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Cooling Tower Wood Deterioration

Over the past decade considerable attention has been focused on the problem of cooling tower wood deterioration—and for good reason. Complete collapse of some cooling towers has occurred. In other cases, supports have deteriorated and fans have fallen through the tower. Accidents have occurred due to collapse of ladders, decking and other parts of the tower. Wood deterioration has shortened the life of cooling towers from the anticipated 20-25 years to 10 years or less in many cases. Repair and replacement costs have been excessive, and cooling tower operation has been inefficient.

Redwood is the most commonly used material for cooling tower construction. It has been used for this purpose almost since the advent of cooling towers themselves. Originally, this material was selected because of high strength to weight ratio, ready availability, ease of fabrication, cost, and natural resistance to decay. Other species are used for this purpose, particularly Douglas Fir and less frequently cypress and pine.

Wood is composed of three main components: cellulose, lignin and natural extractives. The cellulose exists as long fibers, almost identical to cotton fibers, and gives wood its strength. Lignin acts as a cementing agent for the cellulose. The extractives contain most of the natural compounds which contribute to the resistance to decay. In general, the more highly colored woods are the more durable. A typical analysis of redwood, based on dry weight, will show approximately 50% cellulose and hemi-cellulose, 30% lignin and 20% extractives. The extractives in redwood make this material one of the most resistant to decay. Unfortunately, the extractives present in all woods are largely water soluble and will be leached from the wood by the circulating water. The strength of the wood does not appear to be affected by leaching. However, the wood does become more susceptible to decay.

Exceptionally good service was obtained from redwood during its initial use and it is reasonable to expect that this good service would be obtained today if redwood were still subjected to the same conditions. The large, open natural draft tower was the first type used to cool water. The flow of air through this tower is dependent upon wind velocity and upon the draft produced by the chimney design of the tower. In general, the conditions in these towers from the biological point of view were not nearly so critical. The few natural draft towers which have been in service for the past 20 years or more, are still in a remarkable state of preservation. Because natural draft towers do not exhibit rapid loss of wood structure or strength as a result of attack by decay organisms, does not mean that decay is non-existent but rather it indicates that biological deterioration is not the limiting factor affecting the life of these towers.

The development of the mechanical draft tower has resulted in greater cooling efficiency. A smaller tower is required to supply the process with cooled water, and in addition these towers also give more reliable and uniform performance because they are not dependent upon wind velocity for their operation. Even though mechanical draft towers are more efficient than atmospheric towers, they impose a completely different set of conditions upon the wood. The general design of a mechanical draft tower is more conducive to biological and chemical attack than the natural draft tower. The drift eliminators, cell partitions, doorways, and the compact design of the mechanical draft towers create a greater number of areas where environmental conditions are ideal for the growth and development of objectionable microorganisms. In addition, the amount of water and air handled per unit area is higher and inoculation of the system with air borne organisms is at a greater rate.

TYPES OF WOOD DETERIORATION

Cooling tower wood is subject to three main types of deterioration: chemical, biological, and physical. It is rare when one of these types of deterioration is present without the other. In most cases, these different types of

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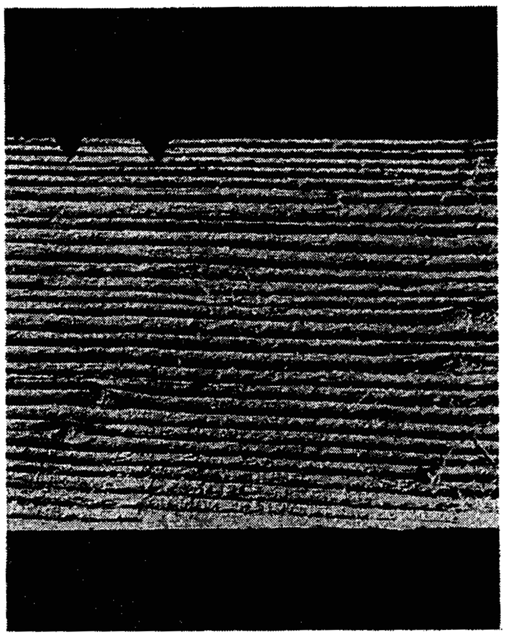


Figure 39-1 • Delignified Wood—Caused by Chemical Attack

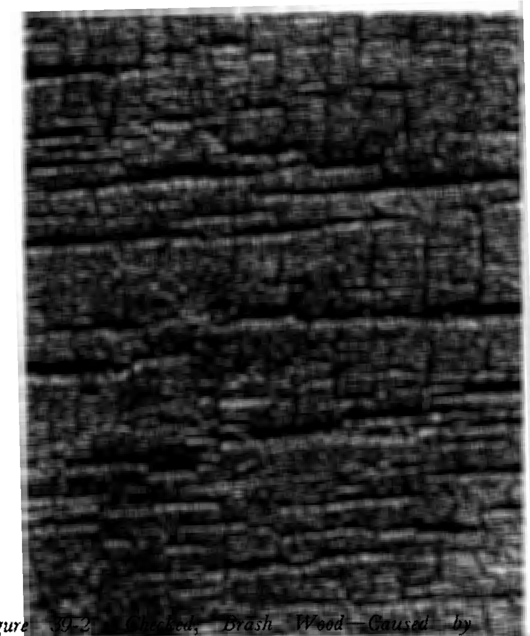


Figure 39-2 • Checked, Brash Wood—Caused by Biological Surface Attack

Figure 39-3 • Fibrillated Wood—Caused by Chemical Attack

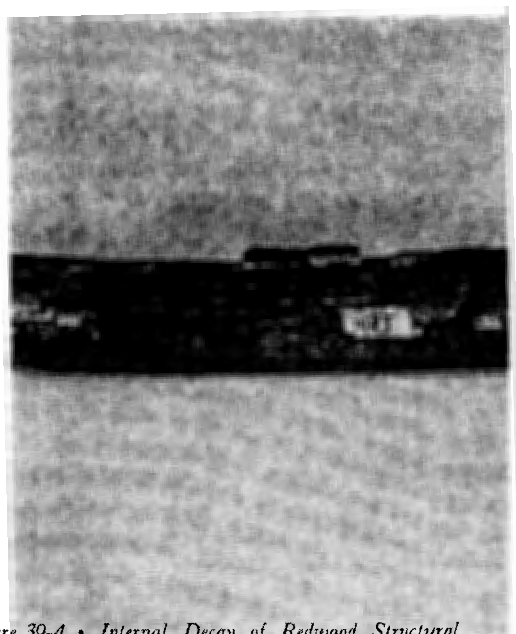


Figure 39-4 • Internal Decay of Redwood Structural Member Showing White Fungus Mycelium deterioration occur simultaneously. When deterioration occurs it is sometimes difficult to determine which type of attack is predominately responsible. However, it is evident that physical and chemical deterioration will render the wood more susceptible to biological attack.

CHEMICAL ATTACK. Chemical deterioration of cooling tower wood commonly is manifested in the form of delignification. Since the lignin component of the wood is affected and removed by this type attack, the resultant residue is rich in cellulose. The chemicals most commonly responsible are oxidizing agents such as chlorine, and alkaline materials such as sodium bicarbonate and sodium carbonate. The attack is particularly severe when the combination of high chlorine residuals and high alkalinity concentrations are maintained simultaneously.

Typically, the wood takes on a white or bleached appearance and the surface becomes fibrillated. This attack is restricted to the surface of the wood and the strength of the unaffected area is not impaired. However, severe thinning of the wood will occur wherever cascading water has an opportunity to wash away the surface fibers. In serious cases, the loosened fibers have caused plugging of screens and tubes, and have served as focal points for corrosion at areas where the fibers accumulate in heat exchange equipment.

Chemical attack most frequently occurs in the fill section and flooded portions of the tower where water contact is continuous. However, it will occur also in those areas where alternately wet and dry conditions develop—such as on the air intake louvers and other exterior surfaces. Chemical attack occurs also in the warm, moist areas of the plenum chamber of the tower as a result of chlorine vapors and the entrainment of droplets of tower water.

BIOLOGICAL ATTACK. Biological attack of cooling tower wood can be divided into two basic types—soft or surface rot and internal decay.

The organisms that are responsible for attack of cooling tower wood are those that can utilize cellulose as their source of carbon in their growth and development. Degradation of the cellulose is accomplished by the secretion of enzymes which convert the cellulose into compounds that can be absorbed by the organisms. The attack tends to deplete the cellulose content of the wood and leaves a residue rich in lignin. Characteristically the wood becomes dark in color and loses much of its strength. The wood may also become brash, soft, punky, cross-checked or fibrillated. The principal cellulolytic organisms isolated from cooling tower wood are primarily fungi, which include the classical wood destroyers (Basidromycetes), and members of Fungi Imperfecti. However, bacterial organisms that exhibit cellulolytic properties also have been isolated but their exact role in cooling tower wood deterioration is yet to be determined. The wood destroying organisms are common air and water borne contaminants, and are widely distributed in nature.

The classical *internal decay* is restricted generally to the plenum areas of the tower, such as cell partitions, doors, drift eliminators, decks, fan housing and supports. It is

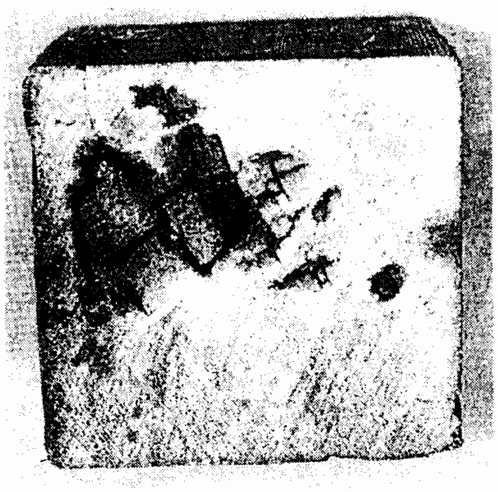


Figure 39-5 • Structural Member Showing Sound Outer Surface and Typical Internal Decay the more insidious of the two types of biological attack. It is characterized externally by an apparently sound piece of wood, which upon breaking shows severe internal decay. Because the decay is internal, it is difficult to detect in its early stages. Rarely is internal decay found in the flooded portions of the tower such as the fill section. In these sections, the wood is saturated completely with water which excludes oxygen from the interior of the wood. The lack of oxygen limits the growth and development of these organisms.

Soft or *surface rot* is found predominantly in the flooded sections of the tower but also occurs in the plenum areas. The water flowing over the wood surfaces in the flooded portions contains enough oxygen to support growth. Surface rot is detected more readily, and its effect is less severe than internal decay.

In addition to oxygen, moisture and temperature have a marked bearing. Locations where the moisture content of the wood range between 20 and 27% and temperatures range between 88 and 105 F, usually permit optimum growth and development of the organisms.

Physical and Other Factors. One of the major physical factors is the effect of temperature on wood. Wood technologists have long recognized that high temperatures have an adverse effect on wood. It is known that continuous exposure to high temperatures will produce gross changes in anatomical structure and will accelerate loss in wood substance. These resultant effects will weaken the wood and predispose it to biological attack, particularly in the plenum areas of the tower.

There are other factors which also have a bearing on the deterioration of tower wood. For example, areas adjacent to iron nails and other iron hardware usually deteriorate at an accelerated rate. These areas invariably lose much of their strength and the wood will crumble easily in the fingers. Slime and algae growths and deposition of dust and oil can all aid the growth and development of the soft rot organisms.

Preferential erosion of the summer wood is relatively common in tower fill. In severe cases of erosion significant losses of wood can result in very short periods of time. Extremely high concentrations of dissolved solids are to be avoided where there is opportunity presented for alternately wetting and drying of certain wood areas. While natural salts have been shown to possess little tendency to attack wood, crystallization of these salts in dry areas may rupture the wood cells.

CONTROL OF WOOD DETERIORATION

The only effective method of protecting operating cooling towers is to adopt a preventive maintenance program. The preventive measures for the flooded sections of the tower where attack of the chemical and biological types is limited to the surfaces of the wood are relatively easy to accomplish. The preventive measures for the non-flooded portions of the tower where internal decay is the primary concern are more difficult and the success of the program is largely dependent on adopting the necessary measures before infection reaches serious proportions.

Flooded Section. The control of chemical and biological surface attack of cooling tower wood in the flooded portions of the tower is a water treatment problem that requires:

1. Control of pH of the circulating water below 8.0 and preferably in the range of 6.0 to 7.0.
2. The use of non-oxidizing biocides alone for control of slime and prevention of biological surface attack.
3. Where chlorine must be used—chlorine should be restricted to 1.0 ppm or less and preferably in the range of 0.3 to 0.5 ppm. In addition, the supplemental use of a non-oxidizing biocide should be employed to control biological surface attack.

In order to minimize delignification, pH of the circulating water should definitely be maintained below 8.0 and preferably lower. Fortunately, most modern treatments for control of corrosion function best when pH is maintained around 6.0-7.0. This pH range corresponds to the range best suited for minimizing attack of wood.

Surveys have shown that in tower systems where non-oxidizing biocides alone are used for control of slime, surface attack is at a minimum. Accordingly, when it is economically feasible non-oxidizing biocides should be used in preference to chlorine.

Where chlorine must be used for control of slime it is necessary that chlorine be used judiciously. Undoubtedly, many of the systems that have shown rapid or excessive attack from the use of chlorine have lacked adequate control of chlorination. In many of these cases, the chlorine residual has been improperly determined, determined at the wrong point for proper control, not checked frequently enough or neglected entirely. In the majority of the systems using chlorine for slime control, the chlorine residual is checked (as it should be) in the water returning to the tower, not after the water cascades through the tower. The water in passing through the tower will have its chlorine residual decreased to very low values or depleted entirely. The reduction in chlorine residual occurs partially due to aeration but mainly through reaction with the wood. Where attempts have been made to control chlorine residuals after the water has passed through the tower, excessive chlorine residuals have been permitted to contact the wood and accelerated chemical attack has been the result.

In instances where intermittent chlorination has been practiced, initially the duration of the chlorination period and the rate of chlorination may have been established properly by testing for the chlorine residual. However, all too often, after initially establishing the rate and duration, infrequent or no further testing for chlorine residual is made. Since the chlorine demand of most circulating waters will vary, this practice has led to low residuals and poor slime control or to high residuals and excessive attack of the wood.

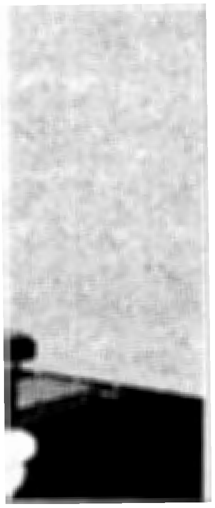
The prevalence of biological attack of cooling tower wood in systems using chlorination has led to the conclusion that chemical attack predisposes the wood to biological attack. In cases where carefully controlled chlorination has been practiced and chemical attack of the wood surfaces is low, studies have been conducted to check the incidence of fungi on the surfaces of the wood and in the subsurface sections. Microtome sections of the wood, such as that shown in Figure 39-8, reveal a high incidence of fungi in the wood from the fill and plenum areas of the tower. These studies indicate that chlorination alone is not effective in controlling the organisms responsible for attack of wood. The judicious use of chlorine requires low residuals be maintained. As the water cascades through the tower the residuals are depleted. The air-borne organisms can and do accumulate readily on the surfaces of the wood and grow and develop in the subsurface sections. Similar studies conducted for systems that use non-oxidizing biocides alone for slime control show that the incidence of fungi on the wood surfaces is negligible. Since these biocides do not react with the wood, they are able to penetrate the wood and effectively control the causal organisms. Accordingly where chlorination must be practiced the supplemental use of a non-oxidizing biocide is recommended to assure maximum tower life.

One standard procedure currently utilized to aid in minimizing biological attack in the flooded portions of the cooling tower requires adding a non-oxidizing biocide to the system approximately once every three months. The concentration of biocide used is in the range of 60 to 120 ppm. The purpose of this treatment is to kill the organisms that have accumulated on the surface and subsurface portion of the wood in the fill or flooded portions of the tower. Supplemental benefits are also secured in that the non-oxidizing biocide will carry down into the lower depths of the cooling tower sump where it is difficult to maintain a chlorine residual. Muck and debris accumulate in these areas and provide ample food for growth and development of microorganisms.

Figure 39-6 • Sectioning of Wood by Use of a Sliding Microtome

Figure 39-7 • Microscopic Examination of Cooling Tower Wood

Figure 39-8 • Microtome Section of Wood Showing Fungus Hyphae Growing through Wood Cells



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These areas serve as a point of inoculation, particularly for sulfate reducing bacteria. The supplemental use of non-oxidizing biocides serves to eliminate this point of infection.

In many cases, it is possible to use a variety of treatment programs which combine the use of chlorine and a non-oxidizing biocide. Where a combination program is possible, chemical attack can be held to a minimum and biological attack can be controlled effectively.

It should be evident that if the makeup water is taken from a stream, river or other surface supply that is not pretreated or clarified, high bacteria counts can enter with the makeup water. In addition, these sources of makeup water usually contain organic matter and other contaminants that serve as food for bacteria as well as increase the chlorine demand of the water. Where water of this type is used, the slime potential is usually heavy and continuous chlorination to a free residual is generally necessary. To minimize the amount of chlorine that contacts the wood many plants have adopted the practice of chlorinating the makeup to secure a total bacteria kill and to minimize bacteria food entering with the makeup. Under these conditions, the slime potential will be substantially reduced and an intermittent chlorination program can be adopted for the circulating water alternating weekly or biweekly with the use of a non-oxidizing biocide.

The adoption of these measures will effectively minimize attack of wood in the flooded portions of the tower and will also aid in minimizing surface attack in the plenum areas of the tower.

Non-Flooded Section. The preventive maintenance program for the non-flooded or plenum areas of the tower requires:

1. Thorough periodic inspections
2. Replacement of damaged wood with pressure treated wood
3. Periodic spraying of the plenum areas with fungicides.

A thorough inspection of the cooling tower should be conducted at least once per year and certainly more frequently if a preventive maintenance program is not in use.

Although soft rot or surface attack occurs in the non-flooded portions of a tower, the effect on loss on wood structure is not as severe as in the flooded areas. This is due primarily to the fact that the wood is not subject to erosion by cascading water. The principal and most serious problem in the non-flooded area is internal decay. When internal decay is restricted to white pocket rot, the affected areas can be very small and easily missed. As a general rule internal decay is detected usually only after extensive damage has occurred. It is very important to look for signs of internal decay in structural members. This is sometimes revealed by abnormal sagging or settling of the wood. When obvious decay is not evident, it is advisable to secure samples of the wood for microscopic examination to determine whether the internal areas of the wood are infected with fungi.

Replacement of infected wood is necessary to retard spread of infection to adjacent sound members. A weakened section will cause additional weight load to be shifted to sound sections of the structure. These in turn may crack under the increased load and become more susceptible to spread of internal decay. The infected wood should be replaced with pressure treated wood. Several different wood preservatives are available as well as a choice of wood species. Willa discusses a seven year study of eight different pressure treatments. On the basis of incidence of internal decay the treatments can be listed in the following order of effectiveness:

1. Creosote
2. Ammonical Copper Arsenite
3. Acid Copper Chromate and Copper Naphthenate
4. Chromated Copper Arsenate
5. Pentachlorophenol
6. Fluoride Chromate Arsenate Phenol
7. Chlorinated Paraffin

Periodic spraying with an effective fungicide is the third essential step in an effective preventive maintenance program. The purpose of spraying the plenum areas with a fungicide is to render the wood resistant to spread and growth of wood destroying fungi. Diffusion of fungicide into the wood at best permits penetration of the wood to a depth of 1/16″ to 1/4″. The degree of penetration is dependent on the preparation given the wood and to some degree on the concentration of fungicide sprayed. The objective is to spray a sufficient concentration of fungicide so that the wood remains fungistatic until the next semi-annual or annual inspection and spraying.

WOOD EXAMINATION

Since several types of wood deterioration are possible in cooling towers, physical inspections along with periodic laboratory examinations of wood samples should be scheduled regularly. In this connection, service laboratories are equipped with specialized equipment to determine all of the important data needed to comprehensively evaluate the condition of tower wood.

Microscopic examination of the wood reveals the degree of grooving, erosion, surface structure and depth of surface attack. Specimens are broken to determine whether the wood is brash, and the degree of brashness as well as apparent loss in structural strength are recorded. Macroscopic study reveals the physical aspects of the wood, whether or not chemical and/or biological factors are present and, if so, to what extent. Figures 39-1 to 39-3 inclusive demonstrate some of these physical characteristics that are helpful to fully evaluate the condition of cooling tower wood.

Microtome studies of wood cells, as shown in Figures 39-6 to 39-8, are of assistance in determining the extent of microbiological deterioration. These microtome sections are usually 25 microns in thickness, and permit viewing of the internal structure of the wood. This examination indicates to the analyst the extent of infection, and whether the infection is due to bacterial or fungal activity. From this study of the wood cells, the microscopist determines whether any fungi present are cellulolytic (wood destroying) or simply fungus organisms.

The most beneficial test when evaluating cooling tower wood is commonly known as the zone of inhibition test. This test determines the relative penetration of any fungicidal agent employed and the degree to which this material is present. Also determined is the susceptibility of the wood to support fungal growth and to become decayed if inoculated with wood destroying organisms.

Briefly described, the zone of inhibition test consists of placing two ½ inch squares of the wood specimen on nutrient agar previously seeded with a wood rotting organism, such as Aspergillus niger or Chaetomium globosum. The plates are then incubated for seven days at 28 C. After the elapsed incubation period, the plates are evaluated for their degree of protection or susceptibility.

A complete zone of inhibition exists when no fungal spores of the test organism are present in a clear zone around the test block. This preventative barrier against fungal infection develops when the effects of a fungicidal application are still present in the wood and inhibit the growth of wood rotting organisms.

A partial zone of inhibition is one which shows some growth of the test organism around the block, but the growth of fungal spores of the test organism is retarded. This partial zone indicates that some residual fungicide or natural inhibitory properties are still present in the wood.

No zone of inhibition is exhibited by a specimen of low resistance, so the growth of the test organism or other organisms inherent in the wood occurs around the block. This growth indicates that the wood is susceptible to fungal attack. Corrective measures must be taken in order to control the spread of fungus in the sound members of the tower.

Figure 39-9 shows two of the conditions that aid the analyst in determining whether or not inhibitory power from a preservative treatment or from the natural property of the wood is at an effective level. This zone of inhibition test may be used to evaluate the residual effect of fungicidal treatment or the degree of resistance restored by an application of fungicide.

METHODS OF SPRAYING

The most effective method of spraying is the direct or manual method. This method is very similar to painting in that the concentrated fungicide is applied directly to the wood by the use of spraying equipment handled by an operator or team of operators. This method of application proves most effective since small areas can be covered thoroughly by the fungicide, and special attention can be given to spraying the joints, holes and other access points into the wood.

Direct spraying can be hazardous unless proper precautions are taken to protect the operator. Figure 39-10 shows an operator properly equipped. He is clothed in air-fed coveralls with the legs secured with tape at the ankles. The outer clothing consists of a rain suit. The rubber gloves are vulcanized to the sleeves of the suit and the legs are secured to the arctics with tape at the ankles. The sandblaster's hood is in place and its air feed can be seen from the rear. The air-fed coveralls and sandblaster's hood permit the operator to stay cool and comfortable while spraying.

OTHER METHODS

In order to decrease labor costs and to further minimize the hazards of direct spraying other methods have been considered. Steam spraying through a permanent piping arrangement has been used. In this procedure the fungicide is forced into the steam and is transported into the cell by the steam. It is essential that the distribution piping be designed properly in order to secure complete coverage. The use of steam causes dilution of the fungicide and compared to direct spraying a relatively dilute solution contacts the wood. As a result the quantity of toxicant that penetrates the wood is smaller and more frequent spraying is necessary to maintain the wood fungistatic.

Recently a revised method of spraying the plenum areas of cooling towers has been introduced. This new method is designed to minimize the hazards and high cost of direct spraying while maintaining its major advantage, namely: spraying of a concentrated solution of fungicide so that the frequency of spraying will be required only once or twice per year. Pneumatic spraying with a portable rig equipped with an atomizing nozzle similar to that shown in Figure 39-11 is used. The rig is inserted through holes in the deck of the tower so that spraying can be accomplished from outside the tower.

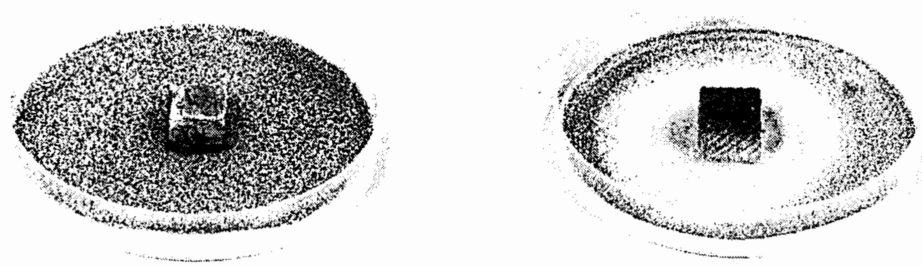

Figure 39-9 • Test Blocks of Wood on the Surface of Inoculated Nutrient Agar. The Block on the Left Shows No Resistance to the Test Organism. The Block on the Right, which has had Fungicide Spray Treatment, Shows a Clear Zone of Inhibition

Diffusion and spray methods are limited for the most part to penetration of the outer surfaces of redwood. Therefore it is essential

Figure 39-10 · Direct Fungicide Spraying by Properly Equipped Operator

that preventive maintenance be started before infection takes place and preferably before the interior parts of the wood lose much of their natural resistance. Under these conditions new infection can be prevented and the life of the tower extended. Where the tower has undergone a serious degree of infection and it is likely that infection cannot be contained by following the normal preventive maintenance program, then consideration can be given to sterilization of the wood by elevating the temperature of the internal portions of the wood to 150 F and maintaining this temperature for two hours.

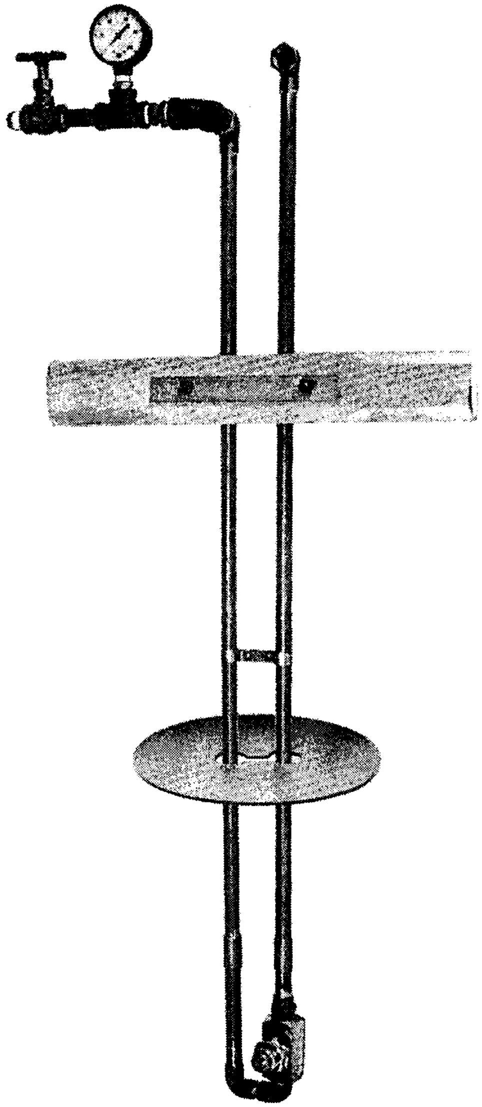

Figure 39-11 · Portable Rig for Pneumatic Spraying

REFERENCES

W. A. Dost, "Certification of Redwood and Effect of Oxidizing Agents on Redwood in Cooling Tower Service", *Proceedings*, Engineers Soc. of Western Penna., pp. 77-83 (1959)

B. F. Shema, "Clarification of Cooling Tower Wood Deterioration", *Proceedings*, Engineers Soc. of Western Penna., pp. 69-74 (1959)

Unpublished data, Betz Laboratories, Inc., Phila., Pa.

J. L. Willa, "Report On Field Wood Preservation Studies", *Proceedings*, Engineers Soc. of Western Penna., pp. 83-96 (1959)