

stead of being allowed to pass to the boilers and form a very dangerous and uneconomical scale. Another is that the water is kept clean, which reduces foaming and prevents scoring of engine cylinders and the moving parts of turbines. Still another is that the efficiency of a surface condenser is increased from 20 to 25 per cent, on account of the absence

of noncondensable vapors throughout the entire condenser instead of just around the dry air suction pipe under ordinary conditions.

The yearly saving effected by a deactivator of this type will show from 25 to 50 per cent on the cost of the installation, regardless of the other advantages enumerated.

## Wood as a Chemical Engineering Material<sup>1,2</sup>

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THE value of wood as a material of construction in the chemical industries is very commonly underestimated. This arises from the fact that little information is available in the literature in regard to the use of wood for such purposes, and it is often true that on account of lack of information the plant operator makes use of unsuitable wood, or puts it to improper uses. It is the purpose of this article to give a fairly comprehensive outline of the various woods and their uses for chemical plant work.

### ADVANTAGES

Chemical apparatus made of wood is usually less expensive in its first cost than when made of metal. In many cases the difference in favor of wood is great. When used for water or other liquids which do not destroy the wood, the life of the wood is very long. Cypress tanks are known to have lasted for 130 yrs., while wooden water pipes have been in service

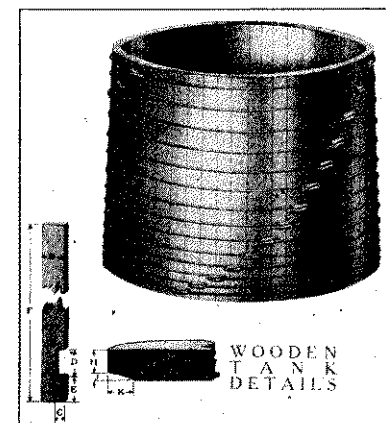


FIG. 1

underground for 100 yrs., such life having much in excess of that obtained from the ordinary steel of to-day. In many localities, the water contains material which quickly corrodes the best of steels while wood is quite unaffected. Wood does not require frequent painting to prevent corrosion as is the case with steel, and it can usually be repaired or remodeled by the local carpenter.

Wood is a poor conductor of heat, and wooden apparatus exposed to frost requires much less heat to keep the contents from freezing than is the case with metals. Conversely the contents of tanks and piping can be kept cold more easily when wood is used.

Wooden piping is not common in chemical plants, but it has many advantages, among which are the absence of corrosion due to electrolysis by stray electric currents, and its greater carrying capacity under given pressure drop. Its value may be indicated by the fact that one large chemical

plant in this country has nearly one hundred miles of wooden pipe. Its cost is also less than that of iron or steel, considerably so in the larger sizes.

### DISADVANTAGES

Wood is not a suitable material for use in apparatus handling strong oxidizing agents, such as concentrated nitric or sulfuric acids. It is readily attacked by strongly alkaline solutions. It must be protected by a suitable protective coating from the action of certain chemicals, such as concentrated hydrochloric acid.

Wood is mechanically weaker than metals, and this limits the use to apparatus of comparatively moderate pressure, steel-banded wooden pipe having been used up to 130 lbs. pressure, and reinforced tanks up to 50 lbs. pressure.

Wooden tanks and piping swell when brought into contact with liquids, and shrink if allowed to dry out afterwards. This permits the joints of the apparatus to open up, and leaks develop. The apparatus must therefore be kept full of liquid and if this is not practicable, it should be filled with water to prevent drying out.

### KINDS OF WOOD AVAILABLE

The kinds of wood most commonly met with in this country are listed below in the approximate order of their popularity for chemical work in general.

- 1—Red Gulf or Louisiana cypress (*Taxodium distichum*)
- 2—Long leaf yellow or hard pine (*Pinus palustris*)
- 3—California redwood (*Sequoia sempervirens*)
- 4—White pine (*Pinus strobus*)
- 5—Douglas, Washington, or Oregon fir (*Pseudotsuga taxifolia*)
- 6—Hard maple (*Acer saccharum*)

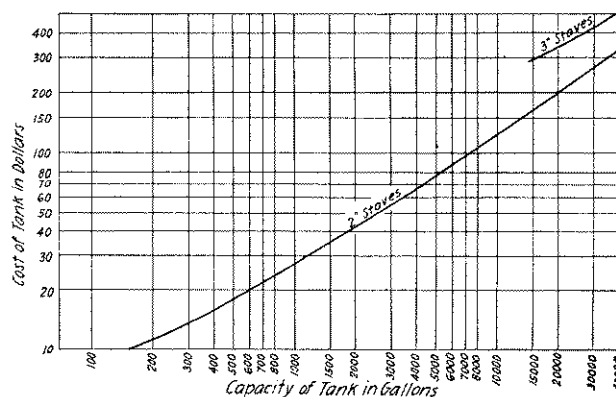


FIG. 2

<sup>1</sup> Received April 4, 1922.

<sup>2</sup> Published as Contribution No. 17 from the Department of Chemical Engineering, M. I. T.

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- 7—Yellow poplar (*Populus deltoides*)  
 8—White oak (*Quercus alba*)  
 9—Tamarack (*Larix laricina*)  
 10—Spruce (*Picea rubra*)  
 11—Norway pine (*Pinus resinosa*)

### TESTS ON EFFECT OF SOLUTIONS ON WOODS

A series of tests were performed by S. J. Hauser and Clarence Behrman for the Hauser-Stander Tank Company on the action of a number of common solutions on six woods: cypress, long leaf pine, Douglas fir, redwood, hard maple, and white oak. These tests included:

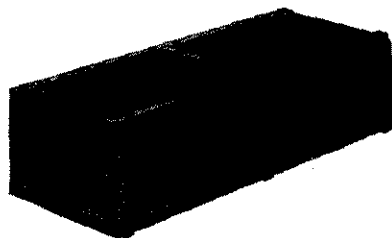


FIG. 3

- 1—The contamination of the liquid by the extraction of coloring matter from the wood.  
 2—The absorption of liquid by the wood.  
 3—The swelling or shrinking of the wood.  
 4—The effect upon the strength and hardness of the wood.

**COLOR**—The color imparted to the liquid, while not important in many chemical operations, is frequently the determining factor in the use of wood for drinking water, for laundry purposes, and in the preparation of many food products.

Oak and redwood contain large amounts of coloring matter which is extracted freely by water both hot and cold, the redwood being a little the better with respect to the latter. Maple is better than oak or redwood, but is considerably worse than fir, pine, and cypress, the last of which has little effect on the water.

Where wood is to be used for handling drinking water or for food products where a taste of the wood must be avoided, fir and pine should not be used. Cypress and maple are best in this respect.

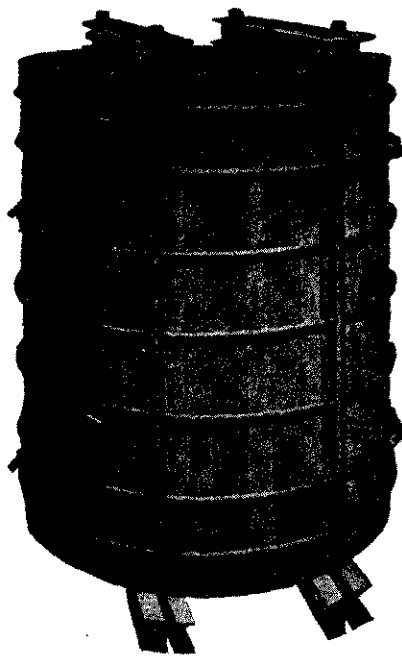


FIG. 4

the colors are of course intensified in all cases.

**ABSORPTION**—The relative absorption of the same chemicals was studied. No relation between the concentration and the amount absorbed was apparent; so Table II gives the results for the average of several concentrations of each solution. Low absorption is represented by 1; large by 4.

1—The contamination of the liquid by the extraction of coloring matter from the wood.

SOLUTION	Cypress	Long Leaf Pine	Douglas Fir	Redwood	Hard Maple	White Oak
5% and 25% acetic acid	1	1	1	2	1	2
50% and 100% acetic acid	2	2	2	3	2	3
5% and 25% HCl	1	1	1	2	1	2
Concentrated HCl	4	4	4	4	4	4
10% H <sub>2</sub> SO <sub>4</sub>	1	1	1	3	1	3
25% H <sub>2</sub> SO <sub>4</sub>	2	2	1	3	2	3
5% HNO <sub>3</sub>	4	4	4	4	4	4
1% NaOH	2	3	3	3	3	3
Concentrated NaOH	3	3	4	4	4	4
Saturated Ca(OH) <sub>2</sub>	2	2	2	3	2	3
5% bleaching powder	1	2	2	2	2	2
Na <sub>2</sub> S solution	4	4	4	4	4	4
5% Na <sub>2</sub> CO <sub>3</sub>	2	3	3	3	3	3
10% NaHSO <sub>4</sub>	2	2	2	2	2	4
10% NaCl	2	1	1	2	2	2
10% CaCl <sub>2</sub>	1	1	1	2	1	2
25% CaCl <sub>2</sub>	1	1	1	2	2	2
Turpentine	2	2	2	2	2	2
Linseed oil	1	1	1	1	1	1

**SWELLING AND SHRINKAGE**—It was found that all the woods expanded in aqueous solutions and that a part of this expansion was lost upon subsequent drying. Some woods after treatment with nitric acid and the alkalis showed shrinkage after drying. Redwood showed the greatest swelling and oak the least.

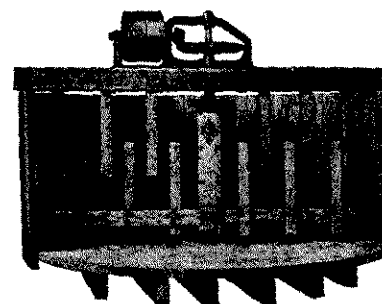


FIG. 5

### EFFECT ON PHYSICAL PROPERTIES

The effect of these solutions upon the softness, brittleness, and other physical properties of the woods was noted.

Acetic acid in any concentration has no effect on any of the woods.

SOLUTION	Cypress	Douglas Fir	Long Leaf Pine	Redwood	Hard Maple	White Oak
	Hot Cold	Hot Cold	Hot Cold	Hot Cold	Hot Cold	Hot Cold
Water	3 2	4 3	3 3	4 3	4 4	4 4
HCl	4 2	4 3	3 2	4 3	4 4	4 3
H <sub>2</sub> SO <sub>4</sub>	4 2	4 2	3 3	4 3	4 4	4 3
HNO <sub>3</sub>	2 2	3 3	3 2	3 3	4 4	4 4
Acetic acid	3 3	2 2	2 2	3 3	4 4	3 3
NaOH	4 4	4 4	3 4	4 4	4 4	4 4
Na <sub>2</sub> CO <sub>3</sub>	4 2	4 3	4 2	4 4	4 4	3 3
Na <sub>2</sub> S	4 4	4 4	4 4	4 4	4 4	4 4
Ca(OH) <sub>2</sub>	4 4	4 4	2 2	4 4	4 4	4 4
Bleaching powder	2 2	2 2	2 2	3 3	4 4	2 2
NaHSO <sub>4</sub>	3 3	3 3	2 2	4 4	4 4	3 3
NaCl	3 1	4 2	3 1	4 3	4 3	3 2
CaCl <sub>2</sub>	1 1	2 2	1 1	3 3	3 3	1 1
Turpentine	4 3	3 2	1 1	3 3	3 2	1 1
Linseed oil	3 2	3 2	1 1	4 3	2 2	1 1
Fatty acid	3 2	3 1	2 1	3 2	3 1	1 1

Dilute hydrochloric acid (5 per cent) makes redwood brittle, while 25 per cent acid has a similar effect on maple and oak; cypress, fir, and pine are unaffected. Concentrated acid destroys all woods.

Dilute sulfuric acid (5 per cent) has little effect on any of the woods, except redwood, which is made brittle. Cypress and pine are not seriously attacked by cold 25 per cent acid, but hot acid of this strength and concentrated acid destroy all woods.

Nitric acid has little action in the cold on cypress, fir, and pine in the 5 per cent concentration. The hot solution attacks all woods.

Maple, oak, and redwood are readily attacked by 1 per cent sodium hydroxide even in the cold, cypress and pine being unaffected up to 10 per cent boiling hot. Pine is not affected by cold 25 per cent sodium hydroxide solution.

Sodium sulfide up to 20 per cent concentration is destructive in the cold only to oak and redwood.

Hot sodium carbonate solution shrinks oak and softens redwood, and hot sodium chloride solution makes the latter brittle. The other woods are not affected.

These experiments indicate that, except for nitric acid and caustic soda, at least one of the six woods tested is suitable

for each of the chemicals used, when in moderate concentrations. Cypress, fir, and pine are the woods least affected; maple and oak are for general use, of restricted value. There is considerable difference of opinion regarding redwood.

#### INFORMATION COMPILED BY FOREST PRODUCTS LABORATORY

A few years ago the Forest Products Laboratory compiled information from users of wood in chemical plants.<sup>4</sup> Experiences were very contradictory, but certain general con-

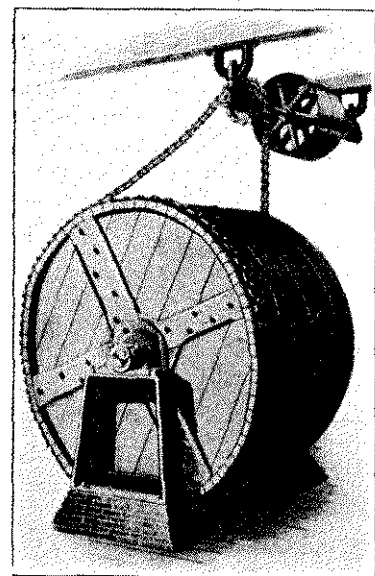


FIG. 6

clusions could be drawn.

For pickling tanks cypress was the most popular, with white pine a close second. The other resinous pines were also used.

For hydrochloric acid, any variety of resinous wood, if impregnated with tar or other protective coating, was apparently suitable.

For acetic acid, any wood was satisfactory, with the possible exception of Douglas fir.

Cypress was preferred for saponifications and for most acid work, while long leaf pine was also very popular.

Filter press plates are usually made of paraffined maple, although other woods are sometimes used.

Tamarack is suitable for hydrofluosilicic acid up to 12 per cent and for dilute organic acids.

In general, the results of the compilation check very well the experimental results of Hauser and Bahlman.<sup>5</sup>

#### SOLVENTS

Wooden apparatus for use with alcohol and other solvents should not be constructed of resinous woods, on account of the solvent action on the resins, but should be made up of either yellow poplar or white oak. The former imparts no color or taste to these liquids, but does not have the strength of the oak, which, however, gives up color readily to many of the liquids.



FIG. 7

<sup>4</sup> Chem. Met. Eng., 18 (1918), 528.

<sup>5</sup> For some further work on this subject see Abrams, "The Effect of Chemical Reagents on the Microstructure of Wood," THIS JOURNAL, 13 (1921), 786.

Solutions which absorb water readily, such as certain hot concentrated solutions of hygroscopic salts, will, when brought into contact with wood, partly dehydrate it, causing it to shrink and to leak. Other materials such as hot tar have somewhat the same effect.

#### HYDROGEN PEROXIDE

Maple has been found to withstand the action of 10 per cent solutions of hydrogen peroxide indefinitely.

#### CRYSTALLIZING TANKS

The use of wood for crystallizing tanks is unsafe only when the wood has absorbed large quantities of the saturated solutions. Under these conditions the tendency is to

cause disintegration of the wood. If relatively nonporous wood be selected, wooden crystallizing tanks are very satisfactory and are long lived.

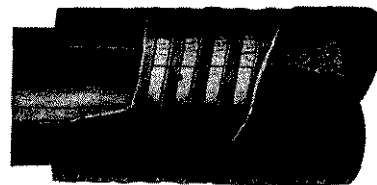


FIG. 8

#### TANKS

Round wooden tanks are constructed either straight or tapered. The construction of the bottom, the sections of which are held together by dowel pins, and of the stave, is shown in Fig. 1. The tanks are shipped ready to assemble according to directions furnished by the makers. The tanks should not be painted on the inside.

The tank hoops are usually made of steel, preferably round, although flat bands are sometimes used, with malleable iron lugs. In cases where the liquid handled will attack steel, monel metal, copper, brass, or other suitable metal should be used. Corrosion may be diminished by placing under the hoops wooden blocks on at least every alternate stave to hold the metal away from the sides of the tank.

The approximate cost at the present time of open top, round, wooden tanks for staves 2 in. and 3 in. thick is shown in Fig. 2.

The tanks should be so supported that all of the weight comes on the bottom and not on the staves, the ends of the latter clearing the floor by at least an inch.

Rectangular tanks are constructed as shown in Fig. 3.

These tanks are heavily rodded, the rods being made of resistant metals and completely buried in the wood where necessary to avoid corrosion. Long tanks must either have a partition as shown, or have external bracing. One company imbeds the rods in acid-resistant pitch.

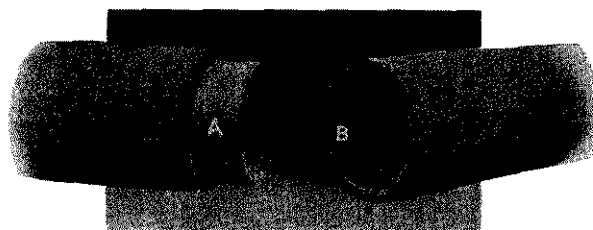


FIG. 9

Tanks to withstand a vacuum are usually made with internal partitions, while for pressure external bracing with thick staves of strong wood such as oak is used. A typical pressure tank good for 40 lbs. pressure is shown in Fig. 4.

Agitators for wooden tanks can be constructed of either wood or metal. An all-wood stirrer is shown in Fig. 5.

Revolving drums of wood are used in tanneries. These must be specially braced at the ends to take care of the bearings. Such a drum is shown in Fig. 6.