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THE USE OF WOOD IN CHEMICAL APPARATUS

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The great expansion in the chemical and metallurgical industries during the past three years has resulted in increased interest in the use of wood for apparatus, particularly apparatus for use with acid solutions. In some cases manufacturers have constructed wooden apparatus because they could not obtain metal; but in many cases wood has a distinct advantage over all other materials when used in the presence of acids. The receipt by the Forest Products Laboratory of numerous inquiries about the suitability of various species of woods for use in such apparatus led to an attempt to collect such information as might be available on the subject.

Laboratory experiments, while possessing some value, were considered inadvisable since years would have been required to complete the tests; also it would have been impossible even to approximate certain commercial conditions. Accordingly, a large number of letters were sent out to various manufacturers and users of wooden apparatus asking what their experience had been, especially in regard to the use of wood with acid solutions. The numbered paragraphs of this paper embody a summary of the replies received. No responsibility is assumed for their accuracy.

It is interesting to note the geographical influence upon the replies, preference generally being given to a wood growing in the region in which it was used. In the North, Central, and New England States white pine and Norway pine were used most; in the West, redwood, and Douglas fir; and in the remaining territory, longleaf pine and cypress.

Effect of Inorganic Acids on Wood

Wood is readily attacked by most of the inorganic acids. A 40 per cent solution of hydrochloric acid and concentrated sulphuric acid dissolves cellulose readily. More dilute acids attack the lignin and have slight action on the cellulose. In fact numerous attempts have been made to manufacture paper pulp by removing the incrusting materials with acids. For this purpose Barne and Blondel[1] used nitric acid; Orioli[2] using 40 per cent of a mixture of 20 per cent HNO_3 and 80 per cent HCl, obtained 50 per cent of long, strong fiber from 100 parts of wood; Lifschutz[3] employed a cold mixture of dilute nitric and sulphuric acids (3:1) and obtained 95 per cent of fiber. The solution was reused until the nitric acid was exhausted, leaving a solution containing H_2SO_4 and saturated with oxalic acid. Highly concentrated mixtures of nitric and sulphuric acid nitrate the wood.[4] Even very dilute solutions of hydrochloric acid or sulphuric acid contained in wood char it when it is dried at a temperature of 100° C. The main action of acids on wood is hydrolytic. The lignin is separated from the cellulose fibers, the wood gradually disintegrating.

Pickling Tanks

1. A Chicago firm using hydrochloric acid and sulphuric acid at room temperature in its galvanized department preferred Norway pine, but owing to inability to obtain suitable lengths was using yellow pine. The tank, using sulphuric acid of 15° to 16° Be. and steam heated to a temperature of 82° to 99° C. was made from longleaf yellow pine.

2. Wooden vats 15 to 40 feet in circumference are made of common pine, native of Massachusetts (probably white pine). This material requires less attention and shows a longer life than longleaf pine, cypress, or spruce. All of these woods have been thoroughly tried out. Absolutely dry cypress gave a slightly longer life than any of the others, but it was found commercially impractical to obtain thoroughly dry lumber. The sulphuric acid solution varies in strength from 3.5 to 8 per cent and the temperature ranges from 74° to 98° C. The life of the tanks varies from one to two and one-half years, depending upon the size of the tank and the nature of the service, the smaller tanks lasting longest.

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[1] Dingler's Polyt. J. 164 (1862) 464; 172 (1869) 238.

[2] Prakt. Handbuch der Papierfabr. 42 (1896) 163-32.

[3] German Patent 60,233.

[4] Lifschutz, Ber. 24 (1891) 1186.

3. We use dilute sulphuric and hydrochloric acid at a temperature of about 65° C. in our galvanizing plant. Both white pine and cypress have been used. The tanks fail by wearing off at the top and at the joints. The acid seems to eat away the material that holds the fibers together. Pine tanks last seven years and cypress from eight to nine. They are used only 10 hours daily.

4. The hydrochloric acid is used undiluted and the sulphuric acid in about a 2 per cent solution, the former being generally used at a temperature of 21° C. but has been used up to 65° C.; the sulphuric acid is used at 65° C. The tanks for these acids have been made of cypress, white pine, fir or oak, chiefly the first two; and it is our experience that as far as the wood is concerned its chief asset was in its natural advantages as a tank lumber, i. e., for holding water or any liquid, and in its ability to stand hard usage, as thousands of tons of steel are passed through the tanks in the shape of angles, etc. In being lowered and raised in and out of the tanks the steel causes considerable chafing and wear. Tanks which have now been in use six years show no appreciable change in the strength of the fibers 1/16 to 1/8 inch beneath the surface and resist the insertion of a knife blade the same as new wood. The breaking away of a splinter from the planks appears to be almost as difficult as with new wood.

5. For ordinary tanks for pickling steel products we always use cypress, which we understand from users of our tanks is very durable so long as the contents are not stronger than a 5 per cent solution.

6. We use hydrochloric and sulphuric acids at a temperature of 70° to 80° C. We have had best success with cypress wood. The life of the tanks in our galvanizing department is about two years. The acid makes the wood spongy, and in about two years' time the solution begins to ooze through the staves so badly that the tank must be abandoned. The wear and tear upon our tanks is rather severe from the fact that we are galvanizing heavy parts and heavy bundles of small parts.

7. We use cypress with the best results for galvanizing tanks.

Storage Tanks for Hydrochloric Acid

1. The hydrochloric acid is stored in a double-walled tank, the inner being made from "Louisiana red gulf cypress" and the outer tank of "special heart grade" long-leaf yellow pine. The space between the tanks is filled with highly refined pitch-tar, which remains in a plastic condition. The inside tanks are sometimes painted with two or three coats of a mixture of rosin and pitch, and before assembling each stave is dipped in a hot tar solution.

2. Our experience -- that is to say, the reports of our customers -- has been that the best material for muriatic acid is either longleaf pine or Washington fir.

3. In the manufacture of muriatic acid, storage tanks were made of California redwood, and the acid was also shipped in tank cars made of the same wood.

The wood was prepared by first boiling tar until all the volatile products at the boiling point of the tar were distilled off, and then the clear redwood was immersed in this and boiled for about half an hour. The staves were then used to make up the tanks. The muriatic acid was maintained at atmospheric temperature and no heating was carried on in the tanks. To the writer's knowledge tanks made up in this manner lasted twenty years.

4. You can make wooden tanks and coat them with a mixture of asphaltum and some wood tar and they will stand quite a long time. We have some wooden tanks so built that we have been using for quite a number of years for transporting and storing muriatic acid. However, there is no wood that we know of that will stand for any length of time, either treated or not, the effects of either nitric or sulphuric acids.

5. We are manufacturers of sulphuric, muriatic, and hydrofluoric acids; the most serious trouble encountered is that of concentrating our acids to the commercial specific gravity. The fumes from the latter acids are weak, warm, and penetrating. The best grade of wood which we have found to answer our purpose is white pine. We have also used some cypress with fairly good success; nevertheless we consider white pine the best for our purpose and for all the acids produced at this plant at various temperatures and gravities.

6. Hydrochloric acid scarcely attacks wood, especially if the latter is soaked in paraffin wax.

Apparatus for Use with Acetic Acid

1. We use a great many wooden tanks in connection with our acetic acid operations. We have used redwood, cedar, and cypress tanks. The cypress are the most satisfactory. We also use wooden pipe lines, and all of these are made from spruce. They are only fairly satisfactory, however.

2. Wooden tanks are used in the manufacture of the vinegar and in its transportation. In both cases fir and cypress are used and with careful treatment they last a great many years. The acid seems to preserve the wood.

3. Acetic acid and vinegar are usually handled in fir tanks.

4. The writer has had experience in the use of wood in the manufacture of acetic acid. Ordinary white pine tanks were used to store the various strengths of acetic acid. Acetic acid was also shipped in second-hand whiskey barrels and we noticed no effect of the acid on the wood.

We also performed concentration and purification of acetic acid in a wooden tower made of clear white pine. This tower showed no effects of the acid.

5. We use wooden tanks made of cypress and pine in the manufacture of vinegar, the acetic acid content of which never exceeds 11 per cent.

6. Douglas fir is used almost exclusively by vinegar plants.

7. During the past few years we have had occasion to make smoke condensers for a certain company. The material must resist the action of acetic acid. After a good many years of experience they have settled on Norway pine as the proper material. They have tried Western fir and condemn it absolutely.

8. We have used wooden tanks as containers for pyroligneous acid, and with good results. These tanks are made of pine, and we have some still in good condition that have been in constant use for the last 15 years.

9. A great many cypress tanks are used in the generation of vinegar and acetic acid and for holding vinegar.

Separators for Storage Batteries

Wood is used extensively for separators in lead storage batteries containing sulphuric acid of from 1.2 to 1.4 specific gravity.

The wood must be given a preliminary treatment; for when it is used in the natural state substances very injurious to the lead plates are formed in presence of the sulphuric acid. Acetic acid is generally considered to be one of the most undesirable substances produced, but according to Skinner[5] a small quantity of acetic acid is beneficial rather than harmful to the negative plates. He finds that "white pine, Douglas fir, and the common species of cedar" are especially desirable for separators. In Skinner's patent, the woods, before use, are steamed under pressure for about 12 hours or boiled at atmospheric pressure for from 24 to 48 hours. The swelling and softening thus produced lower the internal resistance of the separators. In previous patents the separators were first treated with a 25 per cent solution of sodium bisulphite[6] at a temperature of 100° to 175° C.; or with a 15 per cent solution of sodium sulphite[7] at 100° C. for one hour. These solutions remove a portion of the lignin, and their use is founded on well-known methods of manufacturing paper pulp.

Morrison[8] treats the separators with melted paraffin. Heap[9] employs an alcoholic solution of caustic potash, in which the separators are treated for four hours at 140° C. and at a pressure of 100 pounds. Marino[10] steams the separators for 15 minutes at 120° C. and then subjects them to oxidation by immersion in a 20 per cent solution of hydrogen peroxide for about 3 hours. The separators are finally steamed again for 10 minutes at a temperature of about 110° C. The method of Dodge[11] for preparing the separators for use consists in soaking them successfully in dilute sulphuric acid and caustic potash. Whitehead and Marino[12] first submit the wood to an ammoniacal copper solution and then to a bath of ammonia sp. gr. 0.88. The separators are then treated successfully with

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[5] U. S. Patent 1,130,640 (1915).

[6] Skinner, U. S. Patent 1,052,851 (1913).

[7] Skinner, U. S. Patent 1,098,357 (1914).

[8] U. S. Patent 1,058,779 (1913).

[9] U. S. Patent 1,051,580-2 (1913).

[10] U. S. Patent 1,023,948 (1912).

[11] U. S. Patent 1,000,330 (1911).

[12] English Patent 20,143 (1905).

water, nitric acid, and sulphurous acid, and finally with alcohol, caustic potash, and ethyl acetate in various proportions.

Among the woods considered as having special value for storage batteries are yellow pine,[13] cypress (*Taxodium distichum*),[14] and redwood (*Sequoia sempervirens*).[14] Cypress is also considered to be least effected by alkaline solutions.[15]

Lyndon[16] states that for large size station storage batteries heavy wooden tanks lined with lead are universally used. These should be made of sound oak, pine, or teakwood thoroughly dried and boiled in paraffin or its equivalent, so that the pores may be completely filled. "Resinous wood such as pine has proved to be the most satisfactory and durable." This author also states that basswood is invariably used for separators. At the present time basswood is being used only to a limited extent, preference being given to cypress, redwood, Douglas fir, and Port Orford cedar.

Tanks for Saponification of Fats

1. Several of our customers using our tanks in the process of recovering glycerine from soap fats specify 4-inch genuine Louisiana red cypress for the bottoms and staves, and extra heavy hooping. This, we understand, is not only due to certain acids used in this process, but also because the fat contents of the tank are boiled.

2. Our experience is practically limited to the use of wooden tanks in contact with a solution of sulphuric acid containing also sulphonic acids, at a concentration of 1 to 2 per cent for each component at a boiling temperature, in the operation of the Twitchell process for fat splitting. We use for this purpose Louisiana cypress.

Tanks in continuous use with the Twitchell process, if properly constructed, have a life of at least 10 years. The inner layer becomes charred in appearance and we, therefore, use staves not less than 3 inches thick; the charring will not penetrate more than about 3/4 inch. We have recently

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[13] Waldron, U. S. Patent, 463,879 (1891).

[14] Tayor, U. S. Patent 1,012,751 (1911).

[15] Edison, U. S. Patent 754,858 (1904).

[16] "Storage Battery Engineering" (1911).

taken down a tank which has been used about 15 years and find the inside of the staves charred as described above, while the remainder of the wood still remains in serviceable condition. (A portion of a stave sent to this laboratory proved to be dense, resinous longleaf pine.)

Miscellaneous

1. The slight experience that we have had leads us to believe that cypress wood stands the action of all kinds of acids the best.

2. We have had so many complain of Washington fir that we have given up the manufacture of Washington fir tanks for acid of any kind unless specifically ordered. We consider yellow pine in general better than white pine.

3. We make the tanks principally from Louisiana red gulf cypress. In some cases longleaf pine is requested. We have also made some from Oregon fir. It appears that for certain chemicals longleaf yellow pine is specified by the users on account of the acid-resisting qualities of the pitch contained in this pine.

4. Longleaf pine seems to be most popular with the paper mills for sulphite solution, while cypress is universally demanded by the chemical companies.

5. We have tanks constantly in use exposed to dilute acetic, muriatic, sulphuric, and chromic acids, and, in our opinion, nitric acid could also be used if sufficiently dilute. These acids are in various dilute solutions, say about 5 to 10 per cent, and above the solution they exist in the form of steam. The temperature rises as high as 100° C.

The best wood to use for these tanks is longleaf yellow pine as it seems to last longer than any other kind. Many of the dyestuff and chemical manufacturers use wooden tanks generally, and a good many use acids in them. In time the acid softens the wood and causes the tanks to leak no matter how often they are tightened up. Some of our tanks have lasted as long as four years and given good service.

6. We have recently made some acid towers for one of the paper companies and they find Western fir satisfactory. This material comes in contact with sulphurous acid principally.

7. Wood filter-presses are almost invariably used for filtering acid mixtures. Considerable difference of opinion exists as to what woods are best suited for the filtering of various acids. We usually use paraffined hard maple. The plates are sometimes made of longleaf pine, oak, ash, and cypress.

8. We use an acid solution in our plant which is almost saturated with sodium sulphate and chloride. The acids present are sulphuric, sulphurous, and hydrochloric, the maximum strength being about 1 per cent. The temperature of the solution is about 30° C., although in the leaching tanks 100° is approached at times. We are using both Douglas fir and redwood. After three years of service both kinds of wood appear in good condition.

We also handle our waster smoke after passing through a scrubbing tower, through an exhaust fan built of wood. Under these smoke conditions the Douglas fir loses its strength and becomes black and soft. When there are no particular strains to resist, it lasts for several years. We are trying out redwood for this purpose and expect better results.

9. Fir will withstand the action of 18 per cent hydrochloric acid for about six months; North Carolina yellow pine will withstand the action of weak sulphuric acid up to about 5 per cent for one year, but even before that time, in case the acid is agitated, the wood begins to shred.

10. Most of our experience has been in handling hydrofluósilicic acid (H_2SiF_6) mostly at strength of 10 per cent and 35 per cent. The former solution is always handled at 100° F. and the latter at atmospheric temperature. This acid has been used in wooden tanks made of fir, yellow pine, and cypress. We have also packed the 35 per cent acid in oak barrels. The wooden tanks are always lined with asphalt and the barrels with paraffin. None of these woods will stand for any length of time unless the wood is coated with some lining. Whenever the acid is in contact with wood the alternate fibers are dissolved away, leaving the wood in a condition very much resembling a pad of paper.

P?
Pine made of tamarack was used for carrying 12 per cent hydrofluosilicic acid at a temperature of 100° F. After three years' service it was still in good condition.

11. One of our lines conveys a solution containing 4 per cent or 5 per cent sulphuric acid. The pipe (tamarack) seems to remain as sound as ever.

12. While cypress gives better results for hot acids, yellow pine is superior to it for cold or warm acids.

13. Cypress tanks are used almost exclusively for acids and chemicals, and for hot liquids, as nothing else will give as lasting service.

14. Tamarack is a very satisfactory wood for silos, as it resists decay and the effects of the acids formed by the silage.

15. The pipe is made of white pine selected free of all sap and other imperfections. We have furnished it extensively to acid factories, chemical works, vinegar and cider plants, for conveying vinegar, cider, and various acid liquors such as dilute sulphuric, nitric, muriatic, and acetic acids.

16. Pipes made of white pine and tamarack are used for handling mine waters and dilute acids.

17. The lining of flues and hoods over acid vats (HCl and H_2SO_4) appears to last longer when made of spruce than of native pine (Massachusetts). This is probably due to the fact that the spruce is harder than the pine and does not disintegrate so rapidly around the nails.

18. We use cold HCl 3° Be. and boiling hot H_2SO_4 2° Be., and prefer old growth Oregon fir (Douglas fir).

Boehringer and Sons[16] used chlorinated compounds for coating and impregnating wood. It is claimed that substances possessing a high degree of chemical inertness towards acids, halogens, etc., are obtained when animal and vegetable oils, fats, and waxes, are chlorinated under such conditions as will insure the introduction of at least 30 per cent chlorine. Chlorinated products from mineral oils show a high degree of resistance towards the action of alkalies and acids.