or the bottom of the cellar. In some instances, where it is difficult to reach moist earth, they must be imbedded in charcoal.

9th. Lightning-rods, constructed and erected in accordance with the foregoing principles, will afford full protection in the hour of danger, and their use is strongly urged as a necessary means of safety.

DECAY AND PRESERVATION OF TIMBER.

(By T. J. CRAM, Col. U. S. Corps of Engineers, Bvt. Maj. Gen. U. S. A.)

(Continued from page 186.)

V. *The Observed Condition of the Timber after Treatment.*—As might be expected, I have given close attention to this subject, and submit the following conclusions, drawn from my own observations:

1. The albumen in the wood has been coagulated thoroughly.
2. The outer portions of the sticks, the sap wood especially, are thoroughly impregnated.
3. The inner or heart portions of the sticks that contained air, and little or no sap fluids, are not so well filled as the outer parts, the stuffing being abundant on the exterior, and gradually decreasing towards the centre, where there is little or no evidence of it.
4. That substance, whether it be "hydro-carbon" or "resiniferous," coming from the oil and solidifying in the pores of the wood, is apparent, but it does not seem to stop altogether the absorption of water, yet so little water is taken in after treatment that it does not penetrate beyond the carbolic acid of the oil which has entered the wood.
5. Deeper penetration and a larger deposit of the hydro-carbon in the heart wood of the sticks would have been obtained by more oil and more time for the treatment.
6. A given number, say twenty cubic feet, all in one stick, is far more difficult to treat than the same number cut up into small paving blocks, railroad ties or fence posts.
7. In the large straight grain sticks, the penetration was not so ready nor so abundant as in the cross-grain sticks, showing that the antiseptic enters in directions parallel to the fibres far more easily than transversely to them. It is for this reason that the shorter the stick (like paving blocks, ties and fence posts) the more readily it becomes saturated.

8. In our operations the strength of the timber was not impaired; it was found of greater rigidity after the treatment, and as much lighter

as was equal to the difference of weight of fluids expelled from the green water-logged timber and the substance taken in; it was, however, rendered a little more brittle; but, though the "co-efficients" of elasticity and rupture should be slightly diminished by the process, still the timber would be amply strong, laid in piers, docks and railroads.

9. Could we have framed the timber, by cutting all the notches and dovetails before treatment, it would have been better for the work.

10. It is clearly shown in my observations that it will not do to trust implicitly to samples of wood of small dimensions which have been submitted to the process, for facts to govern us in drawing inferences to apply to large sticks of timber, either for the quantity of the antiseptic imbibed, the amount of the hydro-carbon left in the pores, or for the strength of the wood after treatment, or its weight.

11. It is not yet being two years since commencing the treatment, and immediately putting the timber into the construction, it is impossible to give results that may be observed five years hence, at the expiration of the first period of seven years. The treated sticks are marked in the work with a double cross ($\times \times$), and the untreated with a single ($\times$), and they lie side by side similarly exposed to all circumstances causing decay. At the end of the first period a comparison carefully made will give us the data upon which to judge whether we shall realize anything of what we hope to gain by this great experiment.

12. The inflammability of the wood for the first season after treatment is somewhat increased, though not so much as to cause objection to it for pier constructions. In a hot summer day immediately after treatment, the timber having been turned from its bright clean color to a dirty, sooty brown or black, by the process, was disagreeable to the men to handle, but all complaints arising on this score were due more to imagination or carelessness than to any well founded cause.

13. The whole atmosphere at the work was impregnated with the odor of the tank and scattered piles of treated timber, which was undoubtedly a strong promoter of health to the workmen. I have never known a public work in a marshy influence employing from two hundred to three hundred men as free from malarious diseases to the men or from sickness of any kind. I attribute this remarkable freedom from ill health to the antiseptic influence of the impregnated atmosphere.

VI. *Quantity of Timber Treated. Time of Treatment. Oil Consumed. Cost of Treatment.*—The whole amount treated was 186,580 cubic feet, in sticks of the sizes already given in Chapter III. I intended to have more treated, but the apparatus could not be made ready before the constructing contractor had to commence putting in his work.

The time consumed for each batch was twelve hours, *i. e.*, from when it entered to when it left the tank; the amount of timber in the tank was on an average of 1,100 cubic feet.

When the timber was on hand in good supply, and the apparatus in good working order, and the men diligent, the amount treated in a month of twenty-six working days was 27,738 cubic feet. This is a fair measure of what can be done with large timber that is green and water soaked, in a single tank of the dimensions of the one used.

The quantity of oil consumed for the saturation of the timber in any given case depends on the kind of wood, the thickness and lengths of the sticks and the time taken for keeping the wood under the treatment. The heating of the oil is only continued until all the water and gases are expelled or cease to come over from the pores of the wood.

In our treatment of the *large wet and green, white and red pine sticks*, the oil consumed was one-half ($\frac{1}{2}$) gallon to the cubic foot of timber, on an average, throughout the whole. It cost, delivered at the works, 15 2-10ths cents per gallon. In working the apparatus, one foreman, at \$150 per month, and four hands, at \$75 each per month, required, making the hire of men to amount to \$450 per month. Allow for wear and tear of machinery \$75 per month, and for fuel \$33.75 per month.

The expenses per month, therefore, amounted for oil, labor, wear and tear, and fuel, to \$2,666.84. This divided by 27,738, the number of cubic feet treated, would bring the cost of treatment to very nearly 9-61 cents per cubic foot of the timber, without including the cost of the apparatus.

The apparatus complete, including shed, costs not less than \$9000. I have no idea of the royalty paid the patentee. I find that on the whole job the contractor, after deducting the cost of the apparatus, could not have realized more than \$1056.66 to cover the royalty, the interest on his outlay, his personal expenses for two seasons, besides

what the machinery would be worth, after completing the contract for 186,580 cubic feet.

The contractor for treating the timber, from isolated locality, and being subordinate to the constructing contractor for the supply of timber, was put to expense and loss of time, which would have been saved under more favorable circumstances.

The estimate I have given furnishes the proper criteria to enable one to judge, if he has a given quantity of timber to treat, whether it would be best to purchase the right, construct the apparatus and do the work for himself, or to hire the authorized agent of the patentee to treat the timber by the cubic foot. The cost of treatment may be considerably diminished from the foregoing estimate by attending to what follows in the next chapter.

VII. *Improvements Suggested in the Apparatus.*—Having seen the working in the operations for two seasons, I am prepared to recommend :

1st. That the swinging crane, which was worked by hand for loading and unloading the cars, should be so arranged that the lifting may be done by the steam engine, thus saving the labor of two men, and keeping the engine employed, instead of resting idle half the time.

2d. The timber tank should be covered with a wooden shell, leaving space, however, between it and the tank to allow the water jets to play, in the "cooling off," and thus prevent a loss of heat by radiation, and effect a saving of both time and fuel.

3d. Instead of a full circle, give the timber tank a cross section, like Fig. 6, rounding, however, the lower corners; then less oil would be required to cover the batch, and the timbers could be separated by horizontal and vertical spaces (as in Fig. 6) by thin strips of wood or iron, leaving channels for freedom of circulation of oil all around each stick while heating; and by this shape, too, a large coil of steam pipe could be introduced, and less time occupied in raising the temperature of the oil to the required degree, which, however, should not exceed 290° or 300° F., for much above 300° F. would impair the wood fibre and distil over the oil.

4th. When there is a large quantity of timber to treat, there should be two timber tanks instead of one only, so arranged that while the oil in one is heating the other would receive its batch, and the hot oil from the first flowed into the second as soon as the time comes to cool off in the first.

5th. Put a valve into escape pipe d , to retard at pleasure the escape of steam.

6th. Use a ten-horse-power steam engine with a boiler commonly used with a twenty-horse-power steam engine.

With an apparatus thus improved, one engineer, two skilled laborers all the time, and occasionally a common laborer, could conduct the whole process.

I would also improve the *name* of the treatment. Instead of calling it, what it is not, "creosoting wood," I would designate it by what it really is, viz.:

Carbolic acidizing wood. The chemical tests applied showed that no creosote entered the pores of the wood in the process. If any creosote is found after the treatment, it must have pre-existed therein. Empty the pores and stuff the cells with creosote, and I venture to say the wood will sooner perish.

VIII. *Estimate of the Saving to the Government by the Carbolic Acidizing of the Timber at the St. Clair Flats Improvement.*—I will make the formulæ general, and apply them to this improvement as an example for showing not only the saving on this, but on any other work:

Let t be the first cost in cents per cubic foot of the timber delivered at the location of the apparatus; f the cost in cents per cubic foot of framing and putting the timber into the work, including, on renewing, incidentals thereto; c the cost in cents per cubic foot of the treatment.

We see in Table C, Chapter II, that timber similarly exposed and of like kind, and even of inferior quality, has lasted in Europe, after treatment by Bethel's process, 19, 20, 24, 26, 32 years, and then found as sound as ever; and at the present time all the information I can obtain proves those timbers perfectly sound. There is no knowing yet how much longer they will last. The prevailing impression is with some engineers who have examined them, that they will last until literally worn out. I have a right, therefore, to suppose or assume that the timber treated by the Seely process for the St. Clair Flats Improvement will endure for twenty-eight years before renewals will be required. If time to come proves the assumption to be wrong, the mistake on this point must then be attributed to the circumstance of a decided difference yet to be found between the durations of treated seasoned and treated green timber. Be this as it may,

twenty-eight years is the epoch of duration for the treated, and seven years for the untreated, before this will require renewal. Again, the government pays on its borrowed money an interest equivalent to six per cent. per annum, and in making an estimate involving borrowed capital, the interest thereon must be compounded in order to arrive at the true state of the case. Upon the basis now stated we have the following formula :

$$\left. \begin{aligned} \text{Cost in cents per cubic foot} & \left. \begin{aligned} \text{untreated, for 28 years} & \} = 12.276 \times (t + f) \\ \text{Cost in cents per cubic foot} & \left. \begin{aligned} \text{treated, for 28 years} & \} = 5.112 \times (t + f + c) \end{aligned} \right\} (3) \\ \text{Saving cents per cubic foot by} & \left. \begin{aligned} \text{treatment, for 28 years} & \} = 7.164 (t + f) - 5.112 \times c \end{aligned} \right\} \end{aligned} \right\}$$

In the St. Clair Flats Improvements $t = 21$ 3-10ths cents; $f = 9$ 7-10ths cents; $c = 15$ cents. Substituting these in the last formulæ (3), we find :

Saving per cubic foot by treatment, for twenty-eight years = 145 4-10ths cents; or, the annual average saving in this epoch, 5 2-10ths cents on every treated cubic foot in the work, which contains 186,258 cubic feet treated; or, an annual saving of \$9685.42 on the work in consequence of the treatment.

We shall never hereafter obtain this quality of timber, nor get it framed and put in the work for less than 21 3-10ths cents for t , and 9 7-10ths for f . But I am confident, with the improvements I have suggested in Chapter VII for the apparatus, the cost could be made less than fifteen cents for c , unless the oil should advance very much in price above 15 2-10ths cents per gallon.

For determining the limit of c , above which it would not be profitable to treat the timber, we have the expression $7.164 \times (t + f) - 5.112 \times c = 0$; from which we find $c = 1.4014 \times (t + f)$; i. e., when the cost per cubic foot for the treatment is *one and four-tenths* the cost of the timber and the labor of framing and putting it into the work, there would be nothing gained by the treatment. This simple rule applied to St. Clair Flats Improvement, gives the limit of c equal to 43.4 cents.

IX. *Question of Applying the Seely Process for Preserving Timber to all hereafter to be used in Repairs, Preservation and Construction of Piers, and Breakwaters on the Lakes.*—If these works are to be kept up in good serviceable shape by appropriations from the national

treasury, as ought to be, it will be in place here to briefly present the measure of the economy of this question; also the practical method of effecting this object.

There would be no necessity of treating any of the timber except that above water, and which I call the "superstructure."

In all the harbor piers, breakwaters, etc., upon the lakes, there are probably fifteen miles or more in extent of superstructure. The width will average at least eighteen feet, and height five feet, or five timbers above water. Experience has shown that they should all be planked over. To every running foot pierwise the superstructure will contain at least twenty cubic feet of timber on an average of all the works. In the fifteen miles, therefore, there are 1,584,000 cubic feet exposed to decay and requiring renewal. In periods of seven years to each work, its proportionual part of this should be renewed. This estimate does not include the new works to be commenced hereafter, but the formulæ may be applied to them as readily as to existing work.

In every renewal of timber in the superstructure there is attendant or incidental labor of \$2 per cord, for removing and replacing the stone filling without waste, in order to put in the new timber. This incidental item I find averages six and a quarter cents to every cubic foot of timber in the superstructure. Again, the cost of the iron drift bolts and spikes has to be again incurred at every renewal. I have made several attempts to save the old bolts and spikes, but the expense of pulling, straightening, etc., has proved more than they are worth. In the superstructure there is just about one pound of bolts and spikes to the cubic foot of timber, which at present prices costs not less than 4 1-6th cents, which is another incidental expense at every renewal. Since we have these for every cubic foot of the timber, we may add them to the cost of framing and putting in the timber, which will never be less than ten cents per cubic foot on an average. Putting the three foregoing items together, we shall have $f = (10 + 6\frac{1}{4} + 4\frac{1}{6} - 10) 20.85$ cents.

The untreated square timber itself will cost, provided the plans be made as they should be, to require sticks not to exceed twenty-four feet in length, twenty-one and a half cents on an average delivered at the works, or first delivered at a properly selected place, which I shall name, for the location of an apparatus for treating all the timber before sending it off to the several harbor piers, for the renewals. Hence, we may put $t = 21\frac{1}{2}$ cents.

The treatment of the timber, including royalty for the patent, would probably cost eleven cents per cubic foot after the apparatus is constructed.

The total cost of the apparatus, improved as I have suggested, including preparation of the "Timber Bay," to receive the green timber before treatment, need not exceed \$12,000, which, divided by the whole number of cubic feet to be treated, would be very nearly 76-100th cent per cubic foot. This item is chargeable to the account for treatment.

Again, the cost for freighting the treated timber from the site of the apparatus to the several harbors where the timber would be used would average \$1 per thousand, board measure, or 4 8-10ths cents per cubic foot. This is another item chargeable to the account of the treatment.

Bringing the last three items together, we shall have

$$c = (11 + 0.76 + 4.8) = 16.56 \text{ cents.}$$

By substituting the foregoing values for t , f , c , in the formulæ (3), we shall find the saving by the treatment, for an epoch of twenty-eight years, to be 218.74, or 7.81 cents annually per cubic foot, which, applied to the whole amount, would bring the whole saving to amount annually to \$123,710.40, in consequence of the carbolic acidizing by the Seely process.

NOTE.—If, on a careful summing up from the records in the Chief Engineer's office at Washington, there should be found more or less than fifteen miles of such piers and breakwater constructions, this estimated amount of saving can be modified proportionally.

The best site the government could select for establishing the apparatus for treating the timber is at Fort Wayne, near Detroit, where there is an excellent harbor, a good United States engineer dock already; also, extensive river front for making the "Timber Bay," and plenty of ground, all belonging to the United States.

If two such places should be deemed advisable, probably Green Bay, Wis., at or near the site of old Fort Howard, would be the most advantageous place on Lake Michigan.

All of which is respectfully submitted,

T. J. CRAM,

Col. ret'd Corps Eng'rs, Bvt. Maj.-Gen. U. S. A.

To Brig.-Gen. A. A. HUMPHREYS,

Chief of Engineers, U. S. A.

Detroit, Dec. 15, 1870.