some of the timber which had been put in to replace that which first decayed had been so rotten as to require renewal. The cypress was much better than the yellow pine, and estimating from recollection, I think that not more than 25 per cent of the cypress had been removed on account of decay. Black cypress is the most compact, heavy and durable of any kind that I have used. The red comes next, while the white cypress is but little better than good yellow pine. For cross-ties it is not as good, except in straight track, being too soft to hold the spikes and rails. I think through the Southern States, where there is a long, warm season favorable to fermentation and decay, yellow pine may be expected to last from 5 to 10 years, and red and black cypress from 10 to 20 for ordinary trestle bridge work, where kept up free from the ground. There is little timber other than pine and cypress suitable for bridge work in this section of the country. In 1875 it was decided to rebuild all the bridges on the road with creosoted piles and timber, under the supervision of the writer, who had been investigating the subject for 2 or 3 years. Quite a number of parties were creosoting timber for various purposes, and at first it was thought practicable to contract with them for the required material. Examination of their products, and of the oldest cresoted work that could be properly done, convinced the writer that if creosoting could properly be done, it would be good and effective; but if it could not be better done than any one was then doing, it had better be let alone. Paving blocks, planks and piles were being treated under various patents, but always with oil at a potency that would make glad the heart of a high dilution homeopathist. By their peculiar methods of doing business they drove from the field and almost out of use the best and most durable kind of paving for driving and ordinary street wear that has ever been laid. It is noiseless and elastic under foot, so that horses can endure speed and service; it is not slippery and therefore safe. The result, the general suspension of creosoting, might have been anticipated. Wherever a piece of timber could be found which had been saturated with oil, it was perfectly sound, and these isolated specimens were the evidences that convinced him that creosote was a specific against decay and the ravages of marine animals if properly used. After a series of experiments plans were adopted differing considerably from anything in use. Works were constructed at West Pascagoula, Miss., and the work of reconstructing the bridges with creosoted piles and timber commenced about the 1st of March, 1876. The result of the first year's operations gave a consumption of 1.8 gallons of oil (equal to 15 or 16 lbs.) per cubic foot of timber treated. This included piles and sawn timber; but piles will absorb more oil than hewn or sawn heart timber. Nearly all of the timber treated was long-leaf yellow pine. It included piles and timber for superstructure and waterways and culverts. Our opinion now is that for marine purposes not less than two gallons of oil should be used per cubic foot for yellow pine. For spongy, porous timber, a much larger amount will be required to give an equally uniform and safe treatment. For fresh water or dry land work a less quantity will give good results, but the amount should be proportioned to the kind of timber used, solid, compact timber requiring the least. Timber should be heated through to above 212 degs. Fahrenheit (whether dry or green) and have the air and moisture exhausted, and in that condition receive the oil. We did not gauge ourselves to any given quantity of oil per cubic foot, but endeavored to make the work as thorough as practicable. We did not thoroughly saturate through the piles or sawn timber, and I do not think any process is known whereby solid, compact timber of large size can be thoroughly saturated by a 1 or 2 days' treatment. The bridge over Chef Menteur was the first to be rebuilt of creosoted timber, and this was done during the months of March, April and May, 1876. It is an iron truss, with spans of 110 feet, resting on pile piers of 16 piles each, each pile capped with a cast-iron socket, and the whole surmounted by a wrought girder pier-head upon which the truss rests. The stringers, cross-ties and guard-rails are of wood. All the woodwork of bridge, including piles, was as thoroughly creosoted as practicable, having an average of nearly 2 gallons of creosote oil per cubic foot. The bridges over the mouths of the Pascagoula river were next built in the months of May, June and July, upon the same plan. During the summer of 1876 several small structures, culverts and waterways were built entirely of creosoted timber, and also a sheet piling revetment along the sides of the embankments, across Lake Catharine, which is nearly a half mile long. This revetment was built of creosoted inch plank, driven double, so as to break joints, and bearing against a wale plank or stringer, supported by piles on the outside. During the following winter the bridge across the Great Rigolets, nearly ¾ of a mile long, was built. The piles in these structures are subject to the attacks of the teredo navalis, especially those at the crossing of Pascagoula river, where piles a foot and a half in diameter have been cut off by the teredo in a single year. During the summer of 1877 no creosoting was done, but during the fall, winter and spring following a great number of waterways and trestles, and the bridge over Pearl river were built.

The water in these large streams is from 15 to 45 feet deep, and piles were used from 40 to 95 feet long. During the month of June, 1885, I examined the bridges built 9 years ago. I bored a great number of cross-ties, stringer timbers and piles (always plugging the holes with a creosoted pine) selecting such as I thought most likely to show signs of decay, if any existed. Every piece of timber was in perfect order, the wood inside the line blackened by the oil being as clean and bright as when cut. The piles showed no indication of having been cut by the teredo. Another suspension of creosoting occurred during the yellow fever epidemic of 1878. The work of construction was carried on during the winter following and finished during the summer of 1879, by the rebuilding across Bay Biloxi, one and one-fourth miles long, and across Bay St. Louis, two miles long. The deepest water here is about 15 feet, but the bottom is so soft as to require piles from 40 to 70 feet long. Since then no organization for bridge work has been necessary on the road, as the bridges are in perfect line and surface. The sandy country through which the road runs makes absolutely tight culverts or water-ways necessary. These have been built of creosoted timber and placed in the bank so as to allow a covering of earth of from 10 to 30 feet high, piles were driven, capped enough these were constructed by using plank or timbers set edgewise, and running across the road-bed. They were floored by plank extending into the bank outside the culvert walls about a foot, and covered by plank with a thickness corresponding to the width of the opening. The openings vary from 1 to 12 feet in width, and from 1 to 6 feet high. They have one or more openings to suit the volume of water to be discharged. Where the ground was soft the piles were driven and capped and floored over, and the sides built of double sheet piling plank 1 inch thick, and driven to a depth to guard against washing out. For larger streams, from 50 to 600 feet wide, and the track from 10 to 30 feet high piles were driven, capped and floored over and covered with sand or gravel about a foot in depth, and in this was laid the ordinary embankment cross-ties to be lined and surfaced by the trackmen. This makes a cheap (and we think durable) viaduct, and does away with the jump or bouncing motion so often felt in passing open waterways or trestles, and protects from fire. I do not think creosoted timber half so liable to take fire as timber in the natural state.

Since then a wharf has been built at Ship Island, a foundation put under the light house at Horn Island, and several pieces of work put in on the Mobile and Montgomery R. R., and a wharf at the Mobile depot. Wharves have been built extensively in the Bay of Pensacola, and railroad bridges on the Pensacola and Atlantic R. R. Several thousand creosoted piles are in the waters of Pensacola Bay, where the teredo is very destructive to timber. We have used a larger amount of oil per cubic foot of timber treated than has generally been considered necessary, but the almost universally satisfactory results confirm us in the opinion that creosoting is valuable in proportion to the amount of oil injected, and wherever a piece of timber decays or is destroyed by marine animals, it may be set down as a fact that there has been improper treatment. The most carefully conducted experiments indicate that there is no decay without fermentation, and no fermentation without germs. If a piece of timber be cut green and thoroughly coated with paint, it will soon be destroyed by what is called dry rot. If a similar piece be heated through to 225 degrees

Fahrenheit, and a sufficient amount of oil be forced in to form an impervious coating, no decay will take place until that coating is broken. Wherever that coating is broken and the air, with its dust, allowed to come in contact with the unsaturated wood, decay follows, and extends in each direction from the opening. It does not affect the whole mass of untreated timber at once, but commences at the opening and extends gradually, and it may be years in consuming all of the uncreosoted wood. If absolutely necessary to cut the timber after creosoting, such surfaces should be thoroughly oiled and pitched, or in some other manner protected. I do not think that the "coagulation of the albumen" is much of a factor in the preservation of wood. Something else must be relied on as an antiseptic. The character of the wood seems to be so changed by saturation with creosote oil that the ferment germ finds no nourishment, and though the oil may have become as thoroughly dried out as possible, no fermentation or decay takes place. By the courtesy of the General Mgr. of the Old Colony R. R., I have just been enabled to examine the bridge built over the Taunton river, at Somerset, in 1865. It was referred to by Chief Engineer Winslow in 1878. Nearly all the original 700 piles creosoted have disappeared or have had another driven alongside and are still left bolted in the bridge. Evidently the work was done in what we should now call a very superficial manner. The original "Bethell process" was used, depending solely upon pressure to force in the oil, and with no provision for extracting the sap, except the traditional vacuum pump. Water cannot be drawn out of timber by simply producing a vacuum in the tank containing it. It is not forced in by atmospheric pressure, but by capillary attraction, which remains the same after the air has been exhausted. Neither can it be removed by ordinary steaming, as that only carries more moisture to the wood. The piles were green and generally treated with the bark on. In creosoting the greater part of the oil is absorbed through the side of the timber, and not by flowing along the pores. The bark, being spongy, absorbed more oil than the green wood, and acting as a strainer, retained the densest and best part of it. When, therefore, the bark fell off, which it was sure to do, the piles were left poorly protected. That part of the pile which received oil 20 years ago is as sound as when cut, though the interior may be rotten. The piles apparently have lasted much longer than they would had they not been creosoted. A few piles were used around a draw-bridge that were not creosoted. The bark was relied upon for protection, and in places where the bark was off or where trimming was done, nails were driven in near together, and I think, a cloth or something of that kind was laid on the wood, though I could not ascertain positively. At any rate all such places that I saw, which had been below the water-line were sound and free from attack by the teredo. Some such patches were left above the water, the piles probably not being driven as far as anticipated, and in these the nails had completely oxidized, so that they could be dug out like sand, and the wood between the nails, which were about half an inch apart, was also destroyed, being as brittle and easily dug out as charcoal, while the surface of the wood around these places and out of the influence of the iron was quite good. The difference of the effect of the nails above and below the water line was plainly seen. Some hemlock cross-ties were creosoted and laid in the track near the creosote works about 16 years ago. They had been hewn, and were more or less seasoned, and received a goodly quantity of oil. The oil has become hard and dry on the outside, but inside it is yet limpid and may be squeezed out after removing the outside of the tie. I could not learn that a single tie had been removed for the cause, and they, with others of later date, are doing service. Some other pieces of hemlock and spruce were creosoted and cut up for other use. Wherever the oil penetrated, the timber is perfectly sound, though the center may be soft and rotten. The creosoted part is as tough and fibrous as ever. I do not think the fibre of timber is ever made short or brittle by creosote, though it may be, and sometimes is, by overheating. I do not think timber should be heated to more than 250 degrees Fahrenheit. It has generally been considered that palmetto or cabbage wood was safe from the attacks of marine animals. I found several pieces at Pensacola, 3 or 4 years ago, which had been more or less eaten. This summer, I saw at Charlestown, South Carolina, numerous pieces badly eaten. They were taken out of a wharf at the Custom House, which was being rebuilt. I sent samples to the rooms of the Society at New York. In some of the pieces the teredo seemed to be well fed and flourishing, measuring about half an inch in diameter. With ordinary timber the bark is protection against the teredo, but with the palmetto that seemed to be the choicest part, though they cut both wood and bark. The wood of palmetto seems to be a bundle of interlaced fibres, held in place by a kind of vegetable cement, which dissolves when the timber is used under water, and the fibres can then be drawn out singly. It has but little strength in either direction. Its greatest strength is in the bark.

Respectfully yours,

J. W. Putnam.

Extract Transactions American Society C. E., Vol. XIV., Jan.-Dec., 1885, Pages 339-343. Appendix No. 14.

REMARKS ON CREOSOTING.

Octave Chanute, Esq., Chairman of the Committee on Wood Preservation.

Dear Sir: My own practical experience in wood preservation has been confined to creosoting. In England, where the metallic salt processes, *i. e.*, Kyanizing, Burnettizing, etc., started in the race with creosoting about the year 1838, creosoting alone survives, and has been generally adopted wherever wood is used in railroad construction, or other out-of-door work. Before engaging in creosoting as a business, I satisfied myself, through Eastern correspondence mainly, that properly creosoted wood is indestructible by marine animal life, and will resist decay almost indefinitely. The members of our society were at that time generally unfamiliar with the process, and inclined to be skeptics. Since then sufficient has been learned from actual experience in this country to confirm the good reputation of this process in Europe. In some of our earlier transactions are papers giving results of experiments in so-called creosoting, especially as regards its efficiency in preserving timber from the teredo. The fact is it was not creosoting at all, but a pretense. Mr. C. B. Sears says: "Over 1,000,000 feet was treated by the 'Robbins' process, a modification of the Bethell; it was impregnated with the vapor of hydro-carbon oil, about 1¾ lbs. of oil to the cubic foot, and cost $10 coin per 1,000 feet B. M. This in California.

That such creosoting failed is no wonder, yet it served to prejudice the process. The first really valuable information on wood preservation in the possession of the society is the paper of the Secretary, Jno. Bogard (on permanent way Trans. A. S. C. E., Vol. VIII., Jan., 1879). This paper gives, in tabular form, without comment, categorical answers to a series of questions, asking for actual experience, obtained from an extended correspondence with the chief engineers of all the large railways in Great Britain. From that date the subject of wood preservation has been frequently discussed at our annual meetings, and several valuable papers thereon have appeared in our transactions. As stated above, the early creosoting was very imperfectly done, and generally by companies started with large paper capital for the purpose of selling stock. Creosote was expensive, and the methods adopted by these companies were efforts to dispense with the use of creosote, except in a vaporous state. In 2 or 3 places works were erected to carry out the Robbins vapor process, but there was little business and less faith. This failing, an attempt was made to adapt the weak machinery to good (?) creosoting. The cylinder burst at a pressure of 10 pounds. These attempts were followed by a period of distrust, and later came the creosoting of the present day, with expensive, powerful and efficient machinery and a system of thorough treatment, which, in some respects, is superior to the English system and will give good results. There are 3 essentials to success: First, the selection of suitable varieties of timber. Second, proper desiccation. Third, the injection of a sufficient quantity of creosote.

First. It is safe to say that the varieties of timber which are most perishable without treatment are best suited for creosoting. They are absorptive; without treatment they readily take in from their surroundings the seeds of decay, and under treatment absorb the creosote freely and evenly. Where such wood will be subjected to strains, the engineer must call for larger dimensions than he would use with denser and stronger woods. But such allowances made, the Virginia or North Carolina pine is far better for creosoting than the Georgia pine, and porous black or red oak than white oak, and in either case the more sap wood the better as the sap wood is always fully saturated. Spruce is unreliable for the purpose, on account of the diversity in density in different specimens. The most conscientious treatment of spruce will fail to obtain uniform and reliable results.

Second. Desiccation. The Bethell process in use in Engand requires that all timber intended to be creosoted shall be exposed in the air until fully seasoned. In this country, when any important contract requiring timber is awarded, the trees are still standing in the forests. There is no available seasoned timber. Hence, we are compelled to adopt artificial desiccation, with the aid of steam coils within the treating cylinder, before the creosote is admitted. But through this necessity in the American process, we secure additional preservation because the degree of heat employed in the desiccation (about 250 degrees Fahrenheit) coagulates the albumenoids in the sap wood, and thus, in so far as coagulation acts as a preservative, all which is accomplished by the metallic salt process is attained in addition to the action of the antiseptic and other properties of the creosote itself. Without preliminary desiccation, creosoting must always be disappointing in its results as there will be many wet places unprotected.

Third. The injection of a sufficient quantity of oil. Creosoting does not claim to be a cheap process. Its cost, and that alone, stands in the way of its general adoption. On this account, while I protest against the small doses first used in this country, from an ounce of tar vapor to 2 lbs. of oil, I yet believe that more than enough is wasteful. During the first 30 years after the introduction of the process in England, the practice was to inject from 6 to 8 and one-half pounds per cubic foot, and the longest records of sound usefulness are of specimens thus treated; but when the wood was to be protected from the teredo ten pounds per cubic foot were used.

Eleven hundred piles driven at Leith, Scotland, in 1848, and reported by the engineer in charge as perfectly sound in 1882, were treated with 10 lbs. only per cubic foot. Later practice in England sometimes called for 10 lbs., as a protection from decay alone, and Mr. Boulton, of London, who has had more than 30 years of practical experience in creosoting, wrote me that more than 12 lbs. per cubic foot is never called for by English engineers when for use in tropical climates. It does seem to me that the dose proved to be sufficient in England should suffice here. The atmospheric conditions are quite as favorable to decay there, and the cutting tools of the teredo are quite as actively employed, the Gulf Stream maintaining a long season for their work. As a practical creosoter, while willing and able to inject from 20 to 40 pounds per cubic foot in porous wood, if required, I feel impelled in the interest of economy to discourage the specification of more than 10 to 12 lbs. per cubic foot in most cases. Creosote oil is a distillate of coal tar—a residual product in the manufacture of coal gas. Chemists have procured from coal tar a vast number of sub-products and combinations of great usefulness in dyeing, etc. The three principal coarse products of coal tar are the light oils, the heavy oils and pitch, all the results of distillation. The light oils (lighter than water) evolve in the distillation at a temperature of 360 degs. to 480 degs. Fahrenheit. From these all the aniline colors are made. They are expensive and have no value in wood preservation. The heavy oils (heavier than water) are distilled at a temperature of from 480 degrees to 760 degrees Fahrenheit. These are the so-called creosote oils, and contain all the constituents of the coal tar useful in wood preservation. After the creosote comes the pitch. Creosote contains about 5 per cent of tar acids, *i. e.,* carbolic, cresylic, and other acids, but the bulk is made up of semi-solid oils and naphthaline. Wood preservation by the metallic salt processes is solely chemical. Earlier, it was claimed that the zinc chloride, etc., formed insoluble chemical combinations with the albumen contained in the sap wood. Now it is generally allowed that no such combinations are formed, but that the value of metallic salts as antiseptic depends upon their continual presence in the woods, and as they are readily dissolved out of the wood, their effect is only temporary. The life of wood is prolonged by their use, when skillfully applied, yet in moist places they quickly lose their efficacy. The creosoting process is both chemical and mechanical. Besides the carbolic and other acids, it contains many other well recognized antiseptic constituents; but it is probable that the very long life of timber secured by thorough creosoting is due far more to the fact that the pores of the wood are filled up with the thick, gummy, insoluble oils and naphthaline, and thus keep out air and water which contain the germs of decay. That such is the case was conclusively shown by M. Roltier, a Belgian chemist, and later in 1866 by M. Chas. Coisne, Chief of Section of the State Railways of Belgium and Supt. of the Creosoting Works. By the latter two series of experiments were tried during a period of five or six years in burying in a compost heap made of decaying wood, manure, etc., shavings impregnated with creosote containing different percentages of carbolic acid. The results showed that shavings saturated with carbolic and alone were entirely decayed and those saturated with the distillates at the lightest temperature which contained no carbolic acid whatever were perfectly sound. Experience with the metallic salts and the results of above experiments indicate that to preserve timber something more is required than an antiseptic for the purpose of coagulating the albumen. The very small percentage of albumen contained in the sap wood probably ferments readily and may originate decay, but the agencies of fermentation introduced into exposed timber by the air and water absorbed by the wood are vastly more dangerous than the seeds of decay contained originally in the wood itself.

During the past hundred years almost every imaginable substance has been proposed as a preservative of wood, yet it may be that inventors are still at work; if so, their attention would be best directed to such methods or materials as would close the pores of wood to air and water. The following record of experiments made in the harbor of N. Y. by the Dept. of Docks, of that city, and kindly furnished by Mr. G. S. Grene, Jr., M. Am. Soc. C. E., Engineer-in-Chief of the Dept., will probably prove of general interest.

EDWARD R. ANDREWS.

NEW YORK, May 10, 1882.

DEPARTMENT OF DOCKS, 117 AND 119 DUANE ST., ENGINEER'S OFFICE, CHAMBERS STREET, Sept. 13, 1883.

Mr. G. S. Grene, Jr., Engineer-in-Chief:

The accompanying comparitive table gives the results of five annual examinations, made by the aid of a diver, of certain pieces of wood put down in May, 1878, at the end of Pier No. 1, North River, to ascertain the effect upon them of the teredo. These pieces of wood have always been placed where the current is strongest and entirely clear of the mud line, in order to expose them to the full action of the worms, and to show as strongly as possible the value of the different means that were adopted to protect them. * The numbers and groups were as follows:

ALL SPECIMENS WERE IMMERSED UNDER SAME CONDITIONS, MAY, 1878.

Pairs		*Kind of Wood and Treatment	Size of Specimen	Condition of Specimens when Examined				
				May, 1879	May, 1880	May, 1881	May, 1882	May, 1883
No. 1	1	White Pine, Creosoted	2 ft 11 in. x 14 in. x 3 in.	No Worms	No Worms	2 Worms	No Worms	No Worms
	2	White Pine, Not Creosoted	2 ft. 11 in. x 14 in. x 3 in.	A Few Worms	Honey-combed	Honey-combed	Honey-combed	Honey-combed
No. 2	1	Oak, Creosoted	2 ft. 3 in. x 9½ in. x 3 in.	No Worms	No Worms	No Worms	No Worms	No Worms
	2	Oak, Not Creosoted	2 ft. 3 in. x 9½ in. x 3 in.	A Few Worms	Honey-combed	Honey-combed	Honey-combed	Honey-combed
No. 3	1.	Yellow Pine, Creosoted	2 ft. 2 in. x 10 in. x 3 in.	No Worms	No Worms	No Worms	No Worms	No Worms
	2	Yellow Pine, Not Creosoted	2 ft. 2 in. x 10 in. x 3 in.	7 Worms	Honey combed	Honey-combed	Honey-combed	Honey-combed
No. 4	1	Spruce, Creosoted	2 ft. 2 in. x 10 in. x 3 in.	No Worms	No Worms	No Worms	No Worms	No Worms
	2	Spruce, Not Creosoted	2 ft. 2 in. x 10 in. x 3 in.	8 Worms	A Few More	Honey-combed	Honey-combed	Honey-combed

* Groups Nos. 1, 2, 3 and 4 were furnished by Mr. Edward R. Andrews.

(*Signed*) *W. W. MACLAY, Supt. of Section.*

ALL SPECIMENS WERE IMMERSED UNDER SAME CONDITIONS, MAY, 1878

Groups	No. in Gps.	KIND OF WOOD AND TREATMENT	SIZE OF SPECIMEN	CONDITION OF SPECIMENS WHEN EXAMINED				
				MAY, 1879	MAY, 1880	MAY, 1881	MAY, 1882	MAY, 1883
No. 1	1	Spruce, No Nails	4 x 10 x 12 in.	Large Number of Worms	More Eaten than Last Yr.	More Eaten than Last Yr.	More Eaten than Last Yr.	Honey-combed
	2	Entire Surface Covered with Carpet Nails	4 x 10 x 12 in.	No Worms	No Worms	No Worms	No Worms	No Worms
	3	Spruce, Entire Surface Covered with 3d. Nails	4 x 10 x 12 in.	No Worms	No Worms	No Worms	No Worms	No Worms
No. 4	10	Oak Piles, No Nails	10 in. Dia. 31 in. long 11 in. Dia.	Large Number of Worms	Large Increase	Same as Last Year	More Eaten than Last Yr.	Honey-combed
	11	Oak Pile, Carpet Nails, 35 lbs., driven about ¼ in. apart	10 in. Dia. 31 in. long 11 in. Dia.	No Worms	No Worms	No Worms	No Worms	No Worms
No. 5	14	Pine Pile, No Nails	11 in. Dia. 36 in. long 12 in. Dia.	30 to 40 Worms	50 to 60 Worms	Honey-combed	Not as Bad as Last Year	About 180 Worms
	12	Pine Pile, Bellows Nails 20 lbs., Carpet Nails 12 lbs., driven about ¼ in. apart	11 in Dia. 36 in. long 12 in. Dia.	No Worms	No Worms	No Worms	No Worms	No Worms
No. 6	15	Spruce Pile, No Nails	13½ in. D. 36 in. long 14 in. Dia.	30 to 40 Worms	60 to 70 Worms	Honey-combed	Honey-combed	Honey-combed
	13	Spruce Pile, 20 lbs. 3d. Nails, driven about ¼ in. apart, and Zinc Cap on one side	13½ in. D. 36 in. long 14 in. Dia.	No Worms	No Worms	No Worms	No Worms	No Worms
No. 7	16	Spruce Pile, 4 lbs. Carpet Nails	One Worm	One Worm	One Worm	One Worm	One Worm	No Worms
	17	Spruce Pile, 5 lbs. 3d. Nails. Nails in both Nos. 16 and 17 driven ½ to ¾ in. apart	3 to 4 Worms	9 to 10 Worms	About 17 Worms	About 17 Worms	About 17 Worms	10 Worms

Extract Transactions American Society of C. E., Vol. XIV., Jan.-Dec., 1885. Pages 353-355. Appendix No. 18.

ECONOMY OF CREOSOTED TIES.

NEW YORK, April 26, 1882.

Octave Chanute, Esq., Chairman of Committee on Wood Preservation, Am. Soc. C. E.

Dear Sir: I enclose a calculation to show true economy in the use of preserved railway ties. This economy is not shown in the first cost, but in their longer life and in the relative annual cost per mile of track of preserved and unpreserved ties. I assume 16 years as the probable service of creosoted soft wood ties and 8 years for unpreserved white oak ties. The former is the average life of creosoted Baltic fir sleepers on the railways in England, where the traffic is almost constant (see Bogart's paper, Trans. Am. Soc. C. E., Vol. VIII, page 18); the latter is all which is claimed for the best oak ties in this country, and they are generally dozy and unsafe during the last two years of their service. As it is sometimes claimed that the sum representing the extra cost of preserving, if put at interest, would yield enough to replace unpreserved ties when rotten, make the calculations at compound interest. Example: Relative cost per mile of track of white oak ties at 80c. each and creosoted soft wood ties at 90c. each, the quotations at the present time.

April 1, 1882, cost of 2,600 creosoted soft wood, at 90c. each, for one mile of track	$2,340.00
April 1, 1882, compound interest at 6 per cent. for eight years	1,380.60
	$3,720.60

April 1, 1882, cost of 2,600 best quality white oak ties at 80c.	$2,080.00
Compound interest for eight years	1,233.44
	$3,313.44

April 1, 1890, cost of 2,600 creosoted soft wood ties at the end of eight years' service already in place, and good for eight years more	$407.16
April 1, 1890, cost of 2,600 new white oak ties to replace those laid in 1882 at 80c. each	2,080.00
April 1, 1890, cost of transportation and relaying at 15c. each	390.00
	$2,470.00

April 1, 1890, compound interest for 8 years at 6 per cent. on $2,470.00	$1,464.71	
April 1, 1890, compound interest on cost of 2,600 creosoted ties good for 8 years $407.16		$ 241.44
April 1, 1898, balance in favor of soft wood ties per mile of track during service of 16 years		3,286.11
	$3,934.71	$3,934.71
Further the annual cost for ties per mile of track laid with best white oak ties at 80c each, during a period of 16 years is		$453.01
Annual cost of creosoted soft wood ties at 90c. each		241.31
Balance in favor of creosoted soft wood ties per annum during a period of 16 years	$211.70	
	$453.01	$453.01

That the life of creosoted soft wood ties in this country will probably be 16 years seems evident from the experience on the Central New Jersey R. R. which has had laid in its main line, and under very heavy traffic, 10,000 creosoted Virginia pine ties during the past six years, and so far they show no signs of cutting under the rail, and are perfectly sound and apparently good for ten years' more service. From the above figures it appears that the cost of the creosoted ties for the ninth year is $407.16 per mile, or about equal to the annual cost of white oak ties during the first term of eight years, *i. e.*, $414.18. Hence, if, under the heavy rolling stock at present in use, the creosoted soft wood ties will not last 16 years, they will affect a saving of $414.18 per mile of track for each and every year of service beyond nine years. A service of 16 years is allowed for trunk roads with very heavy traffic, but on roads with smaller business and with less wear on the ties, if absorbent woods be used, so that the treatment of the ties can be thoroughly done, it is safe to claim for creosoted ties a service of 24 years. (The English ties belonging to the society are perfectly sound after 20 and 22 years' wear, even on the London and Northeastern, and the Southwestern Railways, where they were subjected to the whole immense traffic of those roads.) On a lower estimate for white oak ties, say 60c. each, and an assumed life for creosoted soft wood ties of 24 years and costing 90c. each, the annual cost of white oak ties lasting eight years requiring two renewals, with an additional charge of 15c. per tie for expense of transportation and relaying at each renewal, would be $227.50, while that of creosoted soft wood ties would be only $97.50, an annual saving per mile of track of $130. I realize that the above figures and considerations will not be applicable in every case, but I hope they may serve to induce engineers to give a careful consideration to one of the most effective means of reducing the expenses of railway road-beds.

Yours truly,

EDWARD R. ANDREWS,
Assoc. Am. Soc. C. E.

Extract Transactions American Society of C. E., Vol. XIV., Jan.-Dec., 1885, Pages 356-357. Appendix No. 19.

ECONOMY OF PRESERVING TIMBER.

By B. M. Harrod, M. Am. Soc. C. E.

The discussion of the methods and results of preserving timber leads to the question of relative economy, and when they can be profitably used. To make this clear, a statement has been prepared with regard to showing what increase of life or duration, under processes of different cost, is necessary to justify their use, by economic considerations. The prices and duration assumed are intended to be a fair average of those prevailing throughout the country. The method of computation can of course be applied to figures altered to suit different localities and circumstances.

If unpreserved ties cost 40c. to deliver, and 15c. to lay, spike and tamp, 2,600 can be laid to the mile at a cost of $1,430. Assuming five years as the average life of such ties, 520 of them must be renewed annually. Each one will cost in place, say, 65c., or 10c. more for relaying, than for the first laying, amounting to $338 annually per mile. This sum capitalized at 6 per cent is $5,633.33. Now, the original cost of ties, plus a capital whose interest will maintain them, can be fairly considered a fixed sum, from which the relative economy and required life of preserved ties can be deducted. This, as estimated above ($1,430—$5,633.33), is $7063.33 per mile. Now, assuming that a tie costing 40c. can be carried to and from the preserving works for 5c. and preserved for 20c. and laid for 15c. (total, 80c.), we have $2,080 as the first cost of 2,600 ties in a mile. This, deducted from the fixed sum, leaves $4,983.33, capitalized for maintenance, producing $299 per annum, at 6 per cent. With a renewed tie costing 40c., preservation 20c., extra transportation 5c., and laying 25c. (total 90c), the interest on the balance for maintenance ($299) is only sufficient for 322.22 new ties per mile, or 1 in each 7.83 annually. It is, therefore, necessary, in order to justify a cost of preservation of 20c. per tie (or of 25c. transportation included), that the average life of each should be 7.83, instead of 5 years, or an increase of two years and ten months. In like manner we find that a cost of preservation at 40c. per tie must insure an average life of 10.68 years; a cost of 60c. a life of 14.29 years; a cost of 80c. a life of 18.99 years, and a cost of $1 a life of 25.37 years. Also, that an indestructible tie is worth in place $2.72. These results can be checked in a table as follows:

First Cost.	Interest.	Annual Renewals.	6 per cent. on $7,063.33.
$1,430 at 6%	=$85.80	$2,600 ÷ 5 =$520.00 at $0.65=$338.00	=$423.80
2,080 at 6%	=124.80	2,600 ÷ 7.83=332.22 at 0.90= 298.80	= 423.80
2,600 at 6%	=156.00	2,600 ÷ 10.68=243,45 at 1.10= 267.80	= 423.80
3,120 at 6%	=187.20	2,600 ÷ 14.29=182.00 at 1.30= 236.60	= 423.80
3,640 at 6%	=218.40	2,600 ÷ 18.99=136.93 at 1.50= 205.40	= 423.80
4,160 at 6%	=249.60	2,600 ÷ 25.37=102.47 at 1.70= 174.20	= 423.80

If we assume the cost of bridge timber at $15 a thousand, its framing at $15, and its average life at seven years, we find, by applying a similar computation to 100,000 feet, that a cost of preservation of

$5 per thousand requires a life of 8.8 years; a cost of $10 a life of 10.85 years; a cost of $15 a life of 13.3 years; a cost of $20 a life of 16.2 years, and finally, a cost of $25 a life of 19.7 years to justify its use. The rigid application of such a statement as this would be modified by certain general considerations which are sufficiently obvious. The more inferior the material, or the more exposed the situation, the greater is the relative importance of preservative processes. Five years additional life doubles the value of material—which, unprepared, would only last 5 years, while it only adds 50 per cent. to the value of material naturally good for 10 years. Under this consideration, the inferior pines, gums, and even cottonwood, might be used for ties. Again, difficulty of access for inspection or repair is a good reason for preservation, even when its immediate economy is not apparent. This would apply to piles and bedded or concealed sleepers. Also, the use of more enduring materials, reduces the cost of maintenance of engineering constructions in various indirect ways, that are difficult of estimate in a general statement. For instance, if cross-ties lasted 12 years instead of five, five men could do the work of replacing over a length of road that now requires twelve men. Under the present rate of consumption, such scarcity of raw material, as will very greatly enhance its value, is in the near future. There is a wise economy in limiting the use of our woodland wealth to the rate at which it accumulates, as well as in preventing other well-attested evils that will surely follow the deforesting of the national domain. It is, therefore, reasonable to claim that when the economy of preserved and of unpreserved lumber, based on relative cost and durability, appears evenly balanced, there are still reasons, perhaps remote, but certainly valid, why a preference should be given the former.

Extract Transactions American Society of C. E., Vol. XIV., Jan.-Dec., 1885, Pages 350-351. Appendix No. 17.

REPORT ON ECONOMY OF BURNETTIZING.

NEW YORK, LAKE ERIE AND WESTERN RAILROAD CO., OFFICE OF THE CHIEF ENGINEER, P. O. BOX 839.

NEW YORK, May 4, 1883.

A. Harris, Esq., Vice-President, Etc.:

Dear Sir: In answer to your inquiry as to what is my estimate of the annual saving to be expected, if burnettized hemlock ties are used instead of the present practice, I beg to report that the following table shows the number of ties annually used in repairs:

Year.	Eastern Div.	Delaware Div.	Susquehanna Div.	Western Div.	Buffalo & Rochester Div.	Totals.
1875	186,700	140,597	118,045	102,375	92,000	639,717
1876	184,110	92,930	125,945	139,426	175,555	717,966
1877	148,201	107,354	123,576	110,141	108,466	597,738
1878	112,342	104,472	153,622	106,537	129,581	606,654
1879	155,000	238,000	215,500	121,130	232,213	961,863
1880	159,799	109,954	138,204	114,645	281,124	803,726
1881	132,300	126,958	118,204	117,419	155,422	650,303
1882	170,218	132,815	61,923	87,923	266,636	719,530
Total						5,697,498

These renewals, for the eight years tabulated, average 712,187 ties a year, and as during that time the road was operating an average of 1,329 miles of main tracks, and of 406 miles of side tracks, there were, during that time, approximately 3,520,000 ties in the main track, and some 1,060,000 ties in sidings, a total of 4,680,000 ties on the whole line. This, divided by the 712,187, which were placed on an average each year, gives an average life of 6½ years each for the unprepared ties heretofore used on the road. I believe, however, that in point of fact the average life of ties is about 5½ or 5¾ years in the main tracks, and about 8 years in side tracks, where they are allowed to remain until they are in a worse condition of decay, and where the lesser running of trains diminishes their cutting under the base of the rails. These ties are of three kinds of timber: white oak, which costs an average of 62c. a tie, and lasts about seven years; chestnut, which costs an average of 45c. a tie, and lasts about five years, and hemlock, which costs an average of 28c. a tie, and lasts about 3½ years. To the above prices must be added some 15c. a tie for the cost of distributing them and putting them in the track, so that the first cost to the road, and the annual charges are as follows:

White oak costs 77c., lasts 7 years, annual charge 11c.

Chestnut costs 60c., lasts 5 years, annual charge, 12c.

Hemlock costs 43c., lasts 3½ years, annual charge, 12.3c.

All experience conclusively proves that hemlock ties thoroughly Burnettized will outlast unprepared white oak. On the German railroads, the returns of several lines show that Burnettized fir (this being the timber which corresponds to our hemlock) endures in the track from 14 to 15 years. A similar result has been obtained in this country on the Lehigh and Susquehanna Railroad, on the Vermont Central Railroad, and on the Chicago, Rock Island and Pacific Railroad, as well as experimentally on the Erie Railway; and such failures as have occurred can be directly traced to improper treatment, such as attempts to impregnate wood while yet full of green sap, or the use of too strong a solution, which tends to make the wood brittle. In order, however, to make sure that the estimates shall be eminently safe, I shall assume a life of but 12 years for Burnettized hemlock in calculations which follow. I am convinced that better results will be attained if the work is well and skillfully done. I estimate the cost of Burnettized hemlock ties in the track as follows:

First cost of unprepared ties........	28c.
Hauling ¼ of output at 16c. each....	4c.
Burnettizing	25c.
Distributing and putting in track....	15c.
Total	72c.

The annual charge, therefore, if they last 12 years, will be 6c. a year a tie, in lieu of the 11c. a year a tie, which the unprepared white oak ties are estimated to cost, while the annual charge on chestnut and unprepared hemlock is still greater. The economy therefore, of Burnettized hemlock ties over unprepared white oak amounts to 5c. a tie in first cost (77c.—72c.) and to 5c. a year a tie upon the number in the track, so that if we suppose two roads of the present mileage of the "Erie"—*i. e.*, with 1,467 miles of main tracks and 517 miles of sidings, on which there are approximately some 5,000,000 of ties, the one laid with Burnettized hemlock would save over the other, if laid with unprepared white oak, $250,000 every 12 years in the first cost, and also $250,000 a year in the average annual charge for renewal of ties. This economy, however, can only accrue as fast as the road is relaid with Burnettized ties. The works which it is proposed to erect will have a capacity of 300,000 ties a year, but to cover mishaps and detentions it will be safe to assume that only 250,000 ties will be annually prepared. The annual economy, therefore, will be a gradually increasing one until the whole road is relaid with Burnettized ties. The first year the saving will be only the 5c. difference in the first cost, say $12,500 for 250,000 ties; the second year it will be $12,500 on that year's purchase, and $12,500 more on the annual charge for depreciation of the 250,000 ties put in during the previous year. The third year the saving will be $12,500 in the first cost, and $25,000 in the annual charges on the 500,000 ties Burnettized during the previous two years, and so on. The following table shows how this annual economy increases:

First year's difference in first cost, 250,000 ties at 5c.	$12,500
Second year, first cost $12,500, annual charge $12,500	25,000
Third year, first cost $12,500, annual charge $25,000	37,500
Fourth year, first cost $12,500, annual charge $37,500	50,000
Fifth year, first cost $12,500, annual charge $50,000	62,500
Sixth year, first cost $12,500, annual charge $62,500	75,000
Seventh year, first cost $12,500, annual charge $75,000	87,500
Eighth year, first cost $12,500, annual charge $87,500	100,000
Ninth year, first cost $12,500, annual charge $100,000	112,500
Tenth year, first cost $12,500, annual charge $112,500	125,000
Eleventh year, first cost $12,500, annual charge $125,000	137,500

Twelfth year, first cost $12,500, annual charge $137,500	150,000
Thirteenth year, first cost $12,500, annual charge $150,000	162,500
Fourteenth year, first cost $12,500, annual charge $162,500	175,000
Fifteenth year, first cost $12,500, annual charge $175,000	187,500
Sixteenth year, first cost $12,500, annual charge $187,500	200,000
Seventeenth year, first cost $12,500, annual charge $200,000	212,500
Eighteenth year, first cost $12,500, annual charge $212,500	225,000
Nineteenth year, first cost $12,500, annual charge $225,000	237,500
Twentieth year, first cost $12,500, annual charge $237,500	250,000

After the twentieth year, when all the ties on the road have been placed with Burnettized hemlock (and I may here remark that nearly as good results can be obtained with Burnettized beech), the full annual economy of $250,000 a year will obtain as compared with the present practice. Nothing has here been said about interest on the sums saved, nor about the certainty that the price of the more durable timbers will rapidly advance in the near future. Such calculations are more or less fallacious, because the cost of interest varies, and because the cheaper woods also advance in price, but I am very clear it will be good economy to avail of the heavy body of hemlock and beech recently opened by the extension of the Bradford Branch by relaying a portion of the road with ties of those woods, Burnettized, before the timber is cut up for other uses.

Respectfully,

O. Chanute,
Chief Engineer.

Experiments in San Francisco Harbor.

Since August, 1879, the Board of State Harbor Commissioners have tried the following processes for preserving piles and timber in wharf construction: The Robbins process, the Von Jensen process (class II), Thelmany process (class II), Horton process (class I), Wood process (class II), Culver process (class I), Asbestos felt (class I), a coal tar process, name not known (class I), Von Schmidt process, Shay or Duffey process, McKeown process, Raye process, the Pierce and Beardsly process, and many other processes not having titles. All of these experiments proved failures.

Transactions of the Technical Society of the Pacific Coast.

Therefore, with the evidence herein presented of the value of creosoting, as compared with any of the other processes that have been tried here and elsewhere, it would appear clear that persons desiring to preserve piles or timber would not be justified in further expensive and doubtful experimenting while a sure thing is obtainable.

To Architects.

Where timbers are to be used in the construction of heavy buildings, or any construction, timber that may be liable to rot or decay can be preserved from such effects by creosoting. Sunken timbers, as often used for foundation base, would last indefinitely if so treated. All timbers for exposed heavy construction should be creosoted.

J. I. Boggs, Assoc. M. Am. Soc. C. E. (by letter). In discussing the Mr. Boggs' paper by Walter W. Curtis, M. Am. Soc. C. E., the writer gave the results of some observations on creosoted pine ties along the line of the Houston and Texas Central Railway. These ties had seen 20 years' service, and it was estimated that fully 80 per cent. of the original number was yet in the track. The objections to them were: First, the soft wood used, which permitted the rail to cut into the timber very badly; Second, their high price. These observations were recently confirmed by M. G. Howe, M. Am. Soc. C. E., the present Engineer of Maintainance-of-Way, and by G. A. Quinlan, M. Am. Soc. C. E., the General Manager of the road, in a late issue of "Engineering News." Twenty years ago Bethell's process was still in its infancy, and, owing to its excessive cost, managers hesitated to use it, except to a very limited extent; but with the facts deduced from our past experience, certainly none can justly say that "no process has yet been discovered which can be fully depended upon" for the preservation of timber, and it appears to the writer that the time for hesitation is past, especially when we consider the depleted conditions of our forests. The writer has seen some rotten creosoted piling, but in nearly every case this was caused by the bridge carpenters cutting off the ends of the sticks after the piling was driven and neglecting to apply the hot preservative to the exposed end, and thereby permitting it to absorb moisture from the atmosphere for days and sometimes weeks at a time. In other cases this decay may be attributed to the treatment of defective timber. The writer has never been troubled with dry rot by the checking of the creosoted pine timbers after they were in the structure. It is unfortunate that a great many of our co-workers imagine the poorest class of timber to be the best for creosoting purposes, because it has given rise to the fallacy that "the timber is much weakened by the process." The fact is, if the timber is properly treated, the dead oil neither adds to nor detracts from its strength; but, in nearly every case, comparisons are made between the very poorest and the very best material, the result being the hastily and erroneously drawn conclusion that "the process weakens" it. The writer has seen "thoroughly creosoted piles sometimes break in handling," but close investigation in each instance has shown that originally they were of the poorest pine, such as is known as the "Loblolly"; that they were stacked in the yard to "dry out" for 2 or 3 months before being treated, and were, in fact, rotten before the oil ever touched them.

Extract Transactions American Society of Civil Engineers, Vol. XLIV., December, 1900, Pages 203-210.

DISCUSSION ON TIMBER PRESERVATION.

R. Montfort, M. Am. Soc. C. E. The writer's attention has been called to Mr. Boggs' discussion, in which the following statement is made: "R. Montfort, M. Am. Soc. C. E., Chief Engineer of the Louisville and Nashville Railway, is in a better position than any one known to the writer to speak with authority on the action of the teredo on creosoted piles, as his line traverses a number of salt water inlets along the Gulf Coast, and probably owns one of the oldest creosoting plants in the country. It is the writer's impression that he has entirely abandoned treating his piling, and is now protecting it with salt-glazed sewer pipe, as creosoting did not protect against the teredo." Mr. Boggs is mistaken in his impression. The Louisville and Nashville Railroad Co., during the past twelve months, constructed a large dock and warehouse at the foot of Commendencia Street, Pensacola, Florida, in which some 6,000 creosoted piles, averaging 70 feet in length, and treated with 20 lbs. of creosote oil per cubic foot, were used. In addition to this, during the same period, about 2,000,000 feet of sawed timber were used by this company on the wharf referred to, and for bridges, culverts, etc. It certainly, therefore, cannot be said that the Louisville and Nashville Railroad Company has entirely abandoned the use of creosote oil for protecting piling and timber against the teredo and against rot. It is true that after a service of 14 years the creosoted piles in trestles across Biloxi Bay, and Bay St. Louis, on the New Orleans and Mobile Division, and across Escambia Bay, on the Pensacola and Atlantic Division of the Louisville and Nashville Railroad, were found to be attacked to a more or less serious degree by the teredo, and the piles in these trestles were further protected against the teredo by concrete or by vitrified clay pipe as described in a paper by the writer, read before this Society, November 1st, 1893. The same creosoted piling, driven in 1878, namely: 2,626 piles at Bay St. Louis, and 1,648 piles at Biloxi Bay, or a total of 4,274 piles, with the exception of 3 that have been replaced by new piles on account of rot, and 122 piles that were destroyed by the hurricane of October 2d, 1893, are still in use, giving good service, and with prospect of lasting several years to come. Untreated piles at these bridges would not last, on an average, more than 7 years as against rot, or 6 months against the teredo. Mr. Boggs does not state as to the treatment adopted, or the quality of the oil used in the piles of the Gulf, Colorado and Santa Fé Ry. at Galveston, Texas, which gave poor results. From the writer's experience he is inclined to think there must have been some defect, either in the treatment or in the quality or quantity of the oil used that caused such results. The writer believes Mr. Geo. S. Valentine, who for years has been in charge of The Eppinger and Russell Company's creosote works, Long Island City, N. Y., treated piles in the early 70's that were driven in Galveston Bay, and are still doing service if they have not been destroyed by the recent hurricane. In discussing the paper referred to, the writer said:

"In recent years we have been experimenting with a mixture of resin and dead oil, with the hope that the resin will aid in fixing the oil and prevent it from being dissolved or washed out. Sufficient time has not elapsed to form any definite conclusion, although, so far, piles thus treated have given satisfactory results." It is to be regretted that further experience with piles treated with dead oil of coal-tar and resin has not given the satisfactory results hoped for. In 1890, it having been found that the teredo had commenced to attack the piles in piers of East and West Pascagoula River bridges, driven in 1876, it was decided to strengthen the piers by replacing 2 piles at each end of each pier, consisting of 16 piles.

These piles were 80 ft. long, 10 ins. in diameter at the small end, and were driven 40 ft. into the bottom of the river. They were treated with a mixture of resin and oil in the proportion of 45 barrels of resin to 30 barrels of creosote oil, which is about the same proportion Mr. Kummer proposes to use. The total number of piles treated in this way and driven at those bridges was 88.

A recent examination of these piles for rot, by boring, showed that of the inside piles driven in 1876, and, therefore, 24 years old, only 8 per cent. showed rot in the heart, while of those treated with the mixture of oil and resin, driven in 1890, and only 10 years old, 43 per cent. showed rot in the heart. An examination by diver showed that the piles 24 years old, originally treated with creosote oil, were in better condition than the piles only 10 years old treated with the creosote oil and resin mixture. From this it will be seen that the idea of mixing resin with creosote oil did not originate with Mr. Kummer, but was used by the late J. W. Putnam, Assoc. Am. Soc. C. E., who did the work referred to, under contract, more than 10 years ago. The writer hopes that Mr. Kummer's experience with piles so treated will be better than the results obtained on the Louisville and Nashville Railroad.

Geo. S. Valentine, Esq. (by letter). In May, 1874, in conjunction with Mr. R. S. Trundy, the writer built a small creosoting plant at Galveston to treat paving blocks, which were afterwards laid on Market Street, in that city. The lumber used was the ordinary sound and square-edged yellow pine, which was treated with 12 lbs. of dead oil of coal-tar per cubic foot, and laid under the Stow patent, which consisted in a wedge being driven between each row of blocks for half the depth of the block. The blocks were 6 ins. deep and 4 ins. wide. The wedge was 6 ins. long and 1 in. thick, and was driven into the ground 3 ins. This left between each row of blocks a groove 1 in. wide and 3 ins. deep, which was filled with fine gravel and a mixture of asphalt. The pavement is still in good condition. A few years ago when the motive power of the railroad was being changed from mules to electricity, the contractor, Mr. J. W. Byrnes, of that city, offered a reward of $50 to anyone who could find an unsound block among those which were taken up, and, although a great many persons were searching, he did not have to pay the reward.

Mr. W. G. Curtis, in a discussion on the subject of timber preservation before the Association of Engineering Societies in 1895, states that he believes creosoted timber or piles, if well treated, will last something like the same as timbers in a covered bridge or in a house; they are protected against air and water; that the heavy oils which are injected into the outer pores of the timber, protect it from the absorption of water or the entrance of air, in the same manner, and thereby protect it for an indefinite period of time.

We have already stated that the chemical processes have failed with the exception of Bethell's process of oil of tar, generally known as the creosoting process. This method when properly carried out, thoroughly protects the wood from the ravages of the teredo and other marine worms. The breakwaters and piers at Leith, Holyhead, Portland, Lowestoft, Great Grimsby, Plymouth, Wisbeach, Southampton, etc., have been built with creosoted timber and in no case have the teredo navalis, limnoria terebrans, or any other marine worms or insects been found to attack these woods, as certified to by the engineers in whose charge the several works are placed. In the case of Lowestoft and Southampton we are enabled to give the detailed reports. A most searching examination, lasting many days, was made in 1849, upon every pile in Lowestoft Harbor, by direction of Mr. Bidder;

and the report of Mr. Makinson, the Supt. of Lowestoft Harbor Works, contains the subjoined statement:

"The following is the result, after a close and minute investigation of all the piles in the North and South Piers:

"North Pier.—The whole of the creosoted piles in the North Pier, both seaward and inside the harbor, 900 in number, are sound, and quite free from the teredo and limnoria.

"South Pier.—The whole of the creosoted piles in the South Pier both seaward and inside the harbor, 700 in number, are sound and quite free from the teredo and limnoria.

"There is no instance whatever of an uncreosoted pile being sound. They are all attacked, both by the limnoria and teredo, to a very great extent, and the piles in some instances are eaten through. All the creosoted piles are quite sound, being neither touched by the teredo or the limnoria, though covered with vegetation which generally attracts the teredo." There was only *one instance* of a piece of creosoted wood in Lowestoft Harbor being touched by a worm, and *that was occasioned by the workmen having cut away a great part of one of the cross heads* leaving exposed the interior or heart of the wood, to which the *creosote had not penetrated.* At this spot a worm entered, and bored to the right, where it found creosote; on turning back and boring to the left, finding creosote all around, its progress was stopped, and it then appeared to have left the piece of wood altogether. In 1849, Mr. Doswell, who had the conduct of experiments on different descriptions of wood at Southampton, where the river was so full of the worm that piles of 14 inches square had been eaten down to 4 in. in four years, reported as follows:

"From my examination last spring tides of the specimen blocks attached, on the 22d February, 1848, to some worm-eaten piles of the Royal Pier, I am enabled to report that Bethell's creosoted timbers all continue to be unaffected by the worms; that the pieces saturated with Payne's solution continue to lose in substance by their ravages; and that the unprepared timbers diminish very fast, except the American elm, which stands as well (or nearly so) as that prepared by Payne's solution." The following are the detailed particulars:

Memel at low water of spring tides Red pine at low water of neap tides	Unaffected by worms.
Yellow fir at high water of neap tides	A few barnacles.

PAYNIZED BLOCKS, PLACED APRIL 6, 1848.

Red pine at low water of spring tides	Worm-eaten.
American elm at low water of neap tides Fir at high water of neap tides	A few barnacles.

UNPREPARED BLOCKS, PLACED APRIL 6, 1848.

Memel at low water of spring tides	Much worm-eaten.
American elm at low water of neap tides	A few barnacles.
Fir at high water of neap tides	Much worm-eaten.

On January 1st, 1852, Mr. Doswell ascertained that notwithstanding the number of teredines and limnoria to be found in the Southampton waters, none of the creosoted blocks had been attacked by them. According to M. Forestier, similar results have been obtained at Brighton, Sunderland and Teignmouth. Allusion has already been made to Mr. Pritchard of Shoreham, with reference to preserving timber. On July 26, 1842, he presented a report to the Treas. of the Brighton Suspension Chain Pier Company, upon the preservation of timber from the action of the sea worms. We give a portion of it as follows: Stockholm tar has been used, and proved to be of little service; this tar is objectionable owing to its high price, and also from its being manufactured from vegetable substances. All tars containing vegetable productions must be detrimental to the preservation of timber, especially when used in, and exposed to salt water. This tar does not penetrate into the wood and in a very few months the salt acid of the sea will eat it all away. Common gas or coal tar has been used to a great extent, and its effects are apparent to all. It does a very great deal of harm, forms a hard or brittle crust or coat on the wood, and completely excludes the damp and unnatural heat from the possibility of escape owing to its containing ammonia which burns the timber and in a few years turns brown and crumbles into dust. Indeed, timber prepared with this tar will be completely destroyed on this coast and pier by the ravages of the teredo navalis, and the limnoria terebrans, in five or six years. Also Kyan's patent, or the bi-chloride of mercury, has been used, but has proved equally useless. The sleepers kyanized 5 yrs. ago and in use at West India Dock Warehouses, have been discovered to decay rapidly and the wooden tanks at the Anti-Dry Rot Company's principal yard are destroyed. To conclude, it results from experiments which the committee has directed during six consecutive years, that first coatings of any sort whatever applied to the surface of the timber in order to cover it with an envelope is insufficient protection; such an envelope soon becomes damaged, either by mechanical action such as the friction of water or ice, or by the dissolving action of water; and as soon as any point upon the surface of the wood is uncovered, however small it be, the teredoes of microscopic size penetrate into the interior of the wood. Covering wood with plates of copper, or zinc, or flat-headed nails are expensive processes and only defend the wood as long as they present a perfect and unbroken surface. 2nd. Impregnation with soluble metallic salts generally considered poisonous to animals does not preserve the wood from the invasions of the teredo; the failure of these salts is partly attributable to their being soaked out of the wood by the dissolving action of the sea water, partly also to the fact that some of these salts do not appear to be poisonous to the teredo. 3rd. Although we cannot venture to say that there may not be found in the colonies a wood that may resist the teredo, yet we affirm that hardness of any timber is not an obstacle to the perforations of this mollusc This has been proven by the ravages it has made on the Gaiac and Mamberklak woods. 4th. The only means which can be confidently regarded as a preservative against the ravages of the teredo is the creosote oil; nevertheless in the employment of this agent great care should be taken regarding the quality of the oil, the degree of penetration and the quality of the wood treated. These results of the experiments of the committee are confirmed by the experience of a large number of engineers of ponts et chaussees (bridges and causeways) in Holland, England, France and Belgium. For example, very lately a Belgian engineer, M. Crepin, expressed himself as follows in his report dated 5th Feb., 1864, upon experiments made at Ostend: "The experiment now appears to us decisive and we think we may consider that fir timber well prepared with creosote oil of good quality is proof against the teredo, and certain to last for a long time. Everything depends, therefore, upon a good preparation with good creosote oil, and on the use of wood capable to injection. It appears that resinous wood is easiest to impregnate and that white fir should be rejected. M. Forestier, the able French engineer at Napoleon Vendee, sums up as follows the results of the experiments undertaken by him in the port Sables-d'Olonne, viz.:

"These results fully confirm those obtained at Ostend, and it appears to us difficult not to admit that the experiments of Ostend and Sables d'Olonne are decisive and prove in an incontestable manner that the teredo cannot attack wood properly creosoted."

WOOD PAVEMENTS

Extract from "San Francisco Call," Nov. 12, 1896.

London has accepted them in preference to other materials.

The interest of the public in the question of street paving is shown in many ways. The bicycle has done wonders, but beyond that there is a growing recognition that the discomfort of bad paving is an infliction that the ordinary citizen has no right to tolerate. It has been said by a modern traveler that a street in which the pedestrians cannot converse in comfort by reason of the rattle of the carriage wheels over the stones is nowadays a disgrace to any municipality. This is the keynote of the latest improvements in street pavement. The tendency is toward a paving that will save the nerve-racking din that Americans have too long looked upon as unavoidable. The pavement of the future will be practically noiseless. For this purpose all tests show indisputably the superiority of wood, whether considered in reference to safety, the facility with which a horse can recover his footing, the speed at which it is safe to travel, or the gradient at which it may be laid. Recently inquiries were made among a large number of drivers of different kinds of vehicles in London to ascertain their opinion in regard to the various pavements laid there with the result that 50 declared in favor of asphalt, 197 in favor of granite, 219 in favor of macadam, and 750 in favor of wood. The general opposition to asphalt both there and here is significant. It is condemned by every person who ever drove a horse.

Its surface becomes uneven, causing a side-to-side motion. It is slippery in winter. It is inefficient, except for streets where there is but little traffic and it has been generally discarded in Europe. The prejudice of this country against wood only exists because of a lack of knowledge. As it is now laid it is an artificial stone pavement with a wood covering which can be easily renewed at little expense. Its average life in London, with repairing, is about 10 years, and it would last as long here. The statement that it is unhealthy is unsubstantiated. The London Engineer of Sewers says that although some of the streets have been paved with wood for upward of 30 years no complaint on that head had reached him. A French bacteriologist has lately given data which entirely disproves the idea of unhealthiness of wood paving. It is now in general use in London and Paris, and it is indorsed by many officials who have given careful study to the question of modern city pavements.—G. H. G., in *Pittsburg Dispatch.*

Extract from Portland, Ore., "Telegram," Nov. 22, 1901.

The current number of the Municipal Journal and Engineer contains an article on wood-block pavement that may be of interest to Portland, hence it is briefly reviewed. The article was written by B. T. Wheeler, Supt. of Streets of Boston. There the problem has been to get a pavement that should be less noisy than granite and less slippery than asphalt, but as durable. It is claimed that Boston has the smoothest granite pavements of any city in the world but while granite will last indefinitely it is offensive and annoying to the ear. Asphalt is objectionable because it is not well adapted to the wide variations of temperature experienced at Boston. It frequently is slippery, so that at some seasons it has to be sanded every morning. Brick, nor coal-tar products, Mr. Wheeler says, will not withstand the immense traffic to which streets in the business districts are subjected. Some experiments have been made with wooden pavements. Small areas of wood blocks, treated with "creo-resinate," were laid last year, side by side with asphalt pavements, in order to make a test, and the Supt. says that after a year's trial the wood pavement is entirely satisfactory in every respect, except as to slipperiness, it being laid on streets with steep inclines. It is noiseless and the surface has become so unified that the joints are indistinguishable, no wear, after a year's use, being apparent. Another area with a three per cent. grade was laid with joints or interstices extending clear across the street one-quarter of an inch wide and one and a half inches deep, these spaces being filled with Portland cement grout concrete. This pavement, Mr. Wheeler thinks, will be less slippery than the other. He thus sums up the advantages of wooden pavements:

"It is noiseless; it remains where it is put, does not creep and crawl and become billowy, like asphalt; it can be taken up for necessary excavation, and I believe the test of time will prove its durability and its superiority under moderate traffic over any other pavement now laid."

Curiously, Mr. Wheeler does not mention the kind of wood used, but it is probably pine. The climate must also be considered with reference to any kind of pavement. What would be best in one place might not be best in another. The climate of Portland is not very dissimilar, however, from that of London, where treated wood-block pavements have been in use for over thirty years, both on streets with heavy traffic, and on fine roadways. Paris has nearly four times as many square yards of wood pavement as of asphalt, and visitors report the Paris wood pavement as the finest they ever saw. Yet our wooden pavements have been largely a failure. They are not as durable as they should be, and as soon as they begin to break up they leave a street in a very bad condition. May it not be that we do not yet understand the best methods of treating and laying the blocks? At any rate, the paving problem, after hundreds, even thousands, of years of experience of past generations, is still a perplexing one.

Value of Pavements.

Alderman Martin B. Maddin, of Chicago, in an article on the subject of the value of street pavements, published in the August issue of "City Government," says: The first cost of a pavement is of great importance, but must be considered in connection with the life of the pavement and the cost of the maintenance. The method in Europe in figuring the value of a pavement, is to take the first cost, add to it the cost of maintenance for a period of, say 20 years, or the estimated life of the pavement and deducting value of the pavement at the end of the period; and dividing this sum by the number of years, the annual cost of the pavement will be obtained. This is a very accurate method of gauging the value of the pavement because it gives ultimate results. If a pavement should cost \$3 a yard, and costs 5c. per square yard for maintenance for a period of 15 years, at the end of which time it would be still almost as good as new, it would be a far cheaper pavement than one the first cost of which was $1.50 a square yard, but which had to be entirely renewed every 4 or 5 years.

Wood Paving.

Street paving is a problem that is receiving a great deal of consideration in all large cities of the world at present and for some time past. The principal results desired are that it be not too costly, that it be durable, and that it be as noiseless as possible, and that it does not become too slippery to give horses a good foothold. As to cost, we would say, that the probable durability and annual cost of maintaining in good condition should be given all consideration in that direction. The authentic and reliable evidence we give in the following pages on this subject should go far in proving that wood paving, if made suitable to climatic conditions, is the best solution of paving problems yet suggested. In consequence of the long dry seasons in California the difficulty with wood pavements, when tried heretofore, has been that when the rainy season sets in, the blocks absorbed so much water that the expansion was so great that the pavement always bulged up and became impassable and useless and in consequence its use was abandoned. Since establishing our creosoting works we have experimented considerable with blocks suitable for paving purposes, and we find that a dried and seasoned block in its natural condition will absorb in the ratio of 24 pounds of water per cubic foot, and a similar block being creosoted does not absorb any perceptible quantity, and while the untreated timber expands about ⅝ of an inch per foot the creosote blocks retain their natural size, and the creosoted blocks become extremely hard, and consequently the annual wear will be reduced to a minimum. This class of pavement would be very cheaply repaired after once being well and properly laid.

In the discussion which is going on as to the best material for paving, wood is scoring a victory over all others. Brick is said to be the ruin of horses in furnishing a poor foothold. The Association for the preservation of Ffth Avenue, N. Y., has not entertained the idea of using brick in connection with asphalt, granite, macadam and wood. In London, England, wood is the favorite, as shown in the opinions taken of drivers of vehicles, as follows: For asphalt, 51; for granite, 197; for macadam, 219; for wood, 750. David Milliken, Jr., of New York, is quoted in the "Evening Post" as saying: There is some prejudice here against wood, but it only exists where there is a lack of knowledge. Laid as it is now, it is an artificial stone pavement with a wood covering, which may be very easily renewed at little expense. Its average life in London, with repairing, is about ten years, and there is no difference in climatic effect here. It is said by some to be unhealthy. This is an unnecessary error, for the engineer of sewers in London says that, although some streets there have been paved with wood for thirty years, no complaints have been made on that head, and recently a French bacteriologist gave data which also disproves this idea. It is in general use in London and Paris. There isn't an objection to it that is based on knowledge and it is indorsed by the city officials who are selected with a view to their knowledge of pavements.

Wood Pavement Growing in Favor.

"The West Coast and Puget Sound Lumberman" calls attention to the growing favor toward wood pavement in cities. Brick is said to be the ruin of horses because it furnishes a poor foothold. In London wood is the favorite, as shown from the opinions taken from drivers of vehicles, as follows: For asphalt, 50 favored it; granite, 197; macadam, 219; wood, 730. David Milliken, of New York, states that there is some prejudice against wood in that city, but it only exists where there is a lack of knowledge of its merits. Laid as it now is, with an artificial stone, or concrete pavement as a basis, it can be easily renewed at little expense. That is the method pursued in Paris, as was lately stated in the "Lumberman," yellow pine from America being the wood preferred. Such a pavement in London lasts 10 years. In reply to the charge that wood pavement of the kind described is unhealthy, it can be said that the engineer for sewers in London, states that, though some streets in that city have been paved with wood for 30 years, no complaint has been received about unhealthiness. Recently a bacteriologist gave data which also disproves the notion that wood pavement is unsanitary. In the northwest, starting with Chicago, cedar block pavement has been in use for 40 years, or more, but it is far from perfection because it is not properly laid. The foundation is earth or scrapings from the streets, mixed up with all sorts of debris, on which is laid hemlock plank. On this are placed cedar blocks perpendicularly with the grain, the blocks being cut from cedar posts 4 to 8 or 10 inches in diameter. This makes a cheap and fairly durable roadway for 5 or 6 years, but fails and becomes uneven under heavy traffic. A good deal of it is annually laid, but asphalt and brick are being substituted for this white cedar block pavement on all good residence streets. But there is no reason why the London and Parisian style of wood pavement should not be extensively introduced in this and all American cities where permanency of foundation can be afforded. The most permanent is the cheapest in the long run, anyway.

Transactions American Society C. E., Vol. XIV., Jan.-Dec., 1885, Page 273.

Experiment No. 14 was tried in New Orleans in 1872. Cypress paving blocks were thoroughly boiled in creosote, or dead oil, in the still of G. H. Fletcher, and were laid in the yard of the New Orleans Gas Light Co. They are said to have been saturated with not less than 20 lbs. and probably with 25 to 30 lbs. of dead oil to the cubic foot, and are now (1885) after 13 years' exposure as sound and perfect as when first laid.

The Development of Wood Paving in Sydney.

With the same experience in macadam, stone cubes, asphalt, and other systems that have taxed the energies, patience and financial powers of other cities, Sydney changed her policy fourteen years ago, and began experiments with wood pavements. The distracting noise, the early deterioration and heavy traction on stone cubes and macadam pavement, with the short life of asphalt and the constant annoyance of repairing, and the failures of all these systems of pavement, were irresistible arguments in favor of a new departure. Of course, many men of experience and observation knew well the qualities peculiar to Australian woods, and the relative merits of many of them. By the use of large quantities of different timbers in railway-sleepers, sills, bridges, wharfs, fence-posts, etc., the better qualities of each had been studied and recognized. The important question of relative durability was fairly well established before wood paving had been suggested. Fourteen years ago the first pavement of this kind was laid in Sydney and now there is over 14 miles, including the chief streets, paved with this material; this includes all streets with heavy traffic. No other material now would be considered, and it is rapidly taking the place of other pavements as new streets are opened and old ones being repaired. The first streets were laid with open joints, or inch spaces between the blocks, the interstices being filled with grout stone screenings or bituminous matter.

The groundless fear of slipperiness lead to laying the blocks with open joints, and the effect of traffic was to batter down or to bevel the corners, and as the filling fractured and was swept away the surface became corrugated, causing jolting, noise, inconvenience and confusion to traffic. The difficulty of cleaning was also very great. With the experience and the aggressive notions of an enterprising city engineer came the gradual closing of the joints as new streets were laid or old ones repaired. Closing the joints to ¼ inch decreased the confusion of traffic, decreased the wear of blocks, and decreased the work of cleaning, and to the surprise of many it did not increase the tendency to slipperiness. The young and progressive engineer was only flattered by this in his desire to reach the ideal pavement, and soon in 1888 came an experiment in close-jointed work. This experience demonstrated the wisdom of the solid concrete foundation, and led to a method of treating the blocks to a non-absorbent solution of hot tar, pitch, etc., and with the closing of the joints appeared a street superior, in the minds of many, in all that goes to make a desirable pavement, to any ever constructed. The fears of the alarmist as to the slipperiness were not realized, and now, as the streets are renewed, the blocks are all placed with closed joints. George and Pitt Streets, the two leading thoroughfares having also the heavy traffic of the metropolis, are now undergoing repairs, the blocks being taken up, the upper end being sawed, and then replaced with closed joints. These streets have been used nearly eleven years, yet the blocks show no signs of deterioration or decay, and it is confidently believed that they will last from twelve to fifteen years longer without further expense. The foundations had no fractures, and needed no repair.

Noise and Slipperiness.

On this wood pavement with closed joints the surface wears so evenly that noise and confusion is reduced to a minimum; while it is a little greater than on the best asphalt streets, it is, at most, of a slight rumbling nature, and not disturbing to the nerves or to business. The jar while riding over it in wheeled vehicles is somewhat greater, and it is accompanied with rather more noise than is experienced while riding over the best asphalt while new, but both noise and jar is so slight and uniform as to produce no disagreeable sensation. As a fact, these streets laid with close joints are almost as even as the sawed end of a log, the new streets are fully as good for the bicycle, and almost as suitable for the roller skate, as the asphalt avenues of splendid Washington. There is a little elasticity, even in these hardest woods, and this breaks the shock caused by wheels striking elevations or dropping from them. This elasticity, too, as slight as it is, is an enormous saving to horseflesh. Rapid driving over stone cubes, brick, or even hardened asphalt, soon tells on the gait of a horse. The "cabbies" of Sydney are hard drivers, but on the wood pavements no horse gets stiff or bunged up. While slipperiness is reduced to a minimum on Sydney's streets, I confess a doubt about the suitableness of close-jointed wood pavements for streets with steep grades. Owing to the cleanliness and absence of dust there is little call for sprinkling, but I feel rather sure that on steep grades this street, when wet, either from storm or sprinkling, would be slippery, especially for any considerable traffic. But this is just as true of a perfect asphalt street, and not only true with stone cubes, because they are not smooth, and because not smooth are not desirabe for street purposes. There are a few places in Sydney having these close-joint pavements with rather steep gradients, on which the authorities have adopted a system of sanding, and this seems to obviate all the difficulty. The expenses for this occasional sanding are very small.

Reflection of Heat.

Another important feature which I think may be justly considered is, that these wood pavements store up and reflect less heat than any solid pavement. The almost unbearable flame-like heat reflected from the asphalt and even granite streets in American cities, in the hottest weather, is fresh in the minds of all city dwellers or visitors. On the wood pavements we are exempt from these suffocating tortures. A dull, unpainted, and unpolished wood surface reflects but little more heat than a common dirt road. When we consider the sum total of suffering by man and beast from the scorching heat reflected from the surface of solid streets, asphalt or stone, this is not an unimportant point to consider.

Traction.

I am not an engineer, a mechanic, or even and experimentalist. I am only an observer. When I state a proposition as a fact, I believe it to be a fact, because the evidence appearing in response to such observation has convinced my understanding. I hope my readers will remember and carefully discriminate between my statements as to facts and my opinions, based upon a course of reasoning from conditions as they present themselves in practical affairs connected with the question under consideration. I have watched with astonishment the ponderous loads hauled through the Sydney streets by one, two, or more horses. Nowhere have I ever seen anything approaching it. Two or three tons for a single horse, four or five, or even six tons for two horses, seven or eight or ten for four horses, are not very uncommon sights. It is surprising how small an obstacle in front of the wheels of a vehicle will check its progress, or, in other words, it is surprising how much the force must be augmented to overcome a seemingly trifling obstacle, elevation or inequality placed in front of the wheels of a heavily laden vehicle. Recently I watched a team of three heavy horses hauling a load of wood, weighing six or seven tons, on a clean, wood paved street. The load was moved with apparent ease; coming, however, to the intersection of another street which had been freshly "sanded," the most casual observer would have noticed the increased efforts of the horses to draw the load across the thinly-scattered

70 or 80 feet of sand. These tiny grains of sand were an obstacle, and the team must give the added force necessary to overcome it. I have talked with several of these teamsters, and while they are not scientists nor philosophers, they have observed that on a smooth wood pavement they need only consider the strength of the wagon, while on the other pavements with gravel, sand, or other inequalities, or even on asphalt, they must regard the pulling power of their teams. From close observation and careful inquiry, I am satisfied that placed upon a common wagon on a close-jointed wood pavement, kept in the order usual in enterprising cities, a given force will haul 8 per cent. more than on the best asphalt street, and 20 per cent. more than on any cube stone or brick pavement.

Cost and Durability.

The experiments in Sydney have been very thorough and the experience very satisfactory. George Street, of which I spoke as being relaid from open to closed joints, after 10 years of use without repair of any kind, is one of the busiest thoroughfares in the world. Remember Sydney has a population of about 420,000, and in the value of its tonnage is about the tenth commercial port in the world. It is the terminus of all the ship lines touching Australia, and has a recorded tonnage of 3,291,188 tons. Five thousand entries and departures of vessels are recorded in its ports. A vast amount of this enormous tonnage is "carted" between "Redfern" Station—but one in the city—and the wharves. That means that nearly the entire products of New South Wales, including 10,000,000 lbs. of wool, come by rail to this station to be hauled to the wharves or warehouses over these streets, including also all that goes from the wharves to warehouses back to the interior of the country. For eleven years this wood paved street has stood this immense traffic without a break, and is only now being relaid to obviate the roughness caused by the open joints. The blocks taken from the middle of this street have worn on an average but 1-28 of an inch per year, or less than ½ of an inch in the eleven years. George Street, too, is very narrow. In the heart of the city it is hardly more than 48 feet between the curbs. The magnitude of the George Street traffic may be better understood by explaining the fact that most of the business done in other cities by street cars and tramways is done here by buses and other vehicles. There are 140 large buses, weighing from 2,100 to 3,500 lbs. empty, which carry from 16 to 42 persons. They are usually well loaded, and will then weigh four to seven tons. They are drawn by three to five horses, which move on a sweeping trot. The vehicles passing on George Street in three hours have been observed at given points or crossings, and it stands as follows as per record: Hunter Street, 636; King Street, 980; Park Street, 731; Goulburn Street, 1,072; Hay Street, 1,451; Harris Street, 1,056; Police Station, 1,469. Then there are 640 heavy "goods vans" and 1,215 cabs, in passenger and transfer service, besides the enormous vehicles that carry the millions of pounds of extra heavy tonnage. I know of no street in any city of the world with more traffic than this narrow Sydney street, where wood pavement has proved its superiority over all others. The City Surveyor's report claims that one wood pavement on these busy streets will outlast three made of stone cubes. Castlereagh Street was laid with close joint blocks ten years ago. It has considerable, but not heavy traffic. There has been no expense for maintenance, and it is one of the finest streets I ever saw in any city. From my observations then, and from such information as I am able to glean from many articles and reports, in the matter of expense, durability and general desirableness, I regard the wood pavement in Sydney superior to any other now in use. Law and Clark's Roads and Streets, page 239, gives the wear of three wood pavements at 3-10 of an inch per annum under a traffic averaging 362 vehicles per day of 12 hours for each foot in width of the street. Mr. Clark says it is claimed, in some instances, blocks have worn down in London to a depth of two and one half inches (the Wells Street pavement was only two inches thick, before removal), and suggests eight or nine inches as a better depth than six inches, now universal. The blocks of the Mincing Lane pavement, which lasted 19 years, were nine inches deep. If we assume that the blocks are six inches deep, and that the road will not break up until they have worn down three inches, there seems no reason why a thoroughly creosoted wood pavement, laid with narrow joints, on a sufficient bed of concrete, with a water tight stratum interposed, should not wear for about ten years in our streets of heaviest traffic with a small amount of intelligent maintenance.

There have been several charges made against wood pavements which are mentioned here, not as a matter of information, viz., that they soon become full of holes, are impossible to clean, are difficult to replace when the street is opened, and that by their rotting the health of the community is endangered, to which may be added that for only a short time do they present any barrier to the saturation of the soil by surface water.

The general practice, as far as observed by the writer, in this country, has been to lay green or wet pine blocks, more or less thoroughly dipped in coal tar, on a bed of sand, not always rammed, with or without the interposition of a tarred pine board, with transverse joints from one to one and one-half inches wide filled with gravel and coal tar, which was theoretically thoroughly compacted. Omitting those which, without the slightest pretense of a one-inch board for foundation, speedily becomes a wood macadam, the first failure was from the blocks rotting on the bottom in patches, so that the surface would first be found to be sheared down by a heavy load; and on taking out the blocks they would be found sound on their tops, where the gravel had been driven into them by the traffic, and also a sound film of about the thickness that tar could be expected to penetrate a wet block, the inside being rotten. In other cases, however, when the layer of sand was too thin, the mud worked up through both boards and blocks, reducing everything to about the state of those having no boards under them.

A layer of concrete, covered with Trinidad bitumen, will effectually stop the mud from coming up, and any percolation of the surface water into the soil through the pavement; the narrow joints, by preventing the edges of the blocks burring over, will both tend to keep the surface smooth, lessening the shocks of the wheels, and greatly facilitate all the operations of cleansing. Creosoting, by the preservative and antiseptic properties of the dead oils used in that process, will probably keep the timber from decay, so that nothing but abrasion need be feared, and the sanitary objections to decaying wood will be removed.

The following note of some experiments by E. R. Andrews (published in the *Engineering News*) shows the efficacy of creosoting for protecting wood from moisture.

The following are the results of some careful experiments with different varieties of wood, half of the specimens being simply dried and the others creosoted, to ascertain to what extent wood is rendered waterproof by creosoting. The specimens were soaked during two days in water, being carefully weighed before and after soaking:

Percentage of water absorbed:

Spruce, creosoted	.0236
Spruce, creosoted	.0306
Spruce, dried only	.1754
Spruce, dried only	.3333
Spruce, Burnettized	.2500
Hard pine, creosoted	.0000
Hard pine, dried only	.1600
Oak, creosoted	.0625
Oak, dried only	.2000
White birch, creosoted	.1240
White birch, dried only	.4300
Cottonwood, creosoted	.3470
Cottonwood, dried only	.7141
Black gum, creosoted	.1250
Black gum, dried only	1.0000
Sequoia gigantea (great tree of California) creosoted	.0000
Sequoia gigantea, dried only	.4722

In the rooms of this society are creosoted fir ties from England that have been in the track for 20 years, and apparently justify the assertion of the engineer sending them, that they are good for ten years more.

The following extract from the *Railroad Gazette,* is also corroborative.

The German Railroad Union, some time ago, made inquiries as to the extent to which processes for preserving ties were employed, and what the results were. It appears from statistics of German railroads which have used treated ties more or less since 1840, and therefore have had time to test thoroughly the life of the ties, that the average life of ties not treated, and of those treated with chloride of zinc or creosote has been:

	Not treated. Years.	Treated. Years.
Oak ties	13.6	19.5
Fir ties	7.2	14 to 16
Pine ties	5.0	8 to 10
Beach ties	3.0	15 to 18

The average life of 831,341 pine ties treated in various ways on 13 German railroads was 14 years.

It follows from this that there is an increase in the life of ties treated with chloride of zinc or creosote, amounting to about 40 per cent. for oak, 100 to 130 per cent. for fir, 60 to 100 for pine, and 400 to 500 per cent. for beech.

It thus appears that there is a great deal gained with any kind of wood, but most with some of those usually not considered good for ties, fir and beech being made almost as durable as oak. Bischoff says that it is of little advantage to secure ties from decay longer than periods above stated, as the ties usually become worn out or crushed by that time, even if not decayed. Commenting on these facts, Bischoff says that it is now generally admitted that the choice lies between creosote and chloride of zinc; that creosote is the best antiseptic material, but also that it is the dearest.

There can be but little doubt that the antiseptic properties of the creosoting process are of more value than the increased life it would give to the blocks. On account of the absence of proper stone and the cheapness of wood in large areas of our country, the small first cost of wood pavements seems to make it worth while to give them an intelligent trial.

The thoroughness with which wood pavements can be cleansed depends on the size of the joints and the firmness of their filling. The practice in London, when the mud is at all sticky and not thick as to require scraping, is to water and then sweep with a revolving broom, the thoroughness of the cleansing being almost directly as to the amount of water. In hot weather a disinfectant is sometimes applied after sweeping.

The number of testimonials given in favor of creosote is very large, and from the most eminent engineers of all countries, in addition to which Mr. Bethell has received several medals at International Exhibitions. The English engineers include Messrs. Brunel, Gregory, Abernethy, Ure, Hemans, Hawkshaw, and Cudworth; the French, MM. Molinos and Forestier; the Dutch, Messrs. Waldorp, Freem, and Von Baumhauer; and the Belgian, M. Crepin. The late Mr. Brunel expressly stated that, in his opinion, well creosoted timbers would be found in a sound and serviceable condition at the expiration of forty years. M. Forestier, French engineer of La Vendee Department, reporting to the juries of the French Exhibition of 1867, cites a number of experiments he has lately tried upon many pieces of creosoted and uncreosoted oak, elm, ash, Swedish, Norwegian, and Dantzic red fir, Norway white fir, plane, and poplar, and shows that in each case, except that of poplar, the resistance of the wood both to bending and crushing weight was much increased by creosoting.

Drs. Brande, Ure, and Letheby, also bear testimony to the efficacy of this mode of preserving timber.

Creosoting has been extensively employed upon all the principal railways in Great Britain. In England, upon the London and North Western, North Eastern, South Eastern, Great Western, etc. In Ireland, on the Great Southern and Western, Midland, etc. In Scotland, on the Caledonian, Great Northern, etc. It has also been and is being employed in Belgium, Holland, France, Prussia, India and America.