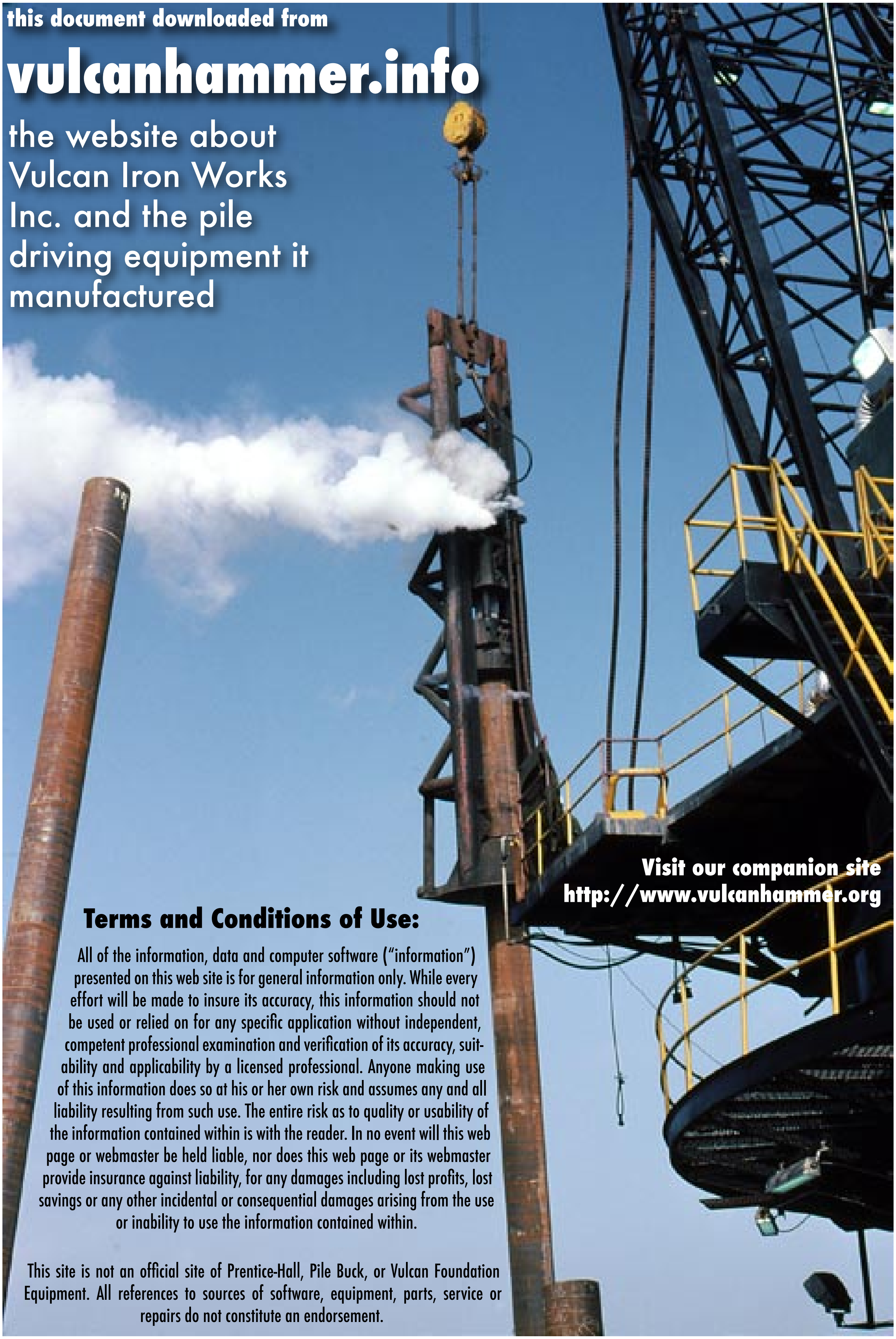

this document downloaded from

vulcanhammer.info

the website about Vulcan Iron Works Inc. and the pile driving equipment it manufactured

Visit our companion site
http://www.vulcanhammer.org

Terms and Conditions of Use:

All of the information, data and computer software ("information") presented on this web site is for general information only. While every effort will be made to insure its accuracy, this information should not be used or relied on for any specific application without independent, competent professional examination and verification of its accuracy, suitability and applicability by a licensed professional. Anyone making use of this information does so at his or her own risk and assumes any and all liability resulting from such use. The entire risk as to quality or usability of the information contained within is with the reader. In no event will this web page or webmaster be held liable, nor does this web page or its webmaster provide insurance against liability, for any damages including lost profits, lost savings or any other incidental or consequential damages arising from the use or inability to use the information contained within.

This site is not an official site of Prentice-Hall, Pile Buck, or Vulcan Foundation Equipment. All references to sources of software, equipment, parts, service or repairs do not constitute an endorsement.

Revised

FABRICATION OF PRESSURE TREATED WOOD FOR BRIDGE AND PIER FENDERING SYSTEMS

James S. Graham, PE
American Wood Preservers Institute
446 Park Avenue
Rye, NY 10580

ABSTRACT

Pressure-treated wood is the most commonly used bridge and pier fendering material due to its availability, durability, flexibility, impact strength, and economy. This paper describes the manufacturing process of pressure-treating Southern Yellow Pine, Douglas Fir, and Oak to engineered design specifications for use as a protective system in various types of coastal bridge and pier structures in the Northeast United States.

INTRODUCTION

When traveling along the coastal areas of the Northeast United States, one fact stands out; pressure-treated wood is the material used most often in waterfront construction, especially for bridge and pier fendering systems. Perhaps its use is best given in the following quotation: (1)

> Wood is the most commonly used fendering material due to its high fiber strength and hardness, its resilience, its relative abundance and low cost. Whenever wood is used in the marine environment, it must be protected by some treatment preventing borer, termite, and ant attack as well as reducing the abrasive effects of sand, silt and ice.

Wood is a renewable resource. It uses very little of our high-cost energy in the process from a tree in the forest to the finished product, a marine fendering system. And, there is a plentiful supply of trees! In fact, one half of the United States is still covered with forests, and recent replanting procedures have renewed the supply of trees at a faster rate than the demands of harvesting. ENR often publishes the current demand for wood products (2).

Most of the wood used in fendering systems is domestically grown and pressure treated. Pressure treatment extends the expected life of wood to about 50 years along the New York and New England coasts (3), where marine borers attack, especially the limnoria tripunctata, is not so severe as it is in the more Southern waters.

This paper is an outline of how pressure-treated wood is manufactured for use in bridge and pier fendering systems. The purpose of the report is to acquaint specifying engineers with the manufacturing process and thus enable them to be more proficient in their work. It is not intended to be a how-to-specify text. Each job is different and must be handled separately.

LUMBER, TIMBER, AND ROUND PILING

The three most commonly used species of wood for fendering systems are Southern Yellow Pine, Douglas Fir, and Oak. The specie of tree is selected depending on its end use, availability, and cost. For example, Southern Yellow Pine is the wood most often used in marine construction on the East Coast. It is readily available, treats well, and will last for years. Douglas Fir is used where large members are required, usually bigger than 16" by 16" and longer than about 30 feet. Oak is often specified where boats will rub up against the structure.

Round piling is supplied in accordance with ASTM Designation D-25 which lists diameter and length in Tables 1 and 2, and gives the size of allowable knots, shakes, splits, etc. (4). The lengths and dimensions given in D-25 are not always available locally, so contact your local AWPI member company for information (5). Generally, Southern Yellow Pine piling (SYP) is available in lengths from 15 to 80 feet, with tip diameters of 7, 8, and 9 inches and butt diameters (3' from the butt) of 8, 9, 10, 11, 12, 13, and 14 inches; Douglas Fir lengths generally go up to 125 feet with 7", 8", and 9" tips and the butt diameters, 3' from the butt, are 12", 13", 14", and 15". Oak is available in lengths of 15' to 60', with tip diameters of 4, 5, and 6 inches and butts (3 feet from the butt) of 10", 11", 12", and 13" diameter.

Round piling is pressure treated in accordance with AWPA Standard C-3, Piles-Preservative Treatment by Pressure Process (6), using Creosote, waterborne salts, and Pentachlorophenol. The exception is that Penta can only be used in fresh water, since it is soluble in salt water. AWPA specifications for SYP require that 20 pcf of Creosote and 2.5 pcf of waterborne salt be retained in salt water installations and 12 pcf of Creosote, 0.80 pcf of waterborne salt and 0.60 pcf of Penta in fresh water conditions. (See table 1.)

The AWPA is considering lowering the retention requirements for marine piling to 20 pcf of creosote in the outer 1/2 inch zone and 14 pcf in the next 1-1/2 inch zone; and 1.5 pcf of CCA in the outer 1/2 inch zone and 1.0 pcf in the next 1-1/2 inch zone. The engineer should always check with current AWPA standards when writing job specifications.

Saw-cut timber walers, struts, and other supporting members of a typical East Coast bridge and pier fendering system are usually constructed from Southern Yellow Pine, i.e., Longleaf, Slash, Shortleaf, or Loblolly, which is grown in the Southeastern states from Maryland to Texas. The timbers are specified by two methods: either according to the Grading Rules of the Southern Pine Inspection Bureau (SPIB), Pensacola, Florida (7), which provides stress rated quality, or by a bending stress value, or both. For example, the specification may be Southern Yellow Pine, rough, No. 1 Dense Stress Rated (SR). This is a grading rule classification, which calls for 1550 psi in bending. Or, the specification may simply state the bending stress of 1100 which is equal to No. 2 Stress Rated (SR) timbers. Not-Stress Rated Timbers are usually not used in fendering systems.

The Southern Pine Timbers are usually treated in accordance with AWPA Specification C-2, Lumber, Timbers, Bridge Ties, and Mine Ties-Preservative Treatment by Pressure Process (8). Other specifications are used, such as AASHTO for highway bridges or AREA for railroads; however, they always refer to the AWPA Standards and have an additional drawback in that they are not always kept up-to-date. The timbers are treated with 25 pcf of Creosote for material subject to marine borer exposure and 10 pcf of Creosote or 0.50 pcf of Penta in fresh water exposure. Sometimes 16 pcf of Creosote is used in brackish water.

For timbers larger than about 16" dimension, Pine is unavailable and Pacific Coast Douglas Fir is often used. The fir is grown in Oregon, Southern Washington, and Northern California. Douglas Fir is classified in accordance with the Standard Grading Rules for Western Lumber published by the Western Wood Products Association (WWPA), Yeon Building, Portland, Oregon, 97204 (9), and also the West Coast Lumber Inspection Bureau (WCLIB). Douglas Fir can be specified using a given stress level, for example, 1750 psi for Dense Select Structural Posts and Beams, but more often the stress level is at 1500 psi for Select Structural Post and Beams and 1550 psi for Dense No. 1 Beams and Stringers.

Since Douglas Fir lumber and timbers consist mostly of heartwood, it must be incised prior to treatment. Otherwise preservative specifications are the same as previously given for Southern Yellow Pine. (See table 1.)

The timber sheathing and other "rubbing" members are specified as rough red or white Oak. A bending stress of 1900 psi is sometimes specified for beams and stringers. This specification has been taken from an obsolete circa 1940 edition of the "Rules for the Measurement and Inspection of Hardwood and Cypress Lumber", issued by the National Hardwood Lumber Association, PO Box 34518, Memphis, TN, 38134 (10).

Since suppliers can no longer guarantee the hardwood bending stress, the recommended practice is to use what is currently available. Often suppliers will furnish Sound Square Edge Oak in accordance with current Hardwood Association rules.

The mixed red and white Oak are usually treated to 6.0 pcf or 7.0 pcf of Creosote, and 0.30 or 0.35 pcf of Penta in fresh water and to refusal with a minimum of 10.0 pcf of Creosote in material subject to marine borer exposure, in accordance with AWPA Standard C-2. A recent trend has been to incise the Oak prior to treatment.

Lumber, planking posts and railing, and other "lighter" wood members are usually constructed from Southern Yellow Pine, using Select Structural grade down to No. 2 or better (SPIB) and treated with Chromated Copper Arsenate (CCA). Some engineers specify a final retention of from 1.0 to 1.5 pcf in coastal marine environments. These members are normally only subject to salt-water splash zone effects, therefore, they do not require the 2.5 pcf recommended by AWPA C-2 for material subject to marine borer exposure but <u>do</u> require more than the 0.40 pcf designated for "soil contact". The 0.40 pcf is often used on inland waterways. Waterborne salt treatment is preferred for this application since a clean, non-skid surface is required for the maintenance walkways.

According to Chellis (3), creosoted timber piles have a life expectancy of 50 years on the New York and New England coasts, however, framing and boring should be done prior to treatment insofar as possible. Marine borers may find the entrance through untreated holes, proceed to the untreated interior of the wood where they progress rapidly, leaving only the creosoted outer fibers a mere shell. For that reason, fabrication prior to treatment, as much as possible, is the recommended practice for timber fendering systems.

PRESSURE TREATMENT

The species of wood used in the construction of fendering systems must be processed by various methods to enable it to receive preservative treatment. Southern Yellow Pine is steam conditioned for Creosote and Penta preservative and dried in a kiln to 19 percent maximum moisture content for waterborne salts. There are exceptions. It is not always necessary to steam condition Southern Yellow Pine when it is to be treated with creosote or penta preservative. It depends on its moisture content. It can be air dried. On the other hand, heavy timbers of Southern Pine, for example 6x6s and 10x10s, are not dried to a moisture content when they are treated with waterborne salts. A heavy timber with lots of sapwood would probably be kiln dried until the moisture content is 30 percent or less at a depth of 2 to 3 inches from the surface. The two pressure-treatment processes are dissimilar. Steam conditioning of pine is a requirement that enables the wood to absorb Creosote and Penta with a minimum (about 15 percent) loss of strength. Steam conditioning has another advantage by sterilizing the pine and preventing any possible decay prior to treatment. Kiln drying is required so that the metallic salts such as Chromated Copper Arsenate (CCA) or Ammoniacal Copper Arsenate (ACA) can penetrate the wood using water as a carrier.

Steam conditioning is performed in the same cylinder but prior to the Creosote and Penta treatments. The pine material to be treated is placed on a tram car and pushed into the cylinder over narrow gauge railroad tracks. The cylinder doors are fastened shut and about 240 degrees Fahrenheit of steam heat is applied to the closed system A good rule of tumb is to steam one hour for each inch of thickness plus an hour. This gets the center of the timber hot so that the material is conditioned throughout the cross-section. When finished conditioning, the excess water is forced out of the cylinder.

At completion of the conditioning process, pine is pressure treated, either by the Full-Cell or Empty-Cell method (11). The Full-Cell, or Bethell process, is used by all waterborne salt treatments, no matter where it is used in construction and for creosote to be used in coastal marine applications. The Empty-Cell process is applicable to fresh water installations of bridge fendering systems where less Creosote-preservative is required. Both the Full-Cell and Empty-Cell methods follow almost the same procedures. A preliminary vacuum is drawn on the charge to about 28 inches of mercury for some two to three hours. At this point, however, the procedures differ somewhat. In the Full-Cell method, the cylinder is next filled completely with hot creosote. For marine structures, this will sometimes be specified as a solution of 70 percent Creosote and 30 percent Creosote-coal tar solution for Southern Yellow Pine in accordance with AWPA P-12 (12). However, in the "Empty-Cell" method, 30 psi air pressure (Rueping process) is added prior to the injection of the preservative oil. This air becomes trapped in the wood and after treatment is completed, helps push the preservative out, leaving only a coating of preservative on the cell linings. During the treatment process, Creosote is kept at about 180 psi of pressure and at about 200 degrees Fahrenheit (not to exceed 210 degrees Fahrenheit) for five to six hours for marine structures, or about two hours for fresh water fenders. A final vacuum is then applied to clean the surface of the wood and withdraw excess oil from the empty-cell method.

Douglas Fir usually is not steamed because it is susceptible to damage from heat. It is "Boultonized", i.e., boiled in oil under a vacuum. "Green" fir is placed in a treating cylinder and covered with hot creosote. A vacuum is gradually applied and the fir then is boiled in oil at temperatures up to 220 degrees Fahrenheit. The preservative treatment process then follows the Full-Cell, Empty-Cell methods similar to those used for pine.

Oak, however, is usually stacked and allowed to air-dry prior to treatment. This is the normal procedure for standard size creosoted railroad ties and treatment with waterborne salts. On construction jobs, however, time is of the essence and oak for fendering systems must be treated green. It is usually Boultonized as described above for fir. Since most of the oak used in the Northeast comes from Pennsylvania and New York, it is sometimes treated in the same cylinders as Southern Yellow Pine. (But not at the same time.) One procedure is to apply air pressure in two stages, at 40 psi for about four hours, released, after which 30 psi of air is applied for three hours. After the second application of pressure, air is allowed to escape, the oak is placed under a vacuum for about one hour and then pressure treated with creosote to refusal, similar to the Southern Yellow Pine treatment.

As previously mentioned, Southern Yellow Pine usually is kiln dried prior to treatment with waterborne salts, but it is not a requirement. Douglas Fir is often treated with ACA without kiln drying. (Oak is generally not treated with salts.) This procedure, i.e., kiln drying, is done in two to three days in accordance with the U. S. Department of Agriculture's Handbook No. 188, Dry Kiln Operators Manual (13). Care must be taken not to damage the wood since Southern Yellow Pine, for example, is reduced from about 85 percent moisture content to an average of

15 percent for 2 inch thick lumber (maximum of 19 percent). Kiln temperature for Southern Yellow Pine will build up to 200 degrees Fahrenheit dry bulb and finish at 230 degrees F. Good stacking practices are important in kiln drying to prevent the lumber from warping. To insure proper control of drying conditions in the kiln, both temperature and relative humidity must be accurately measured, using two thermometers, one recording temperature in the usual way (dry bulb) and the other kept wet with a wicklike cover (wet bulb). Since evaporating water has a cooling effect that increases if the air if dryer, the "wet bulb" records a lower temperature. The difference between dry and wet bulb is a measure of the relative humidity in the kiln. If not large enough, the wood will take too long to dry; if too large a difference between dry and wet bulb, the wood will dry too rapidly, resulting in checks, splits, shakes, and warping. The temperature is raised as fast as is permitted to 200 degrees Farenheit, dry bulb, and the wet bulb drops to about 150 degrees. This results in an excellent quality of

material from the dry kiln. After drying, it actually takes only two hours to treat Southern Yellow Pine and eight hours to treat Douglas Fir to 0.40 pcf of waterborne salt preservative. Higher retentions, up to 2.5 pcf, are achieved by using a higher solution concentrate. After first pulling a vacuum for one-half to one hour, the waterborne salt pressure treatment process is done at ambient temperature, i.e., no heat is added as was for the oilborne preservatives. For Southern Yellow Pine, the treatment pressure is 150 psi to 160 psi; for Douglas Fir it is about 130 psi. The wood is treated to refusal, the pressure released, and a final vacuum pulled for 30 to 45 minutes as in a typical empty-cell method. The excess preservative is then drained off and recirculated back into the storage tank. The pressure-treated wood is usually allowed to dry prior to shipment. If time and temperature permit, it is air dried, if not, then kiln dried.

After pressure treatment, with wood preservatives, the material is tested for conformance with AWPA Standards (see table 1). For Oak, the amount of preservative in the wood is measured by gages during the treatment process. However, this "gage" method allowed too much chance for human error in pine and fir, so the "assay" methods was standardized. Simply stated, this means testing after treatment with chemical analysis to insure a more uniform system of quality control. Small plugs of pressure-treated wood are taken with an incremental borer, usually about 0.20 inch diameter and, as deep as required in AWPA for the assay. Southern Pine marine piles, for example, are assayed to a depth of 3 inches for creosote retention and to 3.5 inches or 90 percent of the sapwood for creosote penetration. Twenty boring are taken from each and every charge. about five inches long. The plug is then analyzed in accordance with AWPA standards. This testing is usually performed by the treater, however, outside testing agencies are often required by the design engineer to certify the testing was done in accordance with appropriate contract documents (14).

INSTALLATION

Probably the most important factor in determining the expected life of a pressure-treated wood fendering system, other than damage from ships and barges, is the method by which the contractor treats his field cuts. For example, many of the tops of treated piling can be observed to be hollowed out by decay. Also Chellis (3) reports that when borers obtain access to the interior of a pile through bolt holes, etc., destruction takes place rapidly. This hollowing out by decay and marine borer attack occurs because the center, or heartwood, of a round piling is comprised of wood that will not accept a preservative pressure treatment.

Insofar as is practicable, all adzing, gaining, incising, surfacing, or trimming should be done prior to treatment of any fendering system. This is to insure that fabrication work will not expose any untreated wood that will be susceptible to decay, especially in material subject to marine borer attach. Unfortunately, however, only about 10 percent of the fabrication work can be done at the plant prior to treatment since exact field measurements are nearly impossible to determine for fender systems. Therefore, field workmanship is critical.

It is recommended that field cuts be treated with preservative in accordance with AWPA Standard M-4. When the original preservative is not available, off-the-shelf products are often used. Marine epoxies are gaining popularity for covering the end cuts of round piling. They are mixed and applied in layers to a final thickness of about 1/4 inch. (Marina owners are using liquid Lifecaulk on piling tops.) (15)

Bolt holes drilled in the field should be filled with preservative. A pressure device once was available to do the job; however, it was dropped from the manufacturer's product line some 10 years ago.

CONCLUSIONS

Pressure-treated wood provides an economical and long-lasting method of protecting bridge and pier structures in the coastal marine waters of the

Northeast. Properly designed and constructed treated wood fendering systems should last about 50 years without replacement. Engineers should specify according to AWPA Standards to insure that the lumber, timber, and piling has been properly pressure treated. Southern Yellow Pine is the most often used wood species in fendering systems on the East Coast. Douglas Fir is used for larger members. Oak is used where large ships will rub against the wood fenders.

Southern Pine must be steam conditioned prior to treatment with oilborne preservatives, i.e., Creosote and pentachlorophenol, and kiln dried for waterborne salt treatment with Chromated Copper Arsenate (CCA). Douglas Fir is "Boultonized", i.e., boiled in oil under a vacuum prior to pressure treatment with oilborne preservatives and kiln or air dried prior to treatment with Ammoniacal Copper Arsenate (ACA). Oak can be treated with Creosote or penta, but it must be air dried for about one year prior to treatment with waterborne salts.

Since limnoria tripunctata are not present in the Northeast, Creosote by the "full-cell" process is the most often used preservative in coastal marine waters for wood structures in bridge and pier protective systems. Penta and waterborne salts are used for walkways, CCA with pine, and ACA with fir. For protection of small recreational boats, wood for the "rubbing" surface is often treated with salts.

Installation procedures are critical to the expected life of a pressure-treated wood fendering system in coastal marine waters. Wood borers will rapidly destroy the untreated interior of piling if access holes are provided during construction. As much as possible, adzing, boring, chamfering, etc. should be done prior to pressure treatment. Field cuts, bolt holes, etc. should be treated in accordance with AWPA Standard M-4.

The purpose of this paper has been to familiarize design engineers with the specifications and manufacturing processes for pressure-treated wood use in fendering systems that protect the numerous bridge and pier structures along the coast in the Northeast United States. The American Wood Preservers Institute (AWPI) will be glad to provide any technical assistance required on future fendering systems.

REFERENCES

1. Kenneth N. Derucker and Conrad P. Heins. _Bridge Protective Systems and Devices_. New York: Marcell & Dekker, 1978.

2. "Depressed Lumber Prices Hold Index to 2.4% Annual Gain". ENR, December 18, 1980, p. 85.

3. Robert D. Chellis. _Pile Foundations_, 2nd ed. New York: McGraw-Hill, 1961.

4. "Standard Specifications for Round Timber Piles". ASTM D25-79, Annual Book of ASTM Standards, Part 22, Wood; Adhesives. Philadelphia, Pa.: American Society for Testing, 1980, pp. 23-26.

5. *a/e CONCEPTS in wood design*, No. 33, Directory Issue Oct-Dec, 1980. McLean, Va.: American Wood Preservers Institute.

6. "Piles--Preservative Treatment by Pressure Process", C3-80. Bethesda, Md.: American Wood Preservers' Association, 1980.

7. "Grading Rules". 1977 ed. Pensacola, Fl.: Southern Pine Inspection Bureau, 1977.

8. "Lumber, Timbers, Bridge Ties, and Mine Ties--Preservative Treatment by Pressure Process", C2-80. Bethesda, Md.: American Wood Preservers' Association, 1980.

9. "Grading Rules for Western Lumber". Portland, Or.: Western Wood Products Association, 1978.

10. "Rules for the Measurement and Inspection of Hardwood and Cypress Lumber". Memphis, Tn.: National Hardwood Lumber Association, 1978.

11. George M. Hunt and George A. Garrall. *Wood*

Preservation, 3rd ed. New York: McGraw Hill, 1967.

12. "Standard for Creosote-Coal Tar Solution to be used in the Treatment of Marine (Coastal Waters))Piles and Timbers, P12-68. Bethesda, Md.: American Wood Preservers' Association, 1980.

13. "Dry Kiln Operator's Manual", Agriculture Handbook No. 188. US Dept. of Agriculture, Forest Service, US Govt Printing Office, Washington, DC. Stock No. 001-000-00690-8/Catalog No. A 1.76:188.

14. "Selection, Production, Procurement and Use of Preservative-Treated Wood, Supplementing Federal Specification TT-W-571". Madison, Wi.: US Dept. of Agriculture, 1977.

15. Clint Chamberlain via telephone conversation of 1 Oct 81, Box 6159, Beaufort, NC.

Table 1
AWPA Standards

Product	Penetration (inch)	Assay zone (inch)	Retention: Creosote (pcf)	Retention: Penta (pcf)	Retention: Waterborne salts* (pcf)
Fresh Water					
Lumber, timber & plywood					
pine	2.50	0 to 0.60	10	0.50	0.40
fir <5" thick	0.40	0 to 0.60	10	0.50	0.40
fir >5" thick	0.50	0 to 0.60	10	0.50	0.40
oak <5" thick	white oak = 95% of sapwood	gauge or weight	07	0.35	0.40
oak >5" thick	red oak = 65% of annual rings		06	0.30	
Round piling					
pine	3.0	0 to 3.00	12	0.60	0.80
fir	0.75 to 1.60	0 to 1.00	17	0.85	1.00
oak	100% sapwood	0 to 2.00	06	0.30	NR
Marine (salt water)					
Lumber, timber & plywood					
pine	2.50	0 to 0.60	25		2.50
fir <5" thick	0.40	0 to 0.60	25		2.50
fir >5" thick	0.50	0 to 0.60	25		2.50
oak	white oak = 95% of sapwood red oak = 65% of annual rings	gauge or weight	10		NR
Round piling					
pine - creosote	4.00	0 to 3.00	20		
pine - waterborne salts	3.50	0 to 0.50 (Zone I) 0.50 to 2.00 (Zone II)			2.50 (Zone I) 1.50 (Zone II)
fir - creosote					
<2" sapwood	1.00	0 to 1.00	20		
>2" sapwood	1.75	0 to 2.00			
waterborne salt	"do"	0 to 1.00			2.50
oak	100% sapwood	0 to 2.00	10		NR

*Ammoniacal Copper Arsenate (ACA) and Chromated Copper Arsenate (CCA)