DEPARTMENT OF FORESTRY · CANADA ·

FOREST PRODUCTS RESEARCH BRANCH

WOODEN MARINE PILING

Transcript of Symposium
Held at the Vancouver Laboratory
on June 25, 1963

Compiled by
G. BRAMHALL
Vancouver Laboratory

DEPARTMENT OF FORESTRY PUBLICATION NO. 1044

1964

Published under the authority of

The Honourable Maurice Sauvé, P.C., M.P.

Minister of Forestry

Ottawa 1964.

Transcript of the
Symposium on Wooden Marine Piling

Held at the Vancouver Laboratory,
Forest Products Research Branch,
Department of Forestry

June 25, 1963

Prepared by: G. Bramhall,
Vancouver Laboratory.

Table of Contents

Introduction

Dr. J.A.F. Gardner, Superintendent, Vancouver Laboratory, FPRB.

This symposium is the result of the efforts of a task-force consisting of A.L. Paterson, Plant Superintendent of Timber Preservers Ltd.; K.B. Dundas, Regional Manager, Canada Creosoting Co.; A. Webster, Assistant to the District Engineer, B.C. and Yukon District, Department of Public Works of Canada; and G. Bramhall, Research Officer, Vancouver Laboratory, Forest Products Research Branch.

The task-force was set up to investigate failures of marine piling in B.C. coastal waters, and to make recommendations which would result in increased life of wooden piling in marine construction.

The purpose of the symposium is to present to those involved in marine construction information on the use of wood, its advantages and disadvantages, how it should be handled, and what practices should be avoided in order to build an economical structure with a long service life.

The program has been drawn up to present first a discussion of marine borers, the cause of most of the difficulties in marine construction. Then papers follow on the characteristics and selection of marine wooden piling, construction practice from two points of view, and on under-water inspection of wooden piles. The program closes with a look into the future on what new developments may be expected in making better piling for marine use.

The speakers today are all experts in their field. What they have to say is the result of their own personal experiences. After each address there will be an opportunity for questions and for discussion.

We hope you who have already shown your interest by coming will make good use of this opportunity presented by having so many knowledgeable people gathered in one place, and present your problems to them for discussion.

MARINE BORERS IN B.C. COASTAL WATERS

Dr. D.B. Quayle, Pacific Biological Station,
Department of Fisheries, Nanaimo, B.C.

My main task this morning is to lay a foundation or a biological background for the succeeding speakers; to give an idea, for those who may not be too well acquainted with these animals, of what these animals are like. To some of you it may be old hat, but you will have to bear with me.

The marine borers that we have in British Columbia belong to two main groups--the Crustaceans, which are allied to insects, crabs, shrimps; and the Mollusks, allied to the clams and oysters, which most of you know very well. The main molluscan animal with which we are concerned is one belonging to the family Teredinidae, hence the general appellation teredo for most shipworms.

Bankia

Shipworms generally all belong to the family Teredinidae--hence the name Teredo as applied to the individuals of the groups. But there are several genera within the family. The genus Teredo is the commonest and most widely spread genus. It is not, however, as yet represented on the B.C. coast. Our species is Bankia setacea although we also have Xylophaga. In 1958 I picked up Teredo navalis in Willapa Harbour. Its previous known northern distributional limit was San Francisco Bay. I would venture to predict that it may be only a matter of time before we have it in Georgia Strait for certainly the necessary ecological conditons exist here.

To return to Bankia and to set the stage for the succeeding speakers, here are the salient features of its biology.

1. It is a bivalve mollusc and has two shells like a clam.
2. The shells are modified to form wood rasps with the muscular adaptations necessary to perform the task of rasping.

3. It has all the other anatomical features of a normal bivalve mollusc such as a clam, with a blood vascular system, nervous system, gill apparatus and siphon or neck.

   (a) The digestive system is modified to permit utilization of some wood fractions as food but it can also feed on plankton, the normal food of most bivalve molluscs.

   (b) The neck or siphons are modified to permit water and waste passage through a relatively small opening between the burrow and the outside water. There is a further modification in the form of calcareous feathers or pallets which permits the animal to stop up tightly the burrow entrance.

4. Growth is relatively fast. It appears that few Bankia survive past about two years.

5. Breeding. There are male and female Bankia and the eggs and sperms are discharged freely into the surrounding water where fertilization takes place. To permit an adequate level of fertilization, mass spawning involving numerous animals must take place. This usually involves some method of stimulus. External fertilization also implies extremely large numbers of eggs. For example an oyster produces up to 500 million. Bankia will produce about the same order of magnitude. After fertilization, there is a larval development with a free swimming period. The length of the period is probably between 10 and 20 days, long enough to permit considerable dispersal. There is high mortality but this is compensated for by the large number of eggs produced.

   At a specific larval size, settlement occurs, initially by means of a byssal thread. Teeth develop rapidly and the animal is soon buried.

Breeding Period

There have been a number of studies to determine the breeding season in B.C. waters and the fact that none are in complete agreement is not surprising. Two reasons are responsible.

1. This type of coastline produces a wide range of ecological conditions not necessarily associated with latitude or proximity to the open ocean.
2. Bankia setacea is relatively a low temperature breeder, hence it has greater latitude in breeding time than a high temperature breeder in these latitudes. Low water temperatures occur more readily and for longer periods than high temperatures. It is suspected that shallow water populations breed in fall and spring while deep water (below the thermocline) populations may breed in summer as well as at other seasons. 12°C. has been mentioned as an upper limit to Bankia breeding.

At any rate, breeding may occur at all times of the year to a greater or lesser degree at one level or another.

The breeding season needs to be determined for each locality and each depth. This may not be exactly the same each year or at the same intensity. More analytical study is required on this phase of life history. The B.C. Research Council's test block program is yielding important information. Long-term observations are essential.

Limnoria

Limnoria, also known as the gribble or pinworm, is an isopod crustacean. It is a very small animal not exceeding five millimetres in length. What it lacks in size it makes up for in numbers.

The body is made up of three regions: the head, thorax and abdomen. The head holds six appendages among which are the mandibles, the main organs used for boring. The thorax is made up of seven segments each of which bears a pair of jointed legs. In the female, brood pouches for holding eggs are formed on the second, third, fourth and fifth sections during the breeding season. The abdomen consists of six sections, five of which carry flat appendages called pleopods which are used for swimming and respiration. The last segment of the abdomen is the telson on which are located the main characteristics for species identification.

Food

Limnoria is capable, by means of cellulolytic enzymes, of attacking cellulose and is thus able to utilize wood as a food, but many aspects of Limnoria nutrition are still in the realm of controversy.

Growth

L. tripunctata can grow 1 mm. in length during the five summer and fall months. Growth is slow during the winter. Death occurs in early winter of the second year. Females are larger than the males.

Reproduction

There is usually a male and a female in each burrow with the latter at the blind end apparently doing the active burrowing. Pairing by the same animals may last for several months. Males usually migrate first and establish the burrow. Animals of the same species occur together. There is no evidence of interspecific breeding.

After fertilization, large yolky eggs are deposited in the brood pouch formed from plates arising from the inner base of thoracic legs two to five. The eggs develop within the brood pouch for about three to four weeks and the young, about one mm. in length, are released as fully formed animals.

L. lignorum produces a maximum of 35 ova with a mean of 22; L. quadripunctata produces a maximum of 17 ova with a mean of 9.5; L. tripunctata produces a maximum of 22 ova with a mean of about seven. Several broods may be produced on one season. The minumum ovigerous temperature for L. lignorum is about 5°C.; for L. quadripunctata above 10°C. and for L. tripunctata, above 15°C.

Migration

There is no planktonic larval stage, so dispersal must occur through transport by floating wood or by swimming. The migratory stimulus is still uncertain. In Europe the maximum migration precedes the maximum reproductive period. Menzies and Johnson suggest over-population as the migratory stimulus, i.e., following intense breeding activity.

Boring

The body is held in position by the legs and claws with those of the first three legs directed backwards and the other four are directed forward. The actual boring is carried out by the assymetrical mandibles. A rasp and file mechanism is suggested. The head can be buried within 24 hours but may take four to six days to be completely enclosed, but this is very variable. The deepest burrow is about one inch from the surface, limited by the need for adequate water circulation for respiration.

General Biology

1. A salinity of 10 parts per thousand is lethal to all species after about 10 days.
2. Each species can exist on 4 hours immersion in 12.
3. The greatest concentration of L. lignorum occurs in deeper waters.
4. L. tripunctata is best adapted to intertidal conditions.

5. In B.C. there seems to be no L. tripunctata settlement between August and April and settlement is not significant until May when surface temperatures range between 10° and 15°C. There is slight activity in L. lignorum through the winter. At Kyuquot the greatest attack by L. lignorum occurs during the period between mid-February and mid-May.

Until May, 1961, we in British Columbia had every reason to congratulate ourselves as being the possessor of only one species of gribble, pinworm, or Limnoria when we looked at California with three species, one of which was a creosotophile. Our own species, Limnoria lignorum, was a nuisance to be sure, but it could be lived with and there was always creosote for protection. But the finding of L. tripunctata at Crofton in May, 1961, shattered the complacency with regard to the gribble menace. All authorities do not look upon L. tripunctata as a separate species, but regardless of its taxonomic status it is certain we are dealing with two different entities. My own feeling, because of significant and constant morphological characters, associated fauna (Falliculina and nematodes) and occupany of separate, or at the best overlapping ecological niches, is that these are two good and distinct species.

Normally, the extension of the range of this animal from San Francisco to Crofton would have excited little more than academic interest, for new distributional records are continually being found. However, the fact that this animal is a wood borer and that it bores into creosote treated timber, at least in semi-tropical waters, removed it immediately from the realm of the academic. Few areas in the world have such a wealth of exposed widely distributed structures as British Columbia, as witness the relative difficulty in obtaining samples of Limnoria in the state of Washington.

This distributional record immediately raised two important questions:

1. Is it indigenous or is it a recent introduction and does it occur only in the Crofton area?
2. Is it as destructive in B.C. conditions as it is reputed to be in semi-tropical waters?

The first question could have been most easily answered by reference to early collections of Limnoria but a reasonably exhaustive search failed to disclose any. If anyone here has a piece of Limnoria-infested wood, from bygone days with a date, I would be glad to have it. This is a serious reflection on our system of recording our fauna and flora and its changes. The alternative indirect method was to determine the distribution of the animal in B.C. to see if this would provide a clue. Accordingly, samples of infested wood, both creosoted and uncreosoted were obtained from many areas between Oregon and the Queen Charlotte Islands. To date, over 10,000 animals contained in 112 collections have been examined and identified.

The results of this survey indicate:

1. L. tripunctata is widely though not continuously distributed throughout Georgia Strait.
2. So far it has been found only two areas outside of Georgia Strait and these are Sooke and Sarita in Barkley Sound.
3. It apparently occurs in areas of relatively high summer water temperatures.

These, in B.C., Washington and Oregon are in turn associated with the culture of the Japanese oyster C. gigas and with the exception of the Sarita sample, the correlation has been perfect, although even here the mechanism for its introduction into Barkley Sound is known.

It may be tentatively concluded from these data that because of its wide distribution, the animal has been in British Columbia waters for a considerable time. The discontinuous distribution would lead one to believe it is not indigenous, for native species usually have, within limits, a fairly continuous distribution. Follow up studies will be required to determine whether the distribution has stabilized.

The correlation between the occurrence of L. tripunctata and the Japanese oyster has been mentioned and the obvious question arises as to its significance. About 14 other marine invertebrate species have been added to our fauna through the mechanism of oyster seed imports. Since Limnoria tripunctata occurs in Japan it is not unreasonable to suppose this could be a possible source. Certainly the mechanism for the transfer is there.

An alternative place of origin is obviously California. It would be expected, however, that if our L. tripunctata were derived from there, we would also have Limnoria quadripunctata whose ecological requirements, particularly that of temperature, are much more suitable for British Columbia conditions than L. tripunctata. This is demonstrated in the following table. In addition, the mechanism for transport is not nearly so obvious as in the case of a possible Japanese origin.

Table I

Temperature and Limnoria

Species	Minimum ovigerous temp.	Mean Sea Water Temp.	Area
Limnoria lignorum	Above 7.5°C.	5° - 10°C.	North Atlantic and Pacific
Limnoria quadripunctata	Above 10°C.	12° - 16°C.	California
Limnoria tripunctata	Above 15°C.	16° - 28°C.	Atlantic and Pacific

Table II

B.C. Area	Mean Annual Sea Water Temperature	Range °C.
Cape Mudge	10.3	6.7-14.0
Amphitrite	10.3	7.5-13.1
Race Rocks	8.9	7.4-10.8
Entrance Island	11.1	6.8-17.0
Departure Bay	11.2	6.5-17.8
East Point	9.2	7.2-11.6
Ladysmith Harbour	11.5	9.6-20.5
Pendrell Sound		8.8-22.1

Table III

Summer Sea Water Temperature	Characteristics--Selected Areas
Cape Mudge	Above 15°C. for 5 - 10-day periods
Chrome Island	Above 15°C. for 3 months
Departure Bay	Above 15°C. for 3 to 4 months
East Point	Not above 15°C.

These are only theories and will remain so until samples of Limnoria from some time back can be found. This search is continuing.

The second problem regarding the destructiveness of *L. tripunctata* to creosote-treated timber in British Columbia waters is still unanswered. It is the experience in collecting the survey samples that both species are equally tolerant to what would appear to be low levels of creosote concentration. In every case in the collection of samples there had been mechanical breaks in the creosote-treated timbers. However, I am departing from biology here and the sample survey was not specifically designed to answer this question. Others may speak of the studies designed for this objective.

DISCUSSION PERIOD AFTER DR. QUAYLE'S ADDRESS

Dr. Gardner: We have a few minutes for discussion. Any question?

Dr. P.C. Trussell, B.C. Research Council: Dr. Quayle, you mentioned three distinct areas on our coast as having L. tripunctata. The Strait of Georgia, Sarita, and what is the third?

Dr. Quayle: Sooke.

Mr. J.A. Rennie, B.C. Forest Products, Crofton: I have one that was remarked upon in "Tidelines" in 1962. With regard to the attack of Limnoria lignorum on creosoted piling, can Dr. Quale or anyone at the Research Council answer this one? Have they found L. lignorum attacking creosoted piling readily or only in cases where the creosote has been leached out over a period of years in the water?

Dr. Quayle: I am immediately concerned in collecting samples, and I always found that either L. tripunctata or L. lignorum were most easily found in creosoted piling where there had been an injury of some sort or another. I reached the point where I did not even look at piling where there was no injury. Certainly both species are into lightly treated wood. Under the microscope and assuming that colour is a very rough guide to the intensity of creosote--certainly they are in lightly coloured wood, both of them.

Dr. Trussell: I might add a bit to that, Mr. Rennie. On the samples from Crofton referred to at that time, which were the first picked up on the coast, they were in fairly dark wood. Now light and darkness does not mean too much so far as creosote is concerned. Many of the fractions are light and possibly many of the fractions that are toxic are light, so that one can be misled on the matter of the darkness of the fragments. I don't see as many specimens around the waterfront as I used to because I don't get around, but I have seen samples of fairly freshly creosoted piles at Ketchikan that have had Limnoria etching on the outside. The Limnoria had not penetrated to any depth. These would be piles of not more than say three years of age. They still had that sort of glossy creosote surface.

Mr. Rennie: With regard to the Deep Sea Dock, Research Council is studying that. L. tripunctata is actually into it now, about three-sixteenths of an inch. I believe that the count is 60 of the L. tripunctata to 40 of L. lignorum, and what I was actually interested in is if anyone had found any cases like that with straight L. lignorum without any association of L. tripunctata.

Dr. Trussell: Some samples I brought down from Ketchikan proved to be L. lignorum. Apparently they had caused some etchings, but no penetrations and essentially no damage.

Dr. Gardner: Any other discussion or questions?

Mr. Rennie: Here is another one. There should be a gentleman here who can answer this one. The length of time exposure to Limnoria tripunctata before the destruction of piling in our local waters. Now I might point out that while there is no definite proof, Research Council did a study of the dock. The dock was supposed to have been reconstructed in 1949 and I believe Mr. Allen over there can confirm the fact that many of the piling were absolutely useless within fourteen years. Now can someone give me the answers on the life of piling under the influence of tripunctata?

Mr. Bramhall: We have many records--in fact one of my jobs over the last several years has been to establish service records of wharves and marine structures in B.C. And because there were a few failures, particularly the Department of Public Works at Port Alberni and Westview, we became particularly interested in marine borers on the coast. With respect to Limnoria, as you have just mentioned, you have approximately a 50-50 attack of L. lignorum and L. tripunctata attacking your wharf at Crofton. Now L. lignorum has been around for a long, long time and because it has been around for a long time, and because some wharves have been in service for up to fifty years in British Columbia, that is, the piling has been in service for fifty years, it would raise a question of whether L. tripunctata or L. lignorum or any other particular species is responsible for those failures that occur. I am pointing out that it may be a defective treatment, or it may have been injury in driving or it may have been one of several other things that I hope will be discussed today. Therefore to associate a particular marine borer with such and such a length of time life of a creosoted piling--I think it would be rather meaningless at this stage. There is the question of how well it was treated and until we can establish that, I think it is not very profitable to discuss it. I hope before the day is out that your question will be answered and probably you can bring it up towards the end of the day if it isn't. We might discuss it better then.

Dr. Quayle: At Lasqueti Bay a creosoted timber held one hundred L. lignorum in the sample that I extracted, and eleven L. tripunctata. In an uncreosoted timber a few feet away, seven L. lignorum and sixty-nine L. tripunctata. A very queer distribution. It indicates there is a very great deal of work to be done on the biology of these species and on treatment.

Dr. Gardner: I think that we had better push on. No doubt this afternoon we can return to some aspects of this paper by Dr. Quayle. Your questions will occur to you as the whole program develops. The next paper is by Mr. J.M. Gurd, Vice-president of Production, Timber Preservers Limited in New

Westminster. He is going to speak on "The Selection and Treatment of Marine Piling". Mr. Gurd has a long history in this industry, and is well known to all of you, no doubt. Mr. Gurd.

SELECTION AND TREATMENT OF MARINE PILING

Mr. J.M. Gurd, Vice-President,
Timber Preservers Limited, New Westminster, B.C.

Species

In the Pacific Northwest, and in particular the Province of British Columbia, are several species of timber which might be thought to be suitable for piling.

Western Red Cedar, although entirely suitable for use as a transmission and distribution pole, is not sufficiently strong for use as a pile. Yellow Cedar, as it is known commercially, has sufficient strength but is not found in sufficiently large quantities in the sizes and lengths required in construction. Both types of cedar resist the penetration of preservatives almost entirely in the heartwood, and although the sapwood of red cedar is relatively easy to treat, the yellow cedar is not. In any event, the average thickness of sapwood does not ordinarily exceed one-half inch in red and usually less in yellow.

Western Hemlock is abundant in the area and in quantities and sizes entirely suitable for the purpose. Its strength is less than that of Douglas fir, but for many uses this would not be too significant.

The sap ring is usually of satisfactory depth and the heartwood can be penetrated in a fairly satisfactory manner under controlled conditions of pre-treatment and treatment techniques. Unfortunately, the results to date have been rather unsatisfactory despite a great deal of experimentation and research by a number of people and over a period of several years.

The unsatisfactory results of treating round hemlock are generally thought attributable to non-uniformity of moisture content throughout the piece. The areas of relative impenetrability, small though they may be, produce after treatment an unevenly penetrated stick which in use may be likened to the weak link in a chain. Because of the changing nature of logging and too, of natural reforestation, Western Hemlock is becoming a predominant species and Douglas fir is becoming less obtainable. This statement is not to be construed as a problem which industry and consumer face in the immediate future, but it is a slow, inevitable transition in our forest resources.

In summary, then, for the purposes of today's use as a marine pile, hemlock is not satisfactory.

In the coastal areas are other species, as the spruces and pines, which may be suitable, as is particularly the case with the latter for poles and for other purposes but there are insufficient quantities of a size and length to meet the needs.

Douglas Fir abounds in most of the coastal areas in quantities, lengths and sizes suitable for the use intended. Douglas Fir is plentiful too, throughout the Province and provides a major source of construction material.

The wood-preserver is faced, unfortunately, with a problem which as yet is unresolved, despite the many approaches to a solution from a great many highly qualified wood preservers and wood technologists. Pacific Coast type Douglas Fir is commonly described as the trees growing in an area lying south of an imaginary line projected from Hope to the Coast in the vicinity of Prince Rupert. Fir growing out of this hypothetical area is known as intermountain fir, mountain fir or Inland Empire fir and is comparatively hard to treat. Actually, there is no real cut-off from the Coast easy-to-treat, to the mountain hard-to-treat, but rather a gradual change from one to the other. It is not known what causes the refractoriness of some types but it is commonly thought to be associated with the number of "valves" permitting the flow of liquids from one wood fibre to another. Marine piling must therefore come from and belong to, the group of relatively easy-to-treat, as mentioned, and classed as Pacific Coast Douglas Fir. Fir from other areas is entirely suitable for uses as railroad ties, poles and structural purposes, other than in marine works where good uniform treatment is essential. This statement applied equally to the structural members associated with the piling.

Storage

It is customary for a wood preserving plant to purchase or produce from its own timber resources or both, sufficient quantities of piling in ranges of size and length to fill any normal requirement. Dependent on the size of the plant and its volume of sales, inventories will range from 10 thousand to 20 thousand pieces. Perhaps the one most difficult problem is to anticipate the next year's requirements as to length, so as to have reasonably suitable quantities on hand and not be left with unwanted items for too long a period.

Round Douglas Fir material varies substantially in the time required to treat with creosote or creosote solutions from about 12 hours in the case of thoroughly dry material, to times in excess of two days in the case of green or freshly-cut material. As the cost of treatment is made up of the raw material, the preservative and the cylinder hours required to provide the proper treatment, and as this latter is substantial due to the capital cost of plant, it is desirable to treat in as short a period as may be practicable. Most usually, a short time elapses between the placement of a customer's order and his required date of delivery which makes it necessary to carry dry stocks. Piles stored in a yard must be stacked on treated skids above ground and properly stripped for seasoning. Weeds and grass are not permitted around the untreated piling stocks because of fire danger and to permit the material to dry under sanitary conditions. The stacks are limited as to height because of the crushing caused by too great a weight on the bottom pieces.

Piling may be carried into the storage yard and placed in stacks by a great variety of mechanical devices. Some plants carry the material from the receiving end, or the peeler, with pneumatic tyred cranes. Others use carriers similar to lumber carriers which straddle the loads, locomotive cranes running on steel rails by overhead cable equipment, or by a great variety or combination of vehicles. Similarly, the material is later taken from the seasoning stack and moved to the treating plant cylinders.

The proper seasoning time must be related to the climatic conditions at the time. Because of excessive rainfall and snow which make the logging inoperable from about December to March and sometimes later in the year, procurement must take place during the balance of the year. Due to normal logging practices and other considerations, the inward flow to the plant is greatest in the fall months.

It is common during the spring or summer, to have a forest closure because of hazardous fire conditions for one or two months. This disorganizes the production operations and it takes several weeks after the closure is lifted, to get the material once again moving into the plant.

Treating plants located on the Fraser River have another problem to contend with, when the river freshet or period of excess flow from the north, makes the towing impossible. This period usually extends from May to August, and so the plant must try to get sufficient stores "up-river" prior to the onset of freshet to keep his plant going during this period.

It is not uncommon for the river to freeze over from the mouth upstream, which renders traffic impossible for a month or so in the winter months. A treating plant grows accustomed to all of these problems and learns to live with them, but these matters do interfere in some cases with the plant's operating costs and his ability to give the buyer the delivery he sometimes requires for his treated piles.

The storage period referred to, therefore, varies considerably as stated, dependent on the receipt of the goods and the climatic conditions following. Generally speaking very little seasoning, if any, takes place during the winter months and the greatest seasoning is from the month of April forward to September. As the rate of drying is highest with a combination of warm winds and relatively high temperatures, fresh cut piling received in April, if and when this occurs, may check rather badly and render a fair number unsuitable for the purpose. It is probably most advantageous from all aspects, to put the piles in the yard from September on, so that some drying at a lower rate will permit the spring and summer drying to take place without too drastic results.

Procurement

Occasionally (once or twice in a lifetime) a phenomenal occurrence such as the hurricane Freida comes along and develops unnaturally large quantities of round forest products which must be removed almost at once for many reasons, but generally the supply of Pacific Coast Douglas fir piling are secured in a number of other ways.

Vancouver Island and the Gulf Islands are probably the source of the largest quantities and then the mainland areas up the coast from North Vancouver north. The piling contractors in these areas are generally of substance, owning their own equipment and able to finance their operations without too much difficulty. The Fraser River Valley from New Westminster to Hope produces a fair quantity of suitable material, but generally, the producers operating in these areas are very small. After making a deal with the owner of the timberlands, they usually hire the services for falling, making and carting. It is not unusual for the treating plant operator to arrange with the several parties involved to deduct from monies owing on the delivered piling, the stumpage and/or royalty, the cat-hire, the logging truck hire, the cartage or towing account and arrange for the insurance in transit. The buyer makes an allowance if the producer hand-peels his piling to specification at such times as the "sap is running" or the bark is easily removed in situ. When the bark is tight on the tree, it is usually found to be too expensive for the operator to peel and this is done at the plant. Winter-cut piling when hand-peeled, often leaves small areas of inner bark which retards the distribution of preservative.

On the other hand, some of the larger companies engaged in logging are willing to sort out the piling type of material and sell at a premium price over that of logs. The breakage in handling with the usual logging equipment, booming-ground sorting problem, and the oft-changing requirements of the saw-mill and the pulp mill generally results in a rather spasmodic supply from this source. Most treating companies try to secure stands of re-growth crown timber and either log this itself, or contract the logging.

The late Chief Justice Gordon Sloan engaged by the Provincial Government in 1945 to survey the forest resources and inquire into all aspects of the continuing supply of logs for all purposes, recognized the problem facing the treating plant operator, if regulations were not imposed to provide a supply, in continuity and in perpetuity of piling and pole material. The Honorable Chief Justice recognized also, that a properly conducted program of thinning or cropping of the young growth would provide the greatest benefits to the economy of the forest industry.

Some experimental thinning operations have been conducted by a few companies in this regard, but it is to be hoped that Government will continue to recognize the problem and take the appropriate steps for the future.

It is usual for a treating plant to publish its own specification for piling, but they generally agree in most matters. There are differences of opinions among operators concerning some items such as whether they will permit one-half turn of spiral in 20 feet or one turn in forty feet, which on the face seems to be the same thing, but some think the former more restrictive. Some purchase on measurements obtained at the extreme butt-end and some at a point one foot or three feet from the butt.

The Department of Public Works of Canada, the Public Works Department of British Columbia, the Railroads and a number of other users, have their own specifications which as stated, although similar, do contain various differences, so that the wood preserving plant attempts to purchase from the producer within a specification which will permit him to meet all requirements.

The Canadian Standards specification CSA-056-1962, which we recommend, is one which should be quite satisfactory to the user.

The wood-preserving plant is frequently called on to provide technical assistance and guidance to the producer in the woods preparatory to the actual making of the piles. Proper and efficient manufacture is an art and unless properly instructed or thoroughly knowledgeable, the result is unsatisfactory and wasteful.

Preparation for Treatment

Piling may be received at the treating plant on railroad cars, trucks, barges, tows, consisting of flat-rafts fastened together similar to logs either in bundles or strung together with wire cables or chains. If unpeeled, they then proceed through a peeling machine to remove the bark and knots. They are then graded according to size and length and if necessary, trimmed to remove excessive bends or other defects. The butt-end is then stamped with the symbols designating the class size and length and carried away to the seasoning yard. At this juncture of operations a list is kept by the grader, including the supplier's name, log-mark, original length and final length, together with reasons for cutting-back or culling. This tally then provides the plant with the basis for payment and the Forest Service with the necessary data on which they assess the amount of stumpage and royalty. The piling grader is an authorized Government scaler.

Mechanical peeling not only removes the bark and leaves the knots flush with the surface, but as the cutters cut across the grain of the wood the surface is more readily treatable. The cutting action also reduces the checking which subsequently develops in seasoning.

Treating

For use in the coastal waters of British Columbia which are infested in varying quantities with the shipworm Bankia, and the surface attacker known as the limnoria, it is necessary to find a satisfactory preservative which will stay within the wood over long periods because it is not soluble in the sea water and is poisonous to these attacking agencies. Creosote oil is probably the best known preservative for this use and is available in the required quantities at all times. Most of the creosote used in Canada is produced in Canada. However, because of our geographical location in relation to the steel mills, the plants in British Columbia import their oil from Great Britain.

Creosote oil is a liquid embodying a large number of different components produced in the destructive distillation of coal. This operation usually takes place in conjunction with the production of steel which uses the coke formed by the still, and the gases driven off during the operation are of significant commercial value for heat and light. The residual creosote oil as stated, is made up of a series (approximately 162 components) of such things as napthols, cresols, phenols, and others which when properly blended, make up an oil of very high toxic value and is relatively insoluble. The specification for quality of creosote is very closely checked and the Preservatives Committee of the American Wood Preservers is carefully and constantly reviewing the specifications to ensure an oil of the highest quality and permanence. It has been well established that suitable Coast Douglas Fir piling when properly treated with creosote to the correct retentions, is eminently satisfactory and to date there appears to be nothing better.

Over sixty years ago some piles were wrapped in sheets of Muntz metal which evidently have satisfactorily withstood the marine borers to this date. Unfortunately this material is too expensive to be used today. Other methods of pile protection employing bandages of tar, concrete collars, driven copper nails and an infinite variety of coatings and sheathings, are constantly being reviewed, and in some cases, tested by immersion.

The wood preserving industry and its parents, the Canadian Standards Association and the American Wood Preserving Association, is very much alive to its responsibilities to its customers and will never stop in its attempts to improve the quality of impregnants and the methods of treatment.

During the last forty years the wood preserving industry in British Columbia has supplied approximately 200,000 pieces of piling for marine installations. In addition, large quantities of creosote treated piling were brought in from the United States during boom construction periods. It is recorded that during the past 20 years, approximately

150,000 pieces of creosote treated marine piles have been installed.

The cost of a treated piling in place must take into account such matters as the cost of the raw pile, the preservative and quantity of same, the treating cost, the transportation to site and pile driving and related matters, and the nature of the super structure. The owner, of necessity, must consider such matters with a view to replacement costs and the problem of obsolescence after an anticipated use.

In considering the quantity of creosote oil to specify for his marine piling, if there should be uncertainty due to lack of advice on the incidence of borer attack in a particular area, the owner might like to consider this suggestion. If a 12 lb. per cubic foot treatment is compared with a 14 lb., the additional cost of the oil alone will add about six per cent to the cost of the raw pile, but this additional cost is only a fractional per cent in the total price in place and ready to support its intended load.

Service records and the continuing authoritative studies by committees and by the Pacific Biological station will usually provide adequate data through the wood preserving plant on which the owner or his engineer can specify the precise details of his piling requirements. If he should be in doubt, he can obtain the very best of information in this and related matters from the Wood Preserving Division of the Vancouver Laboratory, Forest Products Research Branch of the Federal Department of Forestry.

The C.S.A. who collaborates with the A.W.P.A. in specification writing for preservative treatments, will provide the engineer with all the necessary details covering all matters including the Standard Methods of Analysis of Preservatives; Determination of Penetration; Treatment Processes; and Inspection. These specifications are described as C.S.A. 080-1962 with amendments thereto as required and subject to revision at least once a year.

These specifications are very comprehensive and set out the limits of time, heat, vacuum, pressure and other matters, so as to provide the treating plant with a guide and the purchaser with the best possible quality of material. They are readily obtainable for one's own use, by corresponding with either of the aforementioned organizations.

For those who may wish to obtain texts on the subject, the best known and most comprehensive book on the subject is "Wood Preservation" by Hunt and Garratt. A highly authoritative text is "Preservative Treatment of Wood by Pressure Processes" written by J.D. MacLean of the U.S. Forest Products Laboratory. The American Wood Preservers' Association publish a "Manual of Recommended Practice", embodying all the specifications herein mentioned. Many other fine treatises and technical publications are available and one of the best obtainable is the "Protection of Wooden Structures in B.C. Waters" by G. Bramhall of the Vancouver Laboratory, Forest Products Research Branch, Department of Forestry.

Selection of Treatments

As stated herein, practically all of the piling for marine use in this Province are treated with creosote oil. Following will be described the methods and techniques of plant operations, but the owner must first decide on the quantity of preservative he feels is suitable for the intended use. The minimum permitted by any authority for marine use is 12 lbs. which means 12 lbs. of oil in each cubic foot of wood in the pile. The quantity is determined by actual measurements of each top and butt and the application of the prismoidal formula to find the cubical contents.

As stated, most authorities and specifications permit a minimum of 12 lbs. but recommend 14 lbs. or 16 lbs. for severe service conditions. The tendency today is to use 14 lbs. and 16 lbs. for severely infested waters.

The penetration, and hence the retention of the preservative, must be continuously black and concentrated with both springwood and summerwood penetrated. It is a phenomenon in the Douglas Fir wood structure that the summerwood or harder annual growth rings are more readily penetrated; if the process is not properly carried out, the result will be an uneven so-called "Barber-pole" treatment unsuitable for the use. The trade name for the concentrated, juicy black treatment is known as "full-cell".

Treating Plant

An up-to-date wood preserving plant may have one or more treatment cylinders usually ranging in diameter from seven to eight feet and from a hundred to a hundred and seventy-five feet in length. This cylinder is designed to withstand high internal vacuums and as well, pressures up to 200 or more pounds per square inch. This cylinder is serviced from the outside storage tanks through a "working tank" of sufficient size to completely fill the cylinder after load to be treated is in place.

The piling are loaded on steel trams in the treating plant yard and conveyed into the cylinder on rails after which the big hinged cylinder door is closed and bolted in place. Some treatment cylinders have one door and others a door at each end, so that when one load is pulled out, another enters.

At this stage, the oil is dropped from the working tank and is heated to approximately 200°F. A vacuum is started at the same time. The effect of the vacuum is to lower the boiling point of the water within the wood which has to be withdrawn and consequently the wood is subjected to lower temperatures than would otherwise be the case.

If the piling to be treated is thoroughly air-dried as described elsewhere, this heating and vacuum period, referred to as conditioning, is of short duration, but if the material is wet, the process must be continued for a considerable time.

Following the conditioning period, creosote oil is pumped from a measuring tank into the treatment cylinder with a constantly rising pressure up to the prescribed maximum (this may not exceed 150 lbs. per sq. inch) and after sufficient time has elapsed to have actually pressed into the wood the calculated quantity of oil, with sufficient additional to compensate for any "kick-back" due to the release of pressure.

The next and final step is to exhaust the cylinder of oil and usually apply a vacuum of short duration, sufficient only to clean off the surface of the piles of any surplus dripping preservative.

The piling are then pulled from the cylinder and unloaded from the trams for inspection and acceptance for the purchaser. The treating plant, regardless of any other inspection, does its own inspection by sampling each piece in the cylinder load for conformity to the specifications. This is usually done by boring a minimum of one hole and preferably four, around the periphery of each piece and at the midpoint in the length. Such borings provide all the information necessary to determine the depth of penetration on the retention of preservative. These inspection holes are then filled with a very tightly driven, treated plug.

The owner frequently employs an independent inspection agency who is qualified to inspect and report on his goods. Such investigations will include a sampling and testing of the preservative used and copies of the automatically recorded treatment conditions including the quantity of oil.

As a 14 lb. treatment requires a treated ring of 7/8 inch in depth and as any unnecessarily severe handling may puncture this, thus exposing untreated wood to borers, reasonable care must be exercised in the handling of piling from the plant to the job and in position. Sharp-pointed tools used to roll or position the pieces should be avoided except at the ends and holes bored in the pile, of necessity for bracing, etcetera, should be treated where possible, with a portable treating device. Similarly, the freshly cut butt end must be properly treated and capped to prevent the entry of rot. All of these matters are adequately covered in the specification manuals referred to.

The capital invested in a wood preserving plant, equipped to treat long marine piling will vary, of course, according to the length, size and number of cylinders, but all of the equipment required to handle and treat on the basis of a one cylinder plant would approximate two million dollars. In addition, the inventory of piling stock of suitable proportions to meet moderate needs and delivery schedules, would account for approximately another quarter million dollars.

DISCUSSION PERIOD AFTER MR. GURD'S ADDRESS

Mr. W.M. Dierden, Elk Falls Co.: Is infection by Ambrosia beetles of a piece of timber otherwise suitable for piling cause for rejection?

Mr. Gurd: This question perhaps would have to be referred to specifications covering the purchase of the raw material itself. The attack by Ambrosia beetles so far as we are concerned on the exterior of the pile is not a cause for rejection.

Question: Mr. Gurd, to clarify the remarks with reference to burning, fire-resistance and otherwise of the volatiles of creosote. The newspapers mentioned creosote in terms of assisting the fire in the articles referred to. Do you have any comments?

Mr. Gurd: Some years ago the CPR Pier D burned down. As you will recall this was a very destructive fire. It burned the superstructure right off--burned the creosoted piling, but these piling to a very large extent were salvaged. Mr. George Herrmann, who was then the General Manager of the Canada Creosoting Company, wrote an article on this subject which is perhaps available to you. This and other articles and experiences suggest that the wood of the piling acts as a wick and that the creosote on the periphery of the piling burns off as oil would from a wick. The experience in these fires is that freshly treated piling, shortly after it is installed, may have a surface coating of free oil. This oil is quite volatile and if subject to flame it will burn and burn off. After the piling is seasoned for a while this creosote oil is not as volatile and is not present on the surface, and is quite difficult to ignite. Tests made by eminent British authorities on this subject have shown that in actual test it has taken longer to ignite a thoroughly seasoned creosoted piling than it has an old untreated piling. So, in short, my answer to your question is that the oil burns off, perhaps will destroy the upper portion, will still leave an effective piece of wood to support the superstructure and that the oil itself, while it creates a very dense smoke, making it rather difficult to fight, as these newspaper articles have described, it does in many cases extinguish the fire.

Question: Are there any specialized tools on the market for handling heavy timbers without damaging the treatment?

Mr. Gurd: Your question would be related to the handling in place by a contractor directing a dock. Of course in the treating plant we use wire rope slings for this purpose. If there are sharp corners on pieces which for some reason must not be damaged, then some lagging can be attached to the piling or put at the corners. In some instances some plants use a set of tongs with a pad on the tongs instead of the sharp point which clamp on the piece and will not subject it to the intrusion of the sharp pointed tools that would otherwise be used. Perhaps this is not a good answer to your question. I am not quite sure where this is, in what locality, in what part of the job are you using these tools?

Question: In the materials being stock-piled on site, the fellows wrestled it around with peavies and cant-hooks and things. I didn't see any tools that could get a hold of it. A pad didn't work. The pile was too slippery.

Mr. Gurd: Well my only answer to that is that in the wood preserving plants we use slings. Today there is a development which is becoming more and more common and I believe in some of the wood preserving plants they are using a type of equipment which has an upper and lower jaw device which will catch the piling without marking it, clamp it, carry it in position and in some instances these devices will turn. There are two types of this equipment on the market. Now the pole producing plants and wood preserving plants are getting more and more into the use of these machines, particularly for poles as they do not want to crush and cause abrasion on the surface of the piece. Whether this piece of equipment would be suitable for a contractor or not, I am not sure. They are pheumatically-tired units, are quite expensive, being in the order of forty to fifty thousand dollars each, and they may not be suitable where there is an unevenness of the ground. But if it is a serious problem--the handling of this material into place and into stock pile--piling can best be handled by this kind of equipment, certainly without any abrasion. That is the modern development.

Question: Is 16 lb. treatment used very frequently and where would these piles be used in B.C.?

Mr. Gurd: Just off hand, sir, I can only recall one instance--perhaps I can call on someone else here--but the Canadian National Railways for a number of years used 16 lb. piling for their structures in Prince Rupert. I cannot recall any 16 lb. piling that has been specified of recent days.

Mr. K.B. Dundas, Canada Creosoting Co.: I think some of the consultants do specify 16 lbs. in modern installations. H.A. Simons calls for 16 lbs.

Mr. Gurd: And this has been used recently?

Mr. Dierden: The Elk Falls Company have been using 16 lbs. continuously since 1958.

Mr. A. Webster, Department of Public Works: The Wharf at Port Alberni is 16 lbs.

Mr. Gurd: Thank you.

Dr. Gardner: Thank you very much, Mr. Gurd. We very much appreciate your paper and later on in the day, after the last paper, I think we will be able to return to some of the aspects of this symposium brought up by Mr. Gurd and also by Dr. Quayle. No doubt as these papers are given you will think of other things that you didn't think of when the first paper was being given and so on and I hope that we can look forward to more discussion after three o'clock.

FACTORS AFFECTING THE STRENGTH OF MARINE PILING

Mr. W.M. McGowan, Research Officer, Vancouver Laboratory,
Forest Products Research Branch, Department of Forestry

Introduction

Wood differs from most structural materials in that it is a cellular structure rather than a visibly crystalline or granular structure. It is composed of cellulose, lignin and minor quantities of other materials. Cellulose forms the framework of the cell and lignin is the cementing material that binds the cells together. The cellular structure is responsible, to a large extent, for the characteristic differences in wood as a structural material. Design theory applicable to other materials is not always applicable to wood. For this reason, the engineer should know the basic characteristics of wood and factors that affect the strength of timber before undertaking the design of wood structures.

The principal factors which affect the strength, not only of marine piling but of structural timbers in general, are as follows: inherent variability, moisture content, density or specific gravity, natural and other defects, decay, and injurious treatment processes. Each of these factors is now discussed briefly under the following headings.

1. Inherent Variability

Strength variation is common to all materials, but wood, being an organic material which is subject to hereditary and site factors is a particularly variable product even in the clear material of a given species. Strength variation within a species is best illustrated by a plot of strength values against frequency of occurrence as shown in Slide 1. In this instance, the species is white pine in the unseasoned condition; the strength function is the modulus of rupture in pounds per square inch (i.e. the calculated fibre stress at maximum load) and the total number of small, clear specimens is 124. The average value of the test results is 5,450, the maximum value 6,956 and the minimum value 4,200 p.s.i. The difference between the maximum and the minimum values is known as the range or spread of the distribution. It will be noted that, in this example, the distribution is symmetrical and that the curve, fitted to the histogram, is bell-shaped and approximates closely the normal curve of probability. One of the measures used to describe the dispersion of values about the average is the standard deviation. The standard deviation is the distance on each side of the mean which includes about 68 per cent of the values. The calculated standard deviation in this example is 528 p.s.i. The percentage of values falling within successive ordinates is also shown in the lower axis. The trends just described are representative of trends to be expected for a similar plot using other strength functions or for the same strength function at a lower moisture content. If, instead of plotting strength values for specimens in the unseasoned condition, values for the seasoned condition were plotted, the curve would be displaced to the right and would likely be somewhat flatter with a wider spread. If the unseasoned specimens had been structural-sized timbers containing knots, the curve would be displaced to the left and would likely be more peaked in shape.

2. Strength in Relation to Moisture

The development of a growing tree takes place in the presence of moisture; thus, the normal condition for wood is the green or moist condition. The amount of moisture in the living tree varies widely between species and within individual trees of the same species. Values as low as 30 to 40 per cent, based on the weight of oven-dry wood, have been observed in the heartwood for Douglas fir and as high as 200 per cent in the sapwood of cedar.

Storage of moisture in unseasoned wood is partly by absorption in the cell walls and partly by retention in the cell cavities. As wood dries, the cell walls do not release moisture until the cavities are empty. The point at which the cavities contain no free water but the cell walls remain saturated is known as the fibre saturation point. This point may be determined experimentally by plotting curves of strength values at varying moisture contents as shown in Slide 2. Note that, for this relationship for Douglas fir, the strength of wood is essentially unaltered at values of moisture content above 23 per cent. At values below 23 per cent the curve slopes upward indicating increasing strength with decreasing moisture content. The point of intersection between the sloping curve and the horizontal line is accepted as the point of fibre saturation as determined by strength.

3. Strength in Relation to Specific Gravity

Specific gravity, as related to wood, is the ratio of the weight of oven-dry wood to the weight of an equal volume of water. As it is closely related to density, it is an excellent index of the amount of wood substance contained within a given volume. Since increase in wood substance per unit volume is accompanied by increase in strength, specific gravity, therefore, is also a valuable index of strength. Some properties, such as maximum compressive strength parallel to the grain, increase approximately in proportion to the increase in specific gravity as shown in Slide 3. Other properties such as bending strength increase at a more rapid rate. Relationships have been developed whereby the strength of timber can be estimated with reasonable accuracy when the specific gravity and moisture content are known.

4. Natural and Other Defects

From the mechanical viewpoint, defects are imperfections which reduce strength and these include knots, spiral grain, shakes, checks, splits, cracks and fungal or insect attack. Since trees are the source of timber piles and trees possess inherent defects, specifications limiting these defects have been prepared by committees on wood piling and published in C.S.A. Standard 056-1962 by the Canadian Standards Association.

Single knots are not usually a major factor in reducing the strength of piling. Knots as large as 5 inches in diameter are permitted between the mid-length and the tip in piles over 50 feet long. Knot clusters, however, are prohibited because neither the sizes of the individual knots nor the size of the cluster are indicative of the grain distortion about the cluster and the resultant effect on strength. The injurious effect of knots is dependent not only on size, location and grain distortion but also on the nature of the stress surrounding the knot. Thus a tensile stress is more adversely affected than a compressive stress. From the standpoint of stiffness properties, knots have little or no effect. They also have less effect on strength and stiffness in round timbers than they do in squared timbers.

Spiral grain refers to a growth pattern in which the wood fibres are arranged spirally, instead of vertically, about the bole of the tree. It is often difficult to detect in the live tree or the unseasoned log by casual inspection. It is readily identified, however, in snags or well-seasoned peeled logs by the sloping seasoning checks on the outer surface. It appears to be present to a varying degree in most trees and, within limitations, is not a serious defect. In certain trees and occasionally in complete stands of timber, however, the spirality is so excessive as to constitute a major defect in the timber. For this reason, spirality greater than one-half turn in any 20-foot section is not permitted in C.S.A. pile specifications.

Spirality affects the strength of a pile in much the same manner as angle or cross-grain affects the strength of squared timbers. Because of the angularity of the twisted grain, components of an axially applied force act in the parallel and perpendicular to the grain directions. Since the strength of wood perpendicular to the grain is low relative to the strength parallel to the grain, the net effect is a reduction in strength.

The twist, as evidenced on the surface, may be either right-handed or left-handed and may vary in degree and direction both radially from the pith and with height above ground. Spiral grain studies conducted by Northcott at this laboratory on 140 specimens of Douglas fir from 10 sites showed that 64 per cent of the sample had a left spiral during the early years of development; changing to a right spiral at maturity. Nineteen per cent of the sample maintained the left-hand spiral of youth to maturity. This information indicates that a Douglas fir pile exhibiting right-hand spiral at the surface would be a much more acceptable pile than one exhibiting left-hand spiral at the surface, since the right-spiral pile would have a zone of non-spirality within the bole. The theory is substantiated by the twisting and untwisting action of softwood telephone poles with change in moisture content. Left spiralled poles have been known to twist 50 degress in relation to the base between summer and winter climatic conditions whereas right spiralled poles have demonstrated a much lesser twist for the same degree of spirality. The greater stability of the right-spiralled poles is explained by the counter-twisting properties of a left-spiralled inner core within the right spiralled outer shell.

A check is defined as a separation of the wood along the grain, the greater part of which extends across the annual growth rings. A shake is also a separation along the grain but the greater part occurs between and parallel to the adjacent growth rings. A split is a separation along the grain extending from one surface through the piece to another surface.

The formation of checks is caused by internal stresses due to the variation in the amount of shrinkage which takes plaoe in three mutually perpendicular directions as drying takes place below the fibre saturation point. There is a pronounced difference in the longitudinal, radial and tangential shrinkage of wood. In the longitudinal direction, shrinkage from the unseasoned to the oven-dry condition for normal straight-grained wood is very slight, varying between 1/10 to 1/3 of one per cent. Shrinkage at right angles to the grain, however, ranges between 2 to 8 per cent radially to 4 to 14 per cent tangentially. Hence, in drying, the cells tend to decrease the cross-section of a timber but do not affect the length appreciably. If the shrinkage of the individual cells coincided and took place uniformly throughout the timber, no undue stresses would occur. The differential shrinkage between the radial and tangential planes, lack of uniformity in drying and lack of uniformity in density all contribute toward stresses which overcome the resistance of the wood and result in surface checking.

Shakes are observed in wood in the unseasoned as well as in the seasoned condition. They are most frequently found at the junction of two growth rings of unequal width. The actual cause of shakes is somewhat uncertain, although stress resulting from growth and wind action are suspect.

The effect of checks and shakes on strength may be summarized as follows:

Tension - little or no effect in direct tension parallel to the grain. A reduction in strength in tension perpendicular to the grain.

Compression - a reduction due to unequal distribution of stresses across the cross-section.

Shear - a reduction in proportion to the reduction of the area resisting the shear stress.

5. Strength Loss Due to Decay

The disintegration of wood referred to as decay is caused by the growth of wood-inhabiting plants known as fungi. No species of wood is entirely immune from attack when the conditions favourable to decay-producing fungi are present. These are: food, moisture, air and a favourable temperature. Untreated wood is durable only under conditions which do not permit fungus development. Fungi cannot survive in wood which is so saturated with water as to exclude free oxygen from the cells. Thus, submerged untreated piles last indefinitely as evidenced by the foundations of houses of lake-dwellers of prehistoric times which remain today in a thoroughly sound condition. It is in situations where moisture collects and air is available that untreated wood is unsatisfactory for permanent service. Standing timber may contain decay, particularly in the heartwood. This decay may develop in piles at some later date when the conditions for growth become favourable, even though no new source of infection is present. Preservative treatment gives the best protection for the exposed portion of piles, particularly near the ground or water line.

The strength of wood is greatly reduced as rot develops. White rot, in the early stage, may have little effect on the compressive strength due to static or dead load, but it can have a pronounced reducing effect on the toughness or shock resisting ability of a pile. Brown rot, however, has a serious reducing effect on strength, even in the incipient stages.

6. Effect of Preservative Treatment on Strength

Considerable research has been conducted to determine the effect of preservatives and preservative treatments on the strength of wood. Creosote, pentachlorophenol and copper naphthenate have no known injurious effects on mechanical properties. Tests have shown that strength loss after treatment with these preservatives has been due to the method of impregnation rather than the preservative itself. High temperature, often used for long periods in order to obtain satisfactory penetration, can produce permanent change in the wood substance with an accompanying detrimental effect on strength. Toughness properties appear to be more adversely affected than bending or compressive properties.

Poles and piling are less susceptible to treatment-damage than sawn timbers, because of the greater proportion of sapwood in round stock and the sapwood being less resistant to impregnation. Since the absorption requirements for piling are usually greater than for poles, poles are less frequently weakened by treatment. With any given treatment, the possibility of damage depends on the temperature used, the period of exposure and the species.

To conclude, the strength of a timber pile may be influenced by some of all of the factors just described. The limitation of defects and the observance of good manufacturing practice, however, contribute to the production of high-quality piling, which, in turn, provides long-term foundations in otherwise impossible areas.

References

Canadian Institute of Timber Construction. Timber Piles, First Edition. Ottawa, 1962.

Canadian Standards Association. Round Timber Piles, CSA Standard 056, 1962.

Canada, Dept. of Northern Affairs and National Resources, Forestry Branch, Forest Products Laboratories Division. Canadian Woods, 2nd Edition, 1951.

United States, Dept. of Agriculture, Forest Service, Forest Products Laboratory. Wood Handbook. 1955. Agriculture Handbook 72.

Northcott, P.L. Spiral Grain in Wood. Forest Products Laboratories of Canada, Forestry Branch, Dept. of Northern Affairs and National Resources. Reprint from British Columbia Lumberman, Nov., 1958.

Northcott, P.L. Use of Spiral Grained Wood. Forest Products Laboratories of Canada, Forestry Branch, Dept. of Northern Affairs and National Resources. Reprint from British Columbia Lumberman, Feb., 1959.

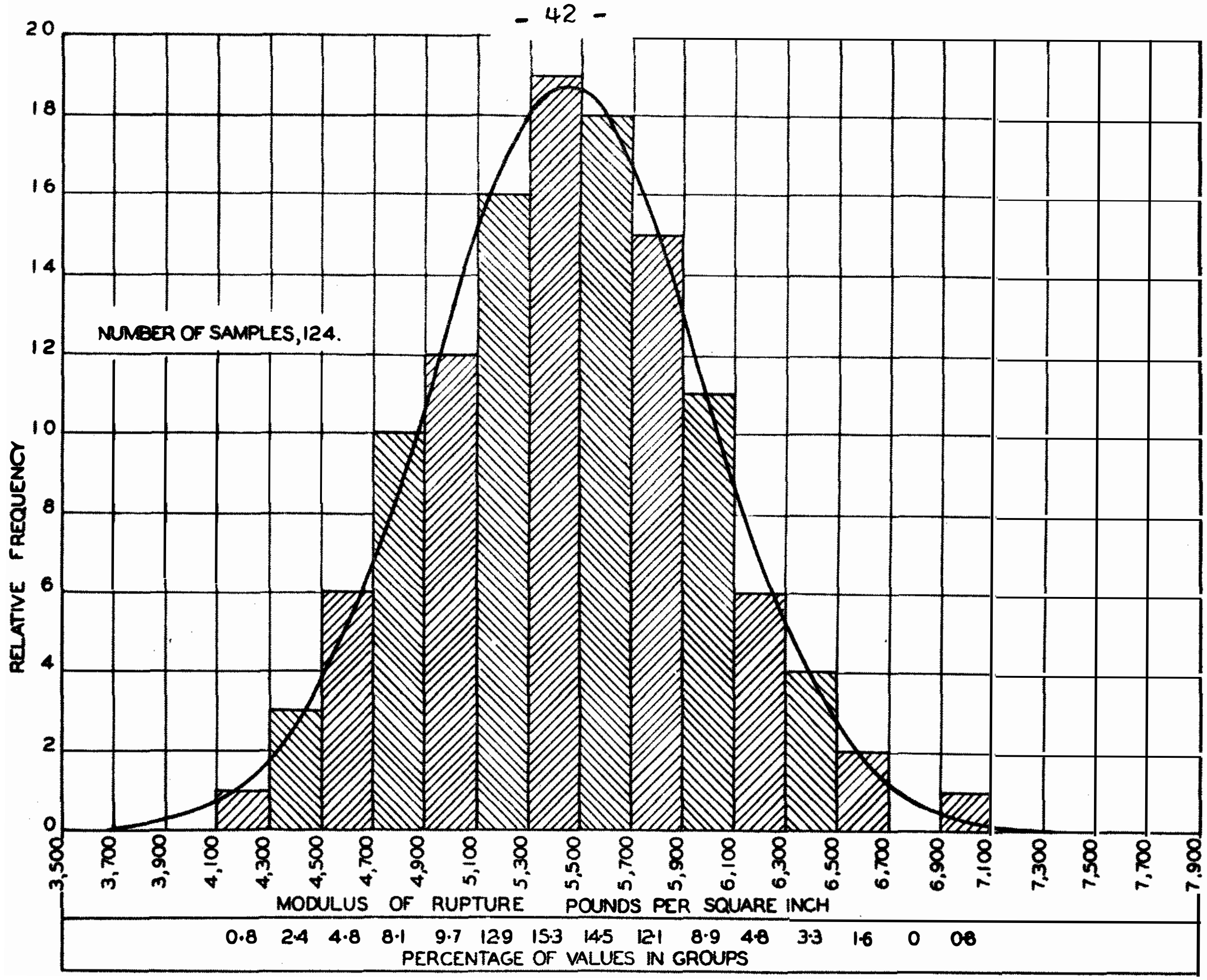
Chellis, R.D. Pile Foundations. First Edition. Toronto, McGraw-Hill Book Co., Inc. 1951.

Wangaard, F.F. The Mechanical Properties of Wood. New York, John Wiley & Sons, Inc. 1950.

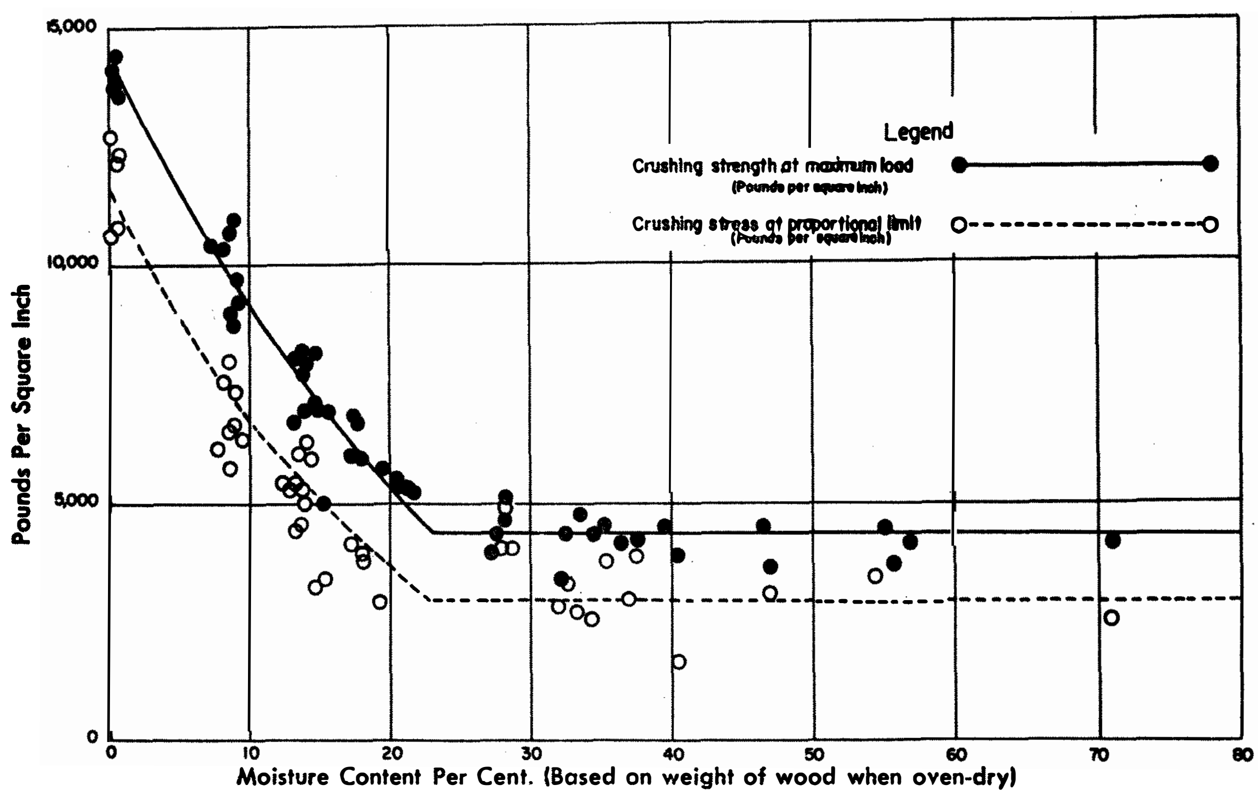
Slide 1 - Fig. 12, Page 111, Canadian Woods.

Slide 2 - Fig. 11, Page 109, Canadian Woods.

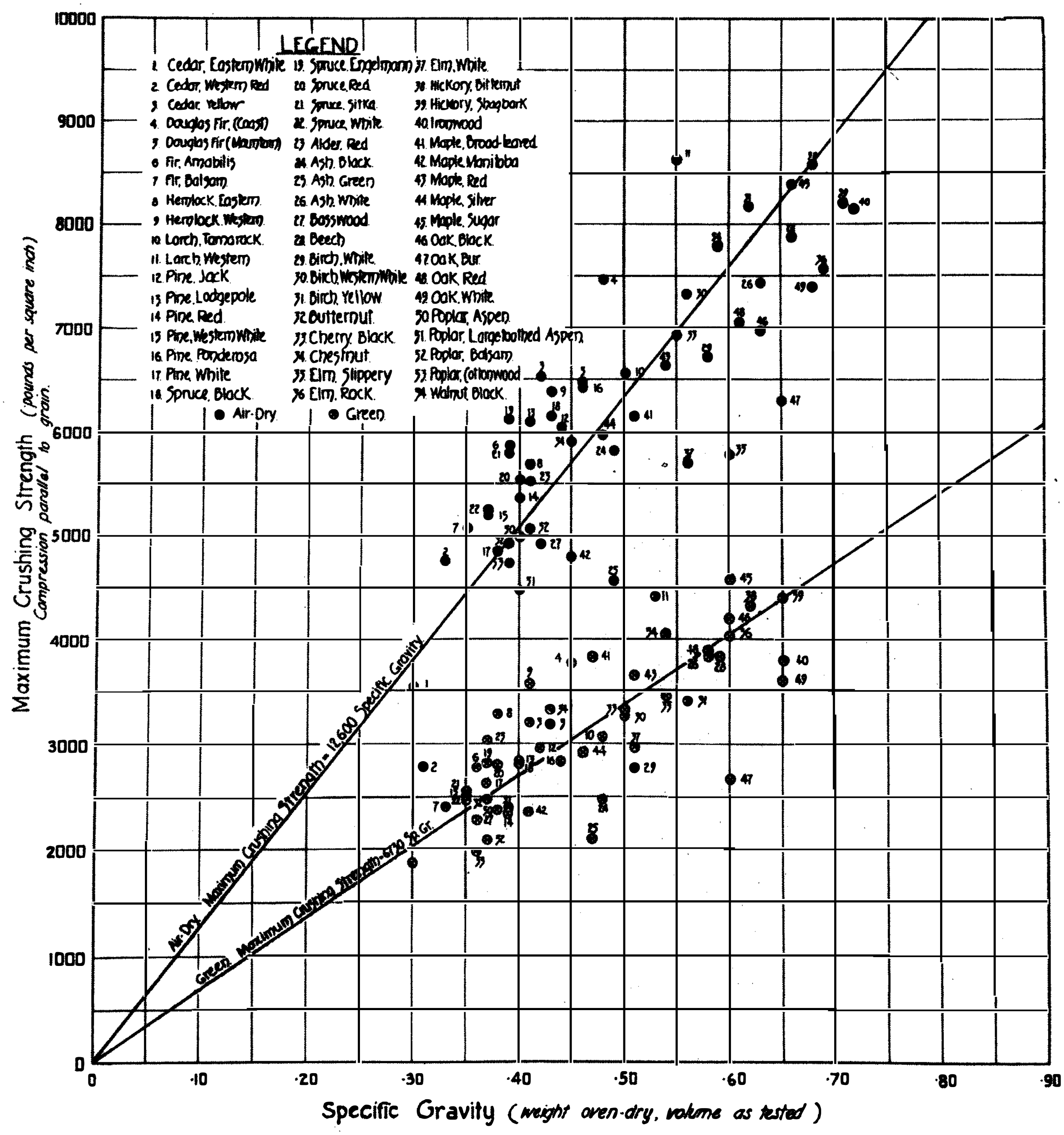
Slide 3 - Fig. 9, Page 106, Canadian Woods.



Slide 1 - Variability of Bending Strength in a Shipment of Green White Pine.



Slide 2 - Relation Between Crushing Strength at Maximum Load and Compression Strength at Proportional Limit in Compression Parallel to the Grain, and Moisture Content, for Douglas Fir.



Slide 3 - Relation Between Maximum Crushing Strength and Density (average species values of woods grown in Canada)

DISCUSSION PERIOD AFTER MR. McGOWAN'S ADDRESS

Question: You mentioned that the strength of round timber is greater than the strength of sawn timber. Machine peeled piling does have the swellings around the knots trimmed a bit. How does the strength of the machine peeled piling compare with the round timber or the sawn timber?

Mr. McGowan: We are presently carrying out an investigation into this very thing you mention. We haven't gone far enough to have conclusive evidence, but it looks like the hand peeled pile may have a little edge on the machine peeled pile, or pole. We were actually working on poles. I am talking about bending properties. The cut fibres due to machine shaving seems to have somewhat of a reducing effect on strength.

Mr. K.B. Dundas, Canada Creosoting Co.*: On spiral grain I conclude from your remarks that during the seasoning period the spiral can be increased or decreased?

Mr. McGowan*: Yes. In softwood telephone poles there is a twisting and untwisting action due to shrinkage caused by change in moisture content. According to the Rocky Mountain Experimental Station in Idaho they observed as much as 50 degrees twist between summer and winter conditions, and there was a much greater twist observed with left hand spirals, where you had left hand spirals at the surface rather than right hand spirals.

Mr. Dundas*: Temperature has an effect?

Mr. McGowan*: Only so far as it affects the moisture content and shrinkage.

Mr. B. Sivak, U.B.C. Student: I have heard of another way to calculate moisture content of wood. I just wondered if they had used it. This is the measurement of water at maximum moisture content.

---

*These questions were misunderstood, and corrected replies are therefore reported here.

Mr. McGowan: We in the laboratory in our own section never use it. We work with specimens that are large enough and it is a matter of just oven-dry weight as compared with weight at test, which gives us the moisture content. I know there is such a method but I don't know it very well. There may be someone in the audience who knows it quite well.

Dr. Gardner: Is this a chemical method you speak of?

Mr. Sivak: No, it is just weighing the samples to begin with to get the green weight of the samples, and saturate for a certain time until fully saturated and then oven-dry it and express the actual water content of the green sample as a percentage of the water that was required for saturation.

Dr. Gardner: This would require vacuum and pressure?

Mr. Sivak: Yes it would.

Dr. Gardner: And it would probably take an hour or so to get this? Have you done this?

Mr. Sivak: I did this with living tissue but I have heard of people doing it with wood. It took many days to have the samples saturated, sometimes more than a week.

Dr. Gardner: The technique Mr. McGowan uses requires a temperature of 105°C. and only a few hours.

Mr. McGowan: If it is a small specimen you can do it over night.

Dr. P.C. Trussell, B.C. Research Council: In the impregnation of piles one of the problems is with knots, that is, the impregnant is not received through the knots very well and the knots are quite often the point of subsequent attack by teredos. What would be the effect on pile strength of excavating knots, and replacing with a short wooden plug?

Mr. McGowan: I wouldn't advise it.

Dr. Trussell: The idea here would be to excavate the knot to a depth of an inch.

Mr. McGowan: Are you thinking basically of compressive properties?

Dr. Trussell: I am thinking of both bending and compressive properties.

Mr. McGowan: I don't think that you would do it very much harm. It is really the grain distortion about the knot that is the greatest factor.

Question: Most handbooks give a considerable reduction in various strengths if the timber is to be used under extreme moisture conditions. Do you think that is a fair criterion in the case of creosoted timber?

Mr. McGowan: Reduction from what stress are thinking of?

Question: Permissible design stress.

Mr. McGowan: Permissible design stress for what? I mean stress should be given at a certain moisture content.

Question: Well, bearing stress is usually given at normal structural load.

Mr. McGowan: Yes, well I think that this reduction should still be there.

Question: Even though it is creosoted?

Mr. McGowan: Yes, even though it is creosoted. There seems to be some reduction in strength just due to creosoting alone.

Dr. Gardner: Thank you very much Mr. McGowan.

TIMBER STRUCTURES FROM THE VIEWPOINT OF OWNER/DESIGNER

Mr. D.P. Dodge, Engineer,
Department of Public Works of Canada

Introduction

This paper will deal with the problems encountered in designing and constructing wooden marine structures from the point of view of the owner/designer.

The objective, of course, is to obtain the most economical structure having regard to the traffic and anticipated required life.

Three main factors enter into the problem of obtaining such a structure--good design, proper material and proper construction methods.

In this paper, frequent reference is made to creosoted material because this is what is generally used in D.P.W. structures. The same comments would apply to any other preservative treatment.

Design

Once the traffic and loading have been established, the structural design is straight-forward. The largest percentage of Public Works wharf installations are constructed of pile and timber. The designs vary mainly in the deck design where several choices are available, such as deck planks, laminated timber with asphalt wearing surface, composite timber and concrete, or pre-cast concrete deck slab. The various designs are used according to the requirements. The substructure of creosoted piles and creosoted, sawn, timber caps remains fairly constant as a type with variations as to spacing and size.

The major problem, in the design of timber wharves, is not the structural problem which in timber is straight-forward, but in producing a structure that can be built to withstand the attacks of marine borers. Any ignoring of this factor is bound to result in a reduced life of the structure and probable failure or expensive maintenance.

I know of one instance where a mining outfit constructed a wharf of untreated piling and superstructure, expecting it to last at least five years. Six months after construction, the whole superstructure fell into the water. The marine borers, specifically teredo*, had totally destroyed the piling.

In treated materials, there are several main points of attack which must be taken care of:

In the piling itself, non-uniform retention of preservative is a problem. Where the sapwood is not uniform, the treatment may be only half an inch or less in depth on some parts of the pile. Attack by limnoria or abrasion by driftwood, rapidly exposes the untreated wood to attack by teredo. Reduction of this marine borer hazard is dealt with under the material supply section of this paper. We have also had a few instances where the teredo have entered the piling through the knots which do not take treatment very well. However, this has not been serious and has not led to any failures.

One of the most prevalent causes of pile deterioration trouble is the use of underwater bracing or bracing in the tidal range, attached to the piles by bolts. No satisfactory method of treating field-bored bolt holes has been developed and the best answer is to avoid the use of underwater bracing by the use of brace piles attached to the bearing piles above the high water line. In most cases, this can usually be done in the wharfhead but it is difficult to do in narrow approaches. Insofar as horizontal walings are concerned, Public Works practice is to attach these to the piles by means of U-bolts. This has proved satisfactory, particularly in the case

---

*In this paper, "teredo" is used in the vernacular, and refers to *Bankia setacea*.

of A-frame breakwaters where the lower waling is just above low water. In one case, at Union Bay, we have a 25-year record of such a structure where no damage has occurred to the piling at these connections.

Another cause of pile failure results from over-driving of the pile, causing checks to open up and exposing raw wood to marine borer attack. Careful investigation of soil conditions, previous to the designing of the wharf, is required so that a realistic penetration can be specified or to use a pile driving formula to drive to a load-bearing value. In either case, careful field control of the pile driving is essential.

One example we have had in overdriving of creosoted piling occurred at Westview. The wharf was reconstructed in 1951 and the soil conditions made driving timber piling difficult. A piling inspection carried out by the B.C. Research Council in 1961 indicated the piles were severely attacked by marine borers and a major cause for this attack was the vertical splits in the piles.

A third major cause of trouble is the use of untreated material attached to treated piling in the area of marine borer activity. It seems the marine borers, specifically teredos, work up a healthy appetite on the untreated wood and just continue right into the treated wood. This was particularly exemplified by the failure of the Navy wharves in New York shortly after World War II. In this case, the underwater bracing was untreated and attached to creosoted piling. While good design will never call for untreated material, in these cases, care must be taken to see that no untreated material is used in such locations in the field. An example of this that occurs quite often, if not protected against by rigid inspection, is the use of untreated shims between creosoted braces and piles.

Another problem occurs in the upper part of the structure--the one of decay. The main points of concern are the pile cut-offs and raw timber ends. Generally, bearing pile cut-offs are given two coats of preservative and covered with ships felt. Mooring piles, above deck level, and brace piles, are capped with aluminum over two coats of preservative. Fender piles present a different problem and have been the subject of considerable study. For many years, fender piles were also capped and aluminum or galvanized iron; however, it was found that ship's lines, dragging over them, quickly tore off the cap. About eight years ago, we set up a number of test blocks of pile cut-offs to test out various mastics; none of these have proven satisfactory and the best protection observed, so far, is afforded by two coats of creosote oil. All field cuts in creosoted material, all timber to timber contacts and all timber ends should receive a field treatment. In Public Works, we normally specify two coats of creosote oil.

In the past, considerable maintenance has been needed on guards and handrails which rotted at the fastenings. The use of pressure treated timber in this, has considerably reduced the maintenance. Tanalith salt treatment has been used because of the necessity of painting over the treated material.

Materials

After the design, the next important step is to ensure that the materials fully meet the requirements specified.

The requirements for timber and piling are clearly defined in C.S.A. specifications and are easily checked. The problem arises in ensuring that the material has accepted the proper treatment. In piling, non-uniform sapwood results in varying penetrations although the net retention is satisfactory. Until recently, we required only one hole per pile to check penetration; now, however, we require three holes per pile. These holes are spaced along the pile, and radially around the pile. In our opinion, this is effective in materially reducing the number of piles accepted with under the specified penetration.

Another problem is post-treatment checking in piles. These combined with over-driving as previously mentioned can expose raw wood to the attack of marine borers. A suggested solution to post-treatment checking is to require piling to be incised. This permits the pile to relieve its stresses in a large number of hairline cracks between incisions rather than in two or three major checks. Properly seasoned piling should be specified in all cases where they are to be used in salt water.

In the case of sawn timbers, under our present inspection requirements, only a percentage of pieces are checked for penetration and dense timbers which have not accepted treatment can easily be missed in inspection. This may not present too much of a problem if the timber is not subject to attack by marine borers. Our practice is now to use hemlock in these areas where attack can be expected and where hemlock will meet the structural requirements, as hemlock takes treatment better than fir.

The problem of the post-treatment checking and twisting and warping is also present in timbers, and pieces which pass the green inspection may check so badly as to be useless structurally.

There have been cases where the post-treatment checking was so severe that some timbers delivered to the site were held together with stitch bolts. In pressure treatment of long, light timbers, they often twist and warp so they cannot be fitted into the structure properly. This is especially serious when the timbers are preframed and prebored.

It is also wise to order treated timbers directly from the treatment plant and put the onus on them for delivery of a good produot. Not all timber can be treated successfully and if the owner chooses to buy his own timber and piling and have it treated, he could be asking for trouble. The treating companies know what areas produce the best timber and piling for treatment purposes.

Field Handling

Constant care is required in the field to ensure that treated material is properly handled and inspectors of construction should be carefully briefed on points to watch during construction.

C.S.A. Standards state that sharp pointed tools may only be used in the ends of treated piling. However, we believe that this is not realistic and the Department permits the use of these tools up to a maximum of 3 feet from either end. Any infraction of this requires the pile to be rejected.

The practice of dogging piles in making up booms must not be permitted. The practice of boring the piles about a foot from the head and stringing them on a wire rope seems to be the best practice as this part of the pile will be cut off, or alternatively the piles can be bored before treatment.

I have referred previously to the matter of overdriving. Specification by formula is probably one way of controlling this but, in an area subject to wide variations in penetration, the Contractor is in a difficult position in determining what piling to order.

A great many Departmental structures are specified for a definite penetration based on test borings and, in many cases, on previous knowledge of the area. In these cases, our policy is to pay for piling up to the specified penetration, even if it is not obtained. This relieves the Contractor from too much waste and allows us to stop driving as soon as solid bearing is reached. It is here that experience on the part of the inspector on the site is of great value in judging when the piling has reached practical refusal.

One important point is to be sure that a suitable sized hammer is used. Too light a hammer requires a higher speed to give the required kinetic energy and tends to shatter the pile before suitable penetration is reached.

In handling treated timber, it must be remembered that the material has been treated to provide protection against marine borer attack or against decay. Any field practices that result in breaking through this protective coating and exposing raw wood must be checked and damaged material should be rejected. A common practice that must be guarded against is the use of wire rope slings for handling loads of sawn timber.

In summary, four major factors enter into the produoing of successful wooden structures in B.C. Coast waters--good design, proper quality piling and timber, adequate preservative treatment, and proper methods of handling in the field. Where these conditions are met, economical structures result which will fill a large percentage of wharf requirements.

<u>Examples of Service Obtained from Creosoted Piling in D.P.W. Structures</u>

Alice Arm Wharf	30+ years
Beaver Point Wharf	42+ years still good when wharf abandoned in 1959.
Brentwood Approach	30+ years - piles sound when pulled tips decayed.
Comox Wharf	30 years.
Cowichan Bay Wharf	32 years old when removed.
Deep Cove Wharf	31 years.
Fanny Bay Wharf	35 years - pile tops rotten when removed.
Gabriola Centre Wharf	37 years - no sign of marine borer attack when inspected in 1957.
Gambier Harbour	48 years - wharf still in place but not used.

Heriot Bay Wharf	48 years - wharf still in place--sold in 1958.
Hopkin's Landing	33 years - pile tops rotten.
Jetty C Esquimalt	42 years - some piles salvaged and re-used in 1961.
Kelsey Bay	30 years.
Kincolith	32 years.
Kyper Island	33+ years - piling attacked by bankia.
Lyall Harbour	32 years.
Mayne Island	33+ years.
Musgraves	35 years.
Porpoise Bay	39 years.
Port Alberni - Argyle St.	32 years.
Port Washington	33 years - rebuilt 1953-54.
Queen Charlotte City	Some piles up to 45 years.
Roberts Bay	33 years.
Sooke Wharf	46 years - some piles salvaged and re-used.
Victoria - Broughton St.	31 years.

CONSTRUCTION PRACTICE - ITS EFFECT ON THE LIFE OF MARINE PILING

Mr. L.A. Corbett, Engineer,
Fraser River Pile Driving Co. Ltd.

This paper will deal primarily with the handling, driving and field treatment of creosoted piling in Marine Structures.

We have already discussed today the marine borer, and creosote treatment to prevent damage by borers. The Contractor is a vital factor, because bad practice can destroy the protection offered by creosote treatment.

You will note throughout this paper that current construction practice is in conflict with the C.S.A. Specifications. This may sound startling, but I hope by the end of this paper you will agree that if properly used, tools prohibited by C.S.A. may be used in construction. I believe if C.S.A. specifications were rigidly enforced the cost of construction would rise very greatly.

Our first consideration will be the transport of piling from the treatment plant to the site of construction. Normally if the site is beyond the Gulf of Georgia area, the piles are loaded on barges. In the Gulf of Georgia the piles are usually towed. This is accomplished by the piles being bored after treatment and a wire rope or chain threaded through the holes. This is called brailing. The practice has usually been to bore the hole about 18 inches from the tip of the pile, and before driving, the bottom two feet are cut off, leaving an untreated end. Normally this presents no problem as the tip is buried in the ground. However, where there is only a small amount of penetration, as in broken rock, borers can and have damaged the pile tip. Recently we have had the piles bored at the butt end, which facilitates towing and prevents possible infestation by borers. The pile is fresh-headed before driving and the hole cut off anyway. There is some danger of borers getting into the pile through these holes if the piles are left in the salt water for several months. However if the piles are attacked this will be seen before driving if the hole is bored near the butt.

Regardless of which way the piles are transported they are put on what is called a "dog line" in the water before driving. Rafting dogs are driven into each pile and held together by a wire rope. This is in direct contradiction to the C.S.A. Specification which states that no sharp pointed tool shall be used. As previously mentioned by Mr. Dodge, it is quite safe to put dogs in the piles providing they are within three feet of the butt end, which will be above high water. If dogs are placed in the pile where it will be in the water after driving, marine borers have a ready made doorway in which to enter the pile. If there is a lot of penetration it is safe to dog the piles near the tip, although this is very seldom done.

Before driving, usually the pile has to be moved in the water, and this is done by means of a pike pole. Again this is against the rules laid down by the C.S.A. Providing the pike pole is used near the butt end of the pile, it will not damage the pile.

As I mentioned a few minutes ago, the butt end of the pile is fresh headed before driving. The creosoted end of the pile is relatively soft and will smash up readily during driving, therefore the top portion of the pile, usually two feet, is cut off square and the edges of the pile bevelled.

Depending on the driving resistance either a wire mesh, a wire rope band or a steel ring is put on the head to prevent splitting. We have on a few occasions used steel strapping around the pile head with good success.

Often when the pile is placed in the leads, it has to be rotated before driving. This is accomplished by using a peevee, which is also against C.S.A. rules. However usually this is done close to the pile tip, which will be buried in the ground. The force required to rotate the pile is usually not very great and the point does not dig into the pile very much. However it is a point that should be watched closely.

The selection of hammer type is usually dictated by the specification. Usually a drop hammer is the most economical and will drive the pile quite satisfactorily, however if the driving resistance is great and considerable penetration is required a mechanical hammer should be used. This may be operated by steam, air, or diesel, depending on the type of hammer. If a drop hammer is used, a heavy one with a short drop will prove the most satisfactory.

One thing that is most important is the point at which driving should cease. Many specifications say that the pile shall be driven to refusal, and some inexperienced inspectors expect driving to continue until the pile quits moving. This oannot be accomplished with a timber pile and if driving continues, invariably the tip is smashed, and cracks will appear in the length of the pile. As a rule of thumb, if the penetration is less than 1/4" per blow with 30,000 ft. lb. of driving energy, or 1/8" per blow with 15,000 ft. lb. of driving energy the pile is being damaged. This will vary with soil conditions, but extreme caution should be exercised with a soft layer of soil over rock or till. We have had to pull many piles to prove to inspectors that the pile was being damaged under these oircumstances.

The field treatment of the pile depends on the use it is to be put to. If it is a bearing pile, the cut off head should be swabbed with creosote oil, given a coat of plastigum mastic and covered with Irish felt. If the pile is not covered with timber, aluminum should be used in place of the Irish felt. It is possible to obtain annealled aluminum which is very workable and gives a good covering. Usually hot creosote is specified, but I do not believe it penetrates any further than cold creosote. The main thing that controls the penetration is the moisture in the wood and the length of time it soaks.

Many marine structures have timber to pile connections in the tidal range. It is possible to bore the hole in the timber before treatment but not the pile. Extreme caution must be taken to protect this hole in the pile. It can be given a coat of creosote oil, but once the tide comes up, the water washes out much of the oil. A tight fitting pipe sleeve can be driven in the hole and a bolt placed within the pipe, or a simple method is to put fibregum under the washers and seal the hole. Sometimes clamps are placed around the pile and the timber. All these methods leave some doubt as to their effectiveness because of the movement between the timber and the pile and eventually there can be exposure to marine borers. The best way is to avoid timber to pile connections as much as possible in the tidal range.

We have experienced considerable difficulty in driving piles which have been given very heavy creosote treatment, say 16 lbs. full cell. These piles tend to sink and are difficult to handle. They seem to be brittle and will smash and crack easily during driving. I think that the extra preservative protection is often destroyed by damage during driving.

One other place where caution must be exercised is the placement of rock rip rap around piles. This occurs quite often and the pile must be protected. I have seen untreated strips of wood nailed onto the piles to protect them from the sharp rock edges. This is extremely dangerous as the marine borer can get a start in the untreated wood and then penetrate the pile. Treated wood, preferably plywood strips should be used to protect the piles from the rock.

Often there is an argument on the site about nailing temporary timbers on piles so as to put them in the correct position. Providing the temporary timbers are placed above the tidal range, they will do no harm. The small hole left by the nail will be filled with creosote oil.

In summary I would like to emphasize the danger of damaging the pile by overdriving and by boring holes in piles in the tidal range. These points in my opinion present the greatest danger to the piling. Also, if pointed tools are not properly used the pile can be permanently damaged.

DISCUSSION PERIOD AFTER MESSRS. D.P. DODGE'S AND L.A. CORBETT'S ADDRESSES

Dr. P.C. Trussell, Director, B.C. Research Council: This matter of bolt-holes and bolting timbers under water, brace piles to bearing piles, is that still current practice in British Columbia?

Mr. Corbett: I would say yes.

Dr. Trussell: The reason I asked is that maybe some of the people from the United States might have a word to say on this. I think this practice has been abandoned in the United States for many years by the commercial people and more recently by the United States Navy. It seems that many years ago, actually in the 20's, fairly heavy loss was sustained at Guantanamo as a result of the bolt-holes, and it is a continuing problem I think with structures on the east coast today suffering limnorial attack at these points. I was wondering if Mr. Christerson might have a word to say on this?

Mr. Paul D. Christerson, American Wood Preservers' Institute, Portland: I think the doctor is quite right as far as the bracing, particularly below the water table or water elevation, is concerned. It is certainly the desire of any designer, including the Navy, as you mentioned, to try to avoid damage from marine life. We are now experiencing a trend to deeper draft vessels and higher design loads in new construction. Those designing marine structures will avoid bracing where possible but when they find it necessary to overcome long L/R ratios on a pile, they will require the bracing. I hope that partially answers your comment. I have one question to ask Mr. Corbett--in dimensioning your sleeve that you drive into the hole--that sounds like a desirable design practice--is it dimensioned somewhat as a drift pin with your sleeve slightly in excess in diameter of the hole, about a sixteenth?

Mr. Corbett: Yes, and one other thing I did omit to mention is that this pipe sleeve is not the full length of the pile and timber, usually about an inch shorter, so that as you are driving it through, you do not split off creosoted material on the other side of the hole. Usually about one inch shorter than the combination of wood and pile.

Mr. W.M. Dierden, Elk Falls Company: Mr. Dodge, you were talking about fender piles. Do I understand you correctly, that that means all piles outside of the edge of the dock, non-bearing piles? Our custom is, in docks constructed at Elk Falls, that you have the bearing piles outside on the edge of the dock, then you have two fender piles and outside that you have one that we call a rubbing pile. Down on the water line we have what we call brow logs which are large boom-stick type of logs with logging chains from end to end so that if the ship takes the dock bow-on, it hits the brow logs and transfers the thrust to several of the piles. Our practice is to have the rubbing pile and the brow logs of untreated green sticks on the theory that they get so much rough treatment from ships and from the movement of the waves, rubbing the brow log against the rubbing pile, that any creosote which you did apply to those would be spoiled. Is it the custom of the Department of Public Works to do the same thing, or do they place creosoted material in these positions?

Mr. Dodge: These brow logs are usually untreated mainly because of the cost of treating them. They are always wearing out anyway, but the general procedure on the rubbing piles now is to use creosoted material, otherwise you would still be putting untreated material up against a creosoted pile. Granted the outside of your rubbing pile is going to be worn, there won't be much attack there, but there is still two-thirds of the circumference of the pile that is open to marine borer attack, specifically teredo, and I think that in most of the Public Works wharves, our rubbing piles and our fender piles are all treated.

Mr. J. Wynand, Timber Preservers Ltd.: Question to Mr. Corbett. Actually two questions. First, are you still using the pressure bolt-hole treater for holes which you use for connecting bracing in the low tidal range? What is your frank opinion about this? It would be interesting to hear if this procedure should be recommended or not. And the second question is again in connection with specifying. How do you apply creosote on the pile cut-off? First of all, do you heat the creosote? Secondly, do you use any device such as a ring set on top of the piles as found in the specifications for giving the creosote enough time to soak into the wood? What actually is the general practice?

Mr. Corbett: This is sort of embarrassing. The bolt-hole treater--here I will be quite honest with you, we use it when we have to, simply because usually the bolt-holes are down in the tidal range and you are fighting for time, to try and beat the tide. The use of the bolt-hole pressure treater takes considerable time and it very seldom is used. It is used mostly on some of these pontoon type floats and the creosoted materials in these are built up on a wharf and then lowered into the water and you don't have to fight the tides. We do use it there, but I would say it is very seldom used in connections of timber to pile in the tidal range. Again, there is some doubt as to actually how effective the penetration of the pressure treater is. Possibly some of the other contractors may have something to say on that, but I would say that seldom do we use it. Again, it is a matter that if it is specified I think then that we expect to use it, but unless it is specified, we are in a competitive field and we just can't afford to use it. That may not be the best practice but that is the fact.

Mr. Wynand: Do you think it is a worthwhile effort? Have you any test results?

Mr. Corbett: I did some testing on my own. Again this was not done in tidal range, this was done on some treated wood in our yard and to be quite frank with you I couldn't see much difference. We used the pressure treater and took sections through it and then saw the difference in that from the hole six inches or so away in the same wood treated by squirting or taking a rag and just swabbing creosote into that wood and there was very, very little difference. Again in the tidal range I feel that your water in there is going to wash your creosote out very quickly. On the matter of cut-offs and putting a band around the top of the pile and putting an inch or two of creosote there--it is difficult to do. It is very time-consuming. It has been done. We have done it in some instances. Again it is done where it is specified. But if it isn't specified it isn't done, simply because it is expensive. Whether it is actually of any great value or not I am not too sure. I do feel that with creosote oil and then mastic, and Irish felt you do have a very good covering that will prevent the water from getting in. You did mention about heating creosote. Again I did some tests in our yard and I couldn't see any great difference between hot and cold creosote. I think the moisture in the wood is far more important than the temperature of the creosote.

Mr. Wynand: My point in asking these questions is simply because if you have found, and Mr. Dodge may confirm it, that doing these things would do a lot of good to the material, then it would simply be a matter of writing an adequate job specification, and in that way avoid any problems on the parts of the contractors bidding on the job. They would then all be faced with the same additional cost of field treating, and in that way they would be only too happy to give these services, whereas if it is more or less left open or only referred to in general terms in accordance with CSA specifications, there may be a possibility of unnecessarily shortening the service life of the structure.

Mr. Corbett: I see Mr. Milavsky from Greenlees Pile Driving, may be he has something to add to this.

Mr. D.S. Milavsky, Greenlees Piledriving Co. Ltd.: I think I would agree with Mr. Corbett, because one of the prime problems our pile drivers find is when they are connecting a brace to a pile and using these pressure guns, they have to bore through, remove the brace, treat it and replace it, and there just isn't time. We have experimented using our compressor, and forcing the oil in under 85 lb. pressure. We don't see any difference. What we do is similar to what Les Corbett does--swab the hole around, put a lot of oil on the bolt, and hope that enough of it stays in. Creosote never soaks into the hole properly after you drill it, it is so wet that you don't get any penetration.

Question: Why would the hole be wet, because you have very little pile in the tide-water.

Mr. Milavsky: Your bracing--most of the time you drill it, you swab it right away, but it will still get a certain amount of moisture inside the pile. And then of course, just as soon as you get out of there, the tide is right up behind you. You really don't have enough time to let it soak in. And temperature-wise, we haven't found any difference between hot creosote and ordinary creosote.

Dr. Gardner: Anybody else on that subject?

Mr. A.F. Blanshard, Department of Public Works: Question for Mr. Corbett. What do you consider to be good practice as far as hole sizes and bolts are concerned?

Mr. Corbett: As far as drift bolts are concerned, I certainly think that the hole should be 1/16 of an inch less than the size of the drift bolt. That gives you a good tight driving fit for the bolt-hole. If it is pre-bored in your timber before it is treated, I think you will find that the diameter of the hole will tend to decrease slightly in the treating process. Normal procedure is to drill the hole 1/16 of an inch larger than the bolt. I think that is a good practice. If you go to a tight driving fit you have to be very careful that when you drive the bolt through, you don't splinter the outside of the pile or the timber when that bolt comes out the other side. I would think that 1/16 of an inch less than the diameter for the drift pin and 1/16 of an inch greater for a bolt.

Dr. Gardner: Another opinion?

Mr. Christerson, A.W.P.I.: Mr. Corbett, in talking about overdriving, you mentioned that you were using as an example a Vulcan I with 15,000 foot pounds energy, and that you watch out after you get 1/8 of an inch to a blow under your Engineering News Record formula, that is developing over eighty tons bearing. Now is it common to be driving your timber piles by formula up to that load?

Mr. Corbett: I would say no. Is your calculation right there? I would think that it is closer to thirty or thirty-five, but I may be wrong. (Calculated at 62 tons. L.A.C.)

Mr. Christerson: One-quarter of an inch to the blow is about 43 tons, but the table I am referring to stops at about 0.2. It appears that when you get to .125 inch per blow you are up around 80 tons, which when one figures the factor of safety with the E.N.R. formula is developing a pretty healthy load.

Mr. Corbett: I would agree that is taking it to a very high load and normally we don't go that high, but again we do run into this, particularly where there are inexperienced inspectors on the job and they call for penetration to refusal. And they expect virtually to get that; we have had some instances where the piles have been totally destroyed through driving and with Vulcan I's where we have got up to say thirty blows to the inch, and still had to keep driving the pile, which is strictly destroying it. But I would think that 1/8 of an inch is as far as we would want to go and normally we don't go to that--I would think that usually we go to about 1/4 of an inch.

Mr. Dierden: Is there any tie-in between Dr. Quayle's studies of the degree of the contamination of the water in the areas where Mr. Dodge says he has lost docks which have been in existence for a considerable number of years? Specifically at Heriot Bay which is reasonably close to Campbell River.

Dr. Quayle: Heriot Bay is one place that I haven't sampled, although at Redonda Bay which is the same general area, there was only L. lignorum. Von Donop Creek at the top end of Cortez Island, getting along toward Heriot Bay, and where we would have expected L. tripunctata, there was only L. lignorum. Any others where you wanted data?

Mr. Dierden: Well, I'll go back to one of Mr. Dodge's other locations. Sooke.

Mr. Dodge: I think you will find all these locations in Mr. Bramhall's book, and structures too.

Mr. Bramhall: The latest publication, which contains records of many of these docks, has not been completed yet.

Dr. Quayle: L. tripunctata is at Sooke, but not at the Government wharf at Sooke. The Government wharf is 100 per cent L. lignorum. At Comox, there is L. tripunctata. Beaver Point has only L. lignorum. The Rayonier Sawmill Wharf at Fanny Bay has 100 per cent L. tripunctata, in creosoted timber.

Dr. Trussell: One thing to consider is the concentration of Limnoria. There are not very many places on the B.C. coast where Limnoria are a problem commercially. Probaby Mr. Allen would know better than I, but I would say only at Crofton; the next place where Limnoria are serious is Ketchikan, Alaska.

Dr. Quayle: L. lignorum is certainly common enough at Massett and Prince

Rupert.

Dr. Trussell: Well, not by southern standards. Even in Massett the Bankia are really the only borers of serious consequence.

Dr. Quayle: Well I don't know, the place where I got my samples were really chewed up by Limnoria. Of course, all associated with damage, permitting the Limnoria to get in, but where they got in the samples were really chewed up.

Dr. Trussell: Our experience on this coast is that outside of California Limnoria are a commercial problem in very few locations. Is Mr. Allen here? Would you bear me out--you see more of the waterfront than I do.

Mr. I. Allen, B.C. Research Council: Well it has been my experience up to the 25th wharf that we have examined, only two wharves showed severe limnorial damage and both of these wharves were sites where we had found both Limnoria tripunctata and L. lignorum. The rest of the wharves showed very little Limnoria damage and that was all L. lignorum.

Mr. Bramhall: Will you say where these wharves were?

Mr. Allen: Yes--one was at Chemainus and the other at Crofton.

Mr. N. Hauffe, Domtar Research: Mr. Corbett, were the difficulties that you had in floating and driving the piling that was treated to 16 lbs. a function of the total weight of the pole, and not only of the 16 lb. treatment? Would you say that if these poles were treated at a lower moisture content then you would not experience these troubles?

Mr. Corbett: Our experience has been that the piling has been very brittle and it will open up--that is, the checks will open far easier under the same driving conditions at heavier treatment than they will with say a 12 lb. to 14 lb. treatment. The head of the pile will crush far more easily on the 16 lb. treatment than on the 12 lb. to 14 lb.

Mr. Hauffe: Do you think that different driving methods might improve this?

Mr. Corbett: I don't know how you can improve on your driving methods, particularly using a mechanical hammer, an air hammer or a steam hammer. Let's put it this way, you would have to take a great deal more caution in driving these piles than you do with a normal--I shouldn't say normal, but a 12 lb. or 14 lb. treatment.

Mr. Hauffe: In driving can you increase your frequency by some method that will achieve the same end result but cause less damage? Using the greater frequency of blows, for example?

Mr. Corbett: That depends on your choice of a hammer. Normally creosoted piles are not driven with a double acting hammer where the frequency is readily altered by changing the volume of air. A single acting hammer is usually used on creosote piles, and these have a standard frequency which is not easily altered. We have made up mechanical adapters to alter the frequency and the striking energy. Because of the difficulty of altering the single acting hammer, once a frequency is decided upon, it must be adhered to for a considerable number of piles.

Mr. Gurd, Timber Preservers: I have a question of Mr. Dodge. Before lunch I believe Mr. McGowan mentioned the loss of strength from various matters such as the creosote treatment. Do you feel that it is necessary to make an allowance for this loss of strength in the design of your structure due to this process, or to any preservative process?

Mr. Dodge: According to National Building Codes, C.S.A. standards, we more or less have to. On timber piling I don't think there is too much need for reducing the strength, although on structural members and sawn timber there could be argument for and against it. I wouldn't want to make a statement right now as to whether or not. On timber piling--actually on any timber construction--the designer has a real easy time of it because he designs for a certain load and if someone else puts a heavier load on it you just say, "Oh well, its timber", and forget about it.

Mr. R. Scarisbrick, B.C. Forest Service: Mr. Corbett, about this question of the brittle nature of creosoted piles. Is an ordinary creosoted pile, say 12 lb. treatment, more brittle than a green pile? The problem comes up when you have used a green pile as a test pile and from its penetration you wish to infer the penetration for a creosoted pile.

Mr. Corbett: Yes, I would say there is some difference. In other words, you are thinking that when going out and driving a test pile you usually use an untreated one partly because it is more economical, and then you may get 25 ft. of penetration with a green pile and you would say you should get that with a creosoted pile. I would think yes. Again it would depend on the resistance, but if it were quite stiff resistance, I would think that you would get twenty feet with the creosoted pile, whereas you would get twenty-five feet with the green pile. I would say definitely that there is a difference.

Question: Going back to bolt holes again, have you ever heard of anyone using neoprene or fabrica washers backed up by steel washers to make a seal to keep these limnoria out of holes, and get out of treating altogether?

Mr. Corbett: I haven't.

Mr. Dodge: The only problem would be to get the contractor to tighten up the bolts.

Dr. Gardner: Anyone else have any experience in that regard?

Mr. Corbett: I did mention that we try to put some mastic on the end of the washer which would tend to do the same thing and seal that bolt-hole, but regarding Don's remark here, this is something that should be borne in mind, that is, that every marine structure after, say, six months should be gone over and all the bolts tightened. I think it is good sound maintenance policy to go over your structure as much as possible and tighten the bolts.

Mr. Dierden: My first question is to Dr. Quayle. We have been informed and understand that it is correct, that teredos do not burrow below the mud level. Is that correct Dr. Quayle?

Dr. Quayle: They can go down.

Mr. Dodge: We pulled quite a number of piling at Port Alberni that were heavily infested with teredos and I made a point of looking to see where the infestation stopped and we didn't find any that started below the mud line.

Mr. Dierden: No, not started, but once they got into the pile ....

Mr. Dodge: We never found any that went a foot below. We cut off quite a number--in fact we spoiled quite a lot of Mr. Corbett's piling--we cut quite a number just at the mud line and if there were one or two on the way down we followed them, but we couldn't find them any further down than a foot or may be two, not so that the piles were really damaged.

Dr. Gardner: Does anyone else have experience? Next question.

Question: We are trying to find out whether galvanized drifts pay off over black iron drifts in drifting stringers and caps together. Is this an economical factor? Because we find that with black iron drifts we have rot in the timber in two years. They rust away and rot .....

Dr. C.C. Walden, B.C. Research Council: You have quite a different phenomenon there. The chemical reaction between the iron oxidation products in the wood and the cellulosic fibres in the timber produce what is known as oxycellulose. This is quite a common phenomenon even on any type of iron fastenings exposed to the atmosphere, and in direct connection to timbers.

Dr. Gardner: I back that up. Is this black iron coated?

Question: People will tell you to use a black iron grid. Then in our coastal

Dr. Gardner: Both.

Mr. Harris: Would you as a chemist be able to confirm that if it was creosoted wood with the holes preframed prior to treatment that they have a good treatment and then you use the black grid in the creosoted wood, would that cause the same fall down or collapse of the wood cells after a number of years because this is not any knowledge I have gained in the last years? I think the black drifts could be used quite successfully in creosoted timber.

Dr. Gardner: If the bolt holes had been treated?

Mr. Harris: Yes, because this is quite frequent--the hole in the cap, for instance, is usually treated, and so is the hole in the stringers, and then I can't see anything wrong with using a black drift.

Dr. Gardner: It would certainly make a difference--what would you say Craig?

Dr. Walden: Well we have oarried out some studies in this connection. Actually you get this degradation only from green wood. If you had something that had been impregnated with oil base preservative such as creosote it does provide mechanical protection for the cellulosic fraction of the wood and the rust products of the iron.

Mr. Harris: Is that pressure-treated or just coated?

Dr. Walden: It has to be impregnated sufficiently to give mechanical protection.

Dr. Gardner: If you take native cellulose, pure cellulose, and put it in contact with rusting iron, this reaction is a very rapid one, but anything that will prevent contact is going to slow it up. It is an electro-chemical reaction.

Mr. Harris: How long would you anticipate that a black iron bolt would last installed in the caps of a wharf and piles? A drift bolt in a pile, which would involve the surface of creosote rubbing against .....

Dr. Gardner: I am just on theory here. Has anyone experience?

Mr. Harris: The reason I ask this question is that we rebuilt Jetty C in Esquimalt. The original part of this wharf is something of the order of 40 years old, and the top three feet of the piling under this wharf were hollowed out in a conical shape except for the shell of creosote, leaving more or less sawdust in the centre of the pile. The bolt itself, while not intact, I guess was black iron, installed 40 years ago. There was still a fair amount of the bolt left. I am just wondering if this rot itself was partly set up by the degradation of the bolt and this reaction you are speaking about.

Dr. Gardner: It usually is, isn't it, Craig?

Dr. Walden: Well, in most cases where you have conditions that are conducive to dry rot, you also have conditions that are conducive to the chemical rusting of iron. They are two phenomena which are not entirely separable in practice.

Dr. Gardner: The result looks like decay.

Mr. W.G. Garry, R.C. Navy, Esquimalt: In examining the structure Ken is talking about, we see that the fittings that are galvanized are the ones that survive. The wood structure around these things is in relatively good shape and effective last year, all the work we do ourselves, or the specifications we draw up curselves, we are calling for all galvanized fittings. All the hardware and iron-mongry is to be galvanized, and there are no exceptions. There is no reason other than the fact that we see on the one hand where bare iron disintegrates, the structure around it disintegrates, whereas galvanized may disintegrate, but it does survive considerably longer.

Dr. Gardner: Certainly it seems to be good practice.

Mr. McGowan: Mr. Corbett, this pipe you were driving into the holes you mentioned a while back--was it galvanized?

Mr. Corbett: Yes, it usually is. The only thing is it must be cut--you can't galvanize the ends of it but it is usually galvanized pipe.

Dr. Gardner: Gentlemen, I think that some more questions might arise here and possibly some arguments too, but I think we had better pass on to the next paper. We are running one-half hour behind time. Thank you very much, gentlemen.

SONIC INSPECTION OF MARINE PILES

Dr. C.C. Walden and Dr. P.C. Trussell
British Columbia Research Council

During investigations of wooden marine structures for borer damage over a period of more than 10 years, the staff of the British Columbia Research Council became aware of the inadequacies of visual inspection under water.

Two types of damage predominate: the first is caused by teredo or bankia species and takes place internally; the second is caused by limnoria and occurs over the outer surface of the wood. Limnorial damage is readily discernible, although attack occasionally occurs in hidden recesses where the borers have entered through small surface openings.

External evidence of teredo or bankia attack is difficult to find under water, and reliable estimates of structural loss can be determined by visual inspection only where destruction has been complete.

Difficulties of Visual Inspection

The only external indications of teredine damage are the two slender tubes the animal extends beyond the wood surface while it is living, or the small pin hole opening at the surface of the wood which remains after the animal has died. Since teredine borers seldom live more than two years, divers examining underwater piling and other wooden structures must look for the fine entry holes left by the borers. They are frequently overlaid by fouling and often difficult to see where the water is murky.

Superficially a pile may appear perfectly sound, whereas internally it may be densely honeycombed by bankian burrows. Furthermore, even if the diver is able to locate burrow openings, he is unable to determine the extent of internal damage. Three or four bankian channels cause essentially no loss in pile strength and to downgrade or reject a pile on this basis would not only be misleading but also very costly. Replacement of individual piles in a wharf has been estimated at $400.

This high replacement cost of piles, combined with the even higher risk and financial loss arising through possible structural failure of wooden marine structures, emphasized the need for an aocurate method of detecting marine borer attack which would express damage in terms of residual structural strength and prompted an investigation into nondestructive testing techniques.

Initially development of a testing unit that could be manipulated from above the water surface was considered, but later work revealed the value of supplementing results from the unit with a diver's visual report. The availability of a diver for moving the equipment from one pile to the next, simplified otherwise fairly complicated mechanical gear. The unit that was finally developed, although it has been used mainly to inspect marine piling, also can be used to examine treated or untreated timbers and heavy planking.

Description of Equipment

After exploring a variety of potential nondestructive techniques for determining the presence and amount of borer damage in wood, John Vitins, BCRC scientist, discovered that the velocity and strength of sound waves passing through wood varied inversely with the borer damage. He developed a sonic testing unit. In principle, sound waves are pulsed from a magnetostrictive transducer, several inches from the wood surface, and directed at the heart of the pile.

The pattern of plane waves that penetrates into the wood initiates sonic activity in the direction of the grain. The high velocity component of the wave train transmitting along the axis of the pile produces a radial set of waves as it progresses, which is picked up by a receiving transducer.

Undamaged wood is an excellent transmitter of these waves.

Where damage occurs in the interior of a pile, the sound waves are delayed and greatly attenuated. The velocity and strength of the sonic signal are amplified and read on an oscilloscope.

A unique feature of this sonic testing device (patent applied for) is that preliminary removal of barnacles and other such coarse fouling from the wood is not necessary. Neither the transmitting nor receiving transducers are impinged against the wood surface.

The sonic testing unit developed for commercial use oonsists of two transducers mounted 42 in. apart on an aluminum shaft which is positioned vertically on a pile and held in place by two sets of spring-loaded rollers. Incorporation of buoyant materials in construction has yielded a unit with slight negative buoyancy.

The sensing mechanism can pick up as few as four or five bankian channels in a cross-section of a pile. Because the extent of damage is expressed most satisfactorily in terms of pile strength, relationship was determined between sonic values, percentage voids in pile cross-sections and residual compressive strength of such sections.

Sonic values were obtained on piles showing a range of damage by bankia setacea, from almost complete loss of section at the mudline to no damage at all in the intertidal zone. After examination the piles were cut into short lengths, the percentage voids determined by calculating the average from the cross-sectional area at each end of each log section, and then each section was subjected to compressive breaking in a 100-ton hydraulic press. From these combined data a working relationship was established between the amount of borer damage as indicated by the oscilloscope values, and the per cent residual strength of the pile sections.

Method of Examination

Inspection of piles is carried out most conveniently from a float which is moved along a wharf as the work proceeds. This float carries the sound pulser, the oscilloscope for examining the returned signal, the operator to read the oscilloscope and record data and accessory equipment for the diver. The operator on the float is in telephone communication with the diver at all times.

During an examination of a wharf, the inspection unit is locked to a pile at the surface and is guided downward in a spiral manner by a scuba diver so that all portions of the pile surface lie, at some time, between the transmitting and receiving transducers. When a weak signal is received the operator informs the diver and a more intensive examination is made, both visually and by instrument, to delineate exactly the length and cross-sectional loss of the damaged region.

At the mudline, the unit is transferred to the next pile by the diver and brought to the surface in the same spiral fashion. To facilitate subsequent identification for maintenance or reexamination, a dated tag is affixed to each inspected pile above the high water mark.

An experimental unit first was used in the field in February, 1961 and its successful performance on piles with known damage immediately brought in numerous requests to BCRC for commercial inspections. Since that date the experimental field unit has been rebuilt to accommodate desirable changes dictated by experience. The basic sonic sensing equipment is virtually unchanged in design and most modifications have involved ease of manipulation.

More than 20 wharves were examined through September, 1962. In several instances every pile in an individual wharf was inspected; but for most wharves, sampling was restricted to a range of 20 to 30 per cent of the total.

Two inspections have been made on some wharves, with a number of the piles being examined in 1961, a second group in 1962 and additional areas of the wharf slated for examination in the future.

Inspection results are transmitted to an individually prepared report, which includes tables showing the per cent residual bearing strength of each pile examined, together with the location and the zone of damage for each damaged pile. A plan drawing also indicates the exact location of each pile and the extent of damage. The cost of inspection ranges between $400 and $500 per day depending on geographical location. The number of piles examined per day ranges from 50 to 125, depending upon their accessibility, length and exposure to unfavorable elements such as extreme cold, strong currents or muddy water. Cited costs include transportation and maintenance of the crew, the inspection itself and preparation of the final report. All inspections performed so far have been in the province of British Columbia or the state of Washington.

DISCUSSION PERIOD AFTER DR. C.C. WALDEN'S ADDRESS

Mr. W.M. Dierden, Elk Falls Co.: Is there any ohance of reduction in cost on the basis of more usage, or are you still recovering research oosts?

Dr. Walden: We are, I would say, still recovering research cost. We are prepared, particularly in view of large scale inspeotion to quote a flat rate which will permit of a lower cost. As you will appreoiate, our per diem charge is all inclusive within the B.C. area, covering transportation, maintenance of our crews on site, actual inspection itself, preparation of the data and preparation of the report. For most jobs, which vary from two to four days in length, present charges virtually just cover expenses. For larger jobs, we are in a position, I think, to quote a quoted rate that will work out at slightly less per diem.

Mr. Dierden: Do you advocate batch samplings or scattered samplings throughout the dock area?

Dr. Walden: Batch samplings is what we normally do, and this has two purposes, but I won't argue for its statistical validity. Certainly on a batch sampling we can cover much more in the field if we go down a bent of piles than if we cover every fifth pile in every bent throughout the whole dock. There is too much transportation and moving of equipment on the site and it interferes oonsiderably with our output per day.

Mr. Dierden: Between Dr. Quayle and Dr. Walden. Is there any possibility of considerable variation of the degree of contamination on a dock, say five hundred feet long. Would it be possible for us to take a batch sample from one end of the dock when in actual fact we should take it at the other because the teredos are down at that end and not at this end?

Dr. Walden: I would say that the problem of sampling is not biological in nature.

Dr. Quayle: There may be very great variability in that distance.

Mr. Dierden: So it is possible to guess wrong on docks? You may have much worse conditions in an untested area if you only test 20 per cent of the docks?

PAST, PRESENT AND FUTURE OF PRESERVATIVE METHODS FOR MARINE PILING IN B.C. WATERS

Mr. G. Bramhall, Research Officer
Vancouver Laboratory, Forest Products Research Branch

Early Times to 1886

Protection of marine structures on the British Columbia coast has passed through several periods. The earliest wharves of which we have any record were those built at Nanaimo for the loading of coal. A picture, supposed to have been drawn in 1858 shows a ship loading coal at the wharf. A Nanaimo member of the Historical Society, however, says that the first structures were built between 1863 and 1865. In any case, from these early times to 1886, it seems that all the wharves built on the coast were built on untreated piling.

Because there was not the food supply in the form of log booms available, the marine borer population was very low, and the life of untreated structures longer than the year or so we can expect today. Even so, the maintenance of these wharves required a continual renewal of the piles, and the engineers responsible looked for ways to protect their piling. Coal tar creosote was beginning to be recognized even at that time as being an effective preservative, but no equipment existed on the west coast for pressure impregnation. A dip treatment of piles in creosote, tried at Nanaimo, was not very effective. In later experiments, the piles were sheathed in sheet iron, but this rusted out very quickly and was not worth while.

Another early method of protection was based on the knowledge that the borers did not attack wood which was protected by its bark. In order to obtain tight-bark piles, Douglas fir was cut during winter. These piles were then driven butt-down, contrary to the usual practice, in order to keep the bark intact. It would usually remain on the pile about two years before it was removed by abrasion or sloughing off, and consequently an additional two years of life could be realized from the pile.

1886-1912

By 1886, British Columbia's marine service was attaining more importance with the completion of the Canadian Pacific Railway to the coast, and the demand for more permanent structures had to be satisfied. Thus started the second period of marine construction, from 1886 to 1912. Two permanent types of wooden piling were used during this period: eucalyptus piling imported from Australia, and Muntz metal-sheathed piles. The first Muntz metal-sheathed piles were used in the coal wharves at Union Bay in 1888, and most of these piles were replaced 37 years later in 1925, although some remained until the wharf was demolished last year, after 74 years' service. The Evans-Coleman wharf, at the foot of Columbia Street on Burrard Inlet, is another of this type, built in 1897. It still retains about 75 per cent of its original piles. Other piles of this type were used in the North Vancouver terminus of the North Vancouver ferry.

Eucalyptus, or gumwood piling was more widely used, and for a longer period. Gumwood was imported from Australia after its resistance to marine borers became known. The oldest structure is probably Kitsilano trestle, but although this was built in 1886, it is not known if it was built on gumwood at that time, or during extensive repairs in 1900. Similarly, the early history of C.P.R. Pier A is obscure. It was built in 1890, and extensive repairs were undertaken in 1908, but whether the gumwood was used in the original wharf is not known. Other C.P.R. wharves built on gumwood piles were those at Nanaimo and Victoria, and the Publio Works wharves at Grantham's, Vananda, Crofton and Union Bay. These piles have all given excellent service, and in those wharves which have been demolished or replaced, the gumwood piles have been salvaged and used in other structures. The demand for gumwood piling became so great that the Australian Government limited its export in order to protect their forests.

<u>1912 to Present</u>

The third period of marine construction began in 1912 with the use of creosoted piling in B.C. waters.

Creosote is a distillation by-product of coal in its conversion to coke for use in the blast furnace smelting of iron ore to make steel. Its production is directly connected to the demands of the steel industry for coke. However, certain components of creosote are in demand as chemical intermediates for the manufacture of plastics, dyes, and other products. The price and availability of creosote are therefore tied to the coal-mining, steel, and chemical industries.

Creosote was proposed in the early 1800's as a wood preservative, and as early as 1838, a patent for its use in pressure impregnation was issued to John Bethell in England. However, it was just another of many suggestions of the time for the preservation of wood, and it required many years of service before it was more widely recognized. It finally came to be used rather widely in the 1870's, and in about 1905, a pressure creosoting plant was built in the Seattle area.

The first creosoted piles were imported from this plant about 1912 and onward for use in permanent Department of Public Works structures at Heriot Bay on Quadra Island, Cowan's Cove on Bowen Island, Savary Island, Shoal Bay and Alice Arm, and in C.P.R. Pier D.

A few years later, in 1916, the first creosoting plant in British Columbia was built at North Vancouver for the Vancouver Creosoting Company. It remained in operation until a year ago when the equipment was moved to

Canada Creosoting Company's Sapperton plant. In 1931, Timber Preservers Ltd. opened a pressure treating plant in Burnaby. Since 1916, these two plants have treated about 200,000 piles for use in B.C. coastal waters, and in addition, shipments of various sizes have been imported from time to time from U.S. plants.

The life of creosoted piling has been variable, and many of the factors responsible for premature failures have been discussed today. However, by contrast, there are many wharves which have given excellent service with a minimum of maintenance. Among these are Miller's Landing, Bowen Island, demolished after 48 years; Terminal Dock, Burrard Inlet, still giving excellent service after 35 to 39 years, and Musgrave's Salt Spring Island, 40 years old. Many wharves have been demolished after much shorter periods of service because the communities they served are no longer in existence, or, because they had grown to the point where the original wharf was no longer adequate. In many cases, the type of service changed, as for example, a different type of ferry service, and wharves had to be changed accordingly. But where a community's needs have not changed, and where a preservative-treated wooden structure has been properly erected and maintained, wooden piling has shown its advantages of economy and reliability.

Concrete piling is probably wooden piling's most serious competitor. Its advantages are a greater degree of permanence, and a lower fire hazard. However, these are offset by a cost of about three times that of creosoted piling, considerably higher erection costs, and even higher demolition costs when this is necessary. It also requires that the designer be able to estimate with confidence the requirements of his client over another half-century or more.

Some criticism has recently been levelled at creosote because in tropical and semi-tropical waters it has been reported to be attacked by a wood borer, Limnoria tripunctata. Although this borer was recently found in the Strait of Georgia, it apparently has not attacked wood treated with recommended retentions of creosote in these waters. This is probably because it has a perilous existence in our colder climate, and cannot tolerate any additional unfavourable conditions. It is possible that L. tripunctata is no more a hazard locally than is our indigenous species L. lignorum. Nevertheless, the attacking of creosoted material in tropical waters points out that creosote is not necessarily the best preservative that will ever be developed, and it is with this critical attitude that we must look to the future.

The Future of Preservatives for Wooden Marine Structures

Two main factors must be considered in thinking of preservatives for the future: the need for a better preservative, and the future availability of creosote. As has already been stated, creosote is a by-product in converting coal to coke for the smelting of iron ore. But considerable research has been done in the steel industry to reduce ores using natural gas or high-grade coal to replace part of the coke. Such methods are now in commercial use, though not throughout the entire industry. It has been demonstrated that with these new techniques, 50 per cent higher production of steel can be achieved in present equipment, using 40 per cent less coke per ton. A similar reduction in creosote production would be expected.

While creosote will be in shorter supply than at present, it will continue to be in demand by the chemical industry for the production of chemicals used in plastics, dyes, and other chemical products. The amount diverted to these products may be expected to increase. A complicating factor here is the lower quantities to be used in wood preservation. For the last 40 years, creosote's greatest use has been in the treatment of railway ties, but here the wood preservation industry has worked itself out of a market. As the railways were converted to the use of creosoted ties, these have lasted an average of 40 years, and the demand for replacements has dropped off. The creosote producers are therefore promoting new uses, which in the future will compete for the available creosote, making less available for preservation.

For these reasons, interested research laboratories are conducting exposure tests of possible new preservatives. The U.S. Navy and the Forest Products Research Branch (Canada) are both active in this field. The U.S. Navy has had hundreds of chemicals under test for over three years, and many more years will be required for their complete evaluation.

One of the most promising of these new compounds is tributyl tin oxide. It has proved very effective against Teredo in California at solids retentions of 1/4 lb. per cu. ft., but it is attacked by Limnoria in Hawaiian waters within six months. On the other hand, the inclusion of certain insect-icides such as endrin and dieldrin in tributyl tin oxide formulations gives protection against all types of borers.

These compounds are quite expensive at the present time, but they have some very distinct advantages: they are very resistant to fouling by barnacles and other marine organisms, and they do not change the appearance of the wood. They are clean compounds that can be painted over as soon as the solvent evaporates. Because of the low loadings required, they can be used on float logs without affecting their buoyancy.

The tests conducted by the Forest Products Research Branch are not nearly so extensive, nor have they been exposed so long. They were set up just about a year ago, and include two types of creosote, and these creosotes combined with coal tar, five chromium-fixed salts, compounds of pentachlorophenol, and of uranium, and copper and zinc naphthenates, as well as tributyl tin oxide and this compound with an insecticide. Several of the materials have failed already, but most compounds look quite good after a year's exposure.

The formulations which have so far been attacked are: Wolman salt, the metallic salts of pentachlorophenol, the uranium salts of naphthenic acid and pentachlorophenol, and zinc naphthenate.

The four creosote and creosote-coal tar mixtures have not been attacked. Tributyl tin oxide looks very good, and so do the various chromium-fixed compounds, including Boliden K-33. Incidentally, this last compound is also being tested by the B.C. Research Council in San Francisco Bay, and is showing up well after over a year's exposure.

In British Columbia, where there is a good supply of suitable material, the advantages of wooden piling will continue to recommend it for marine construction, but we can expect longer life from these structures as present preservatives are improved, as better preservatives are developed, and as better handling and construction techniques are practised.

DISCUSSION PERIOD AFTER MR. G. BRAMHALL'S PAPER

Mr. W.G. Garry, Royal Canadian Navy, Esquimalt: Have you examined any of these protective envelopes that we are getting pushed at us? Some of these polyvinyls, sheath coverings, and anything of that nature.

Mr. Bramhall: We haven't examined them as yet. I hope this summer we will be able to get some of these and try them out.

Mr. W.M. Dierden, Elk Falls Co.: We have one pile at Elk Falls which was covered with this PVC coat you mentioned over a year ago--I think it was a year ago last February. It has been tested for oxygen content at odd intervals by the people who installed it. The oxygen content is away below that which would support marine life.

Dr. Gardner: What does PVC stand for?

Mr. Dierden: Sixty-mil black PVC covering installed from above the surface with the joints formed by laps at either end of the PVC covering and then twisted together, tightened up, and nailed with monel nails onto the pile.

Dr. Gardner: Have you any experience, Sir, that you could tell us about?

Mr. Garry: We tried an installation of our own, but mechanical damage was the problem. It is too tender for our purposes.

Question: Was this TBTO pressure-impregnated?

Mr. Bramhall: Yes, we pressure-impregnated it.

Mr. McGowan: What temperatures did you use, George, with TBTO?

Mr. Bramhall: At the present time, we have only treated small samples in which we have run them cold. But it is a question of your solvent. One of the reasons for creosoting hot is to reduce the viscosity and improve the penetration. Another is to remove moisture from the wood. There are several considerations in deciding on the temperature to be used.

Question: Have you added dieldrin to creosote?

Mr. Bramhall: We haven't tried it, but we may do so this year.

Question: Has there been any attempt made to test the encapsulation of a wood pile with a plastic resin?

Mr. Bramhall: I don't know about it. No.

Dr. P.C. Trussel, B.C. Research Council: Fibreglass has been used. It is very expensive but it works.

Dr. Gardner: The thing about the plastic foil or fibre, whether applied as foil or sprayed on, as the gentleman from the Navy points out, is the mechanical breakage of it. The minute you break in you are back in trouble again.

Dr. Trussell: George, on these Muntz-metal coated piles at Evans-Coleman & Evans Wharf, how many still have the sheathing on? Any?

Mr. Bramhall: Yes, practically all of them but they are puncturedin many places. In 1949 they removed two or three for a matter of general interest. This was before we were interested at the Vancouver Laboratory so they sent some of the samples back to our Ottawa laboratory where they were analysed. They found that the copper had dissolved in the sea water, penetrated to about 1/8 of an inch, then reprecipitated. So the outer 1/8 inch was loaded with copper salt.

Dr. Trussell: I realized this and that's why I asked whether the sheathing was still on.

Mr. Bramhall: Yes--that particular pile which is on display came out of their wharf in 1957. This was a result of collision by a mooring ship which went ahead instead of going in reverse. I went down there and got this section of pile.

Question: With sheathing, if there is any crack or hole formed you could easily get attack, but I notice that this one has holes in it, but presumably no attack. This copper precipitation must be quite potent. Another question

I have is, have you tried lindane?

Mr. Bramhall: We haven't tried it--the U.S. Navy has, and apparently that is quite effective too. In my paper, I gave only a few examples rather than the complete picture.

Question: I think they are trying it in Germany right now.

Question: Have you had any experience with poisons--various types of poisons? To treat the whole area around the wharf or in particular these bore holes and such?

Mr. Bramhall: The whole question of preservatives is one of poison. We don't normally use the term, but creosote, copper salts, zinc salts, arsenic salts, they are all used and they are all poisonous.

Question: How about treating the whole area?

Dr. Gardner: Treating the water?

Dr. Quayle: The Department of Fisheries would no doubt be concerned with such a procedure.

Dr. Gardner: I wonder if the question is understood.

Question: Well I know it has been done to treat rot and such like, and if this has been done extensively well what would be the difference .....

Mr. Bramhall: Well, it is just that it is so temporary. In the case of log rafts you only need protection for three to six months, say, but in the case of a marine structure you are looking for thirty to forty years life and repeated treatment every six months or so is just not economical.

Mr. Corbett: I think it is being done in a number of installations by the B.C. Toll Authority. Their floating wharves at Horseshoe Bay, Earl's Cove and Saltery Bay are examples. Every six months they treat these structures with an arsenite spray.

Dr. Walden: There are a number of installations. They are largely floating installations which are being treated twice a year, and they are largely constructed of untreated logs, green logs, where buoyancy is paramount. There are techniques worked out whereby we can sprinkle them much in the same manner that log rafts are sprinkled. In some instances they can be enrobed in polythene and treated with the same chemical, which is sodium arsenite. These are structures which would be replaced every two years, but with untreated materials.

Mr. Bramhall: This is a possible use for TBTO where the concentration of chemical is so low it wouldn't affect the buoyancy after the solvent has dried out. This, of course, is still in the future.

Mr. S.S. Martin, Imperial Oil: You mentioned that in the use of TBTO, there were no barnacles adhering. Is there any relationship between the barnacle adhesion to wooden piling and the various marine borers?

Mr. Bramhall: Dr. Quayle, would you answer that?

Dr. Quayle: Really not. If you have a heavy enough barnacle set on a piece of wood it will inhibit the settlement of the other borers, but the season for barnacles, depending on circumstances, may not last for a very long time.

Mr. Bramhall: Does the fact that it is resistant to barnacles give any indication that it is resistant to Bankia?

Dr. Quayle: There is a general correlation, but there are some chemicals that are quite specific for crustaceans and do not affect lamellibranchs.

Question: My question was really based on the carrying of the larvae of the marine borers. Is it in any way related to barnacles or any other crustacean adhering to a piling?

Dr. Quayle: There is no relation.

Mr. Dierden: Has there been any investigation into electronic devices either for repelling or killing larva as they approach the deck outside of electric fish barriers?

Mr. Bramhall: Not of that type, but quite a few years ago they tried the electrolysis of the water to liberate chlorine, but it was harder on the observers than it was on the teredos.

Dr. Trussell: We have tried killing them with AC and DC and also by chlorine generation by electrolysis. These methods are impractical. We are dealing here with imbedded borers which can "hole up" and thereby be protected in the wood.

Mr. Dierden: Would ultra sonics have any effect on them?

Dr. Trussell: If you provided enough energy it would probably blast the wood to pieces before it would kill all the borers. Just to give you an illustration we experimented with dynamite a few years ago. We used two pounds of dynamite placed ten or twelve feet below the raft; this was about as close as we could get without seriously damaging the structures. A charge of that sort would result in about 75 per cent kill of the borers. The next day 25 per cent were still active, which would mean several hundred per square foot. Thus the ability of the borers to protect themselves is quite substantial. The surface of the log I might add could be splintered and yet the animals would be extending their syphons out beyond these splinters and still be in business.

Mr. P.D. Christerson, Amerioan Wood Preservers' Institute: Some of the group may be interested in the approach taken to this problem in the United States from the standpoint of marine piling. I think most of you are familiar with the fact that there have been failures--our U.S. Navy was certainly aware of the problem, especially at Ford Island, Pearl Harbour, Guantanamo Bay and at the Panama Canal. They actually told our industry that until such time as we could produce a dependable product, they were going to use alternate materials. So with that urging, in co-operation with the treating industry and the Department of Commerce, it was determined that new specifications must be established. Over the last few years, new Commercial standards have been developed and published by the Department of Commerce, working in co-operation with our industry, the Navy, and the Forest Products Laboratory at Madison, Wisconsin. Separate specifications have been established for fir and southern yellow pine. These are "results-type specifications" where you can take the finished products and determine the amount of preservative in there.

Now it is very new in concept. Here for the first time one specification includes the quality of the untreated pile, provides all the details concerning treatment, inspection and buyer's privileges. The changes actually require a broader selection of material. And while I am explaining these I am not inferring that this is necessary in Canada and in British Columbia, I am just explaining it because you will undoubtedly hear reference to the policing action the industry has taken as we go on. They have established newer and different preservatives, higher in aromatics. They have established deeper retentions, penetrations and in the case of Douglas fir, a minimum of 20 lb. per cu. ft. in the outer two inches. These retentions are determined by assay rather than by tank gauge readings. Privileges for the buyer for his re-inspection rights are established.

The American Wood Preservers' Institute established a subsidiary corporation, The American Wood Preservers' Bureau, which is the policing organization. By qualifying plants and inspection personnel and by inspecting piling, the Bureau ensures that piles bearing its warranty meet at least the minimum standards. This is actually the best piling that the industry knows how to produce. With that now the Navy has prepared new military specifications for their Bureau of Yards and Docks, stating that these are the piling according to those commercial standards and bearing the AWPI quality mark that they will be using. That is starting--in fact it started in recent months--recapturing of the market especially in Southern California and the Gulf States with the Federal Government. Anyone that has questions or wishes to write for copies of the commercial standard, may contact us.

Dr. Gardner: That is the American Wood Preservers' Institute in Chicago?

Mr. Christerson: In Chicago or Portland. Our address there is with the West Coast Lumbermen's Association. A note addressed to AWPI, in care of West Coast Lumbermen's Association, Portland, will get us.

Dr. Gardner: Has there been any change in the fractionation of creosote over the years?

Mr. Bramhall: Yes. There have been changes from time to time. From the earliest times there has been a demand by the chemical industry for starting products for plastics, dyes, drugs and so on.

Dr. Gardner: What is the criterion of toxicity of creosote?

Mr. Bramhall: Toxicity as such is not defined in the specifications. It is defined according to boiling ranges and specific gravities of particular fractions.

Dr. Gardner: But no toxic threshold has been established?

Mr. Bramhall: Oh yes, it is well established, but not in the specifications. Providing it comes within the specifications, creosote has always done a good job ..... But the specifications have nothing to do with toxicity, they are based on specific gravity, boiling range, and the coal-tar source of the creosote.

Mr. Christerson: There are several different grades of creosote. The commercial standards specify a grade three which defines various fractions in such a manner as will provide creosote high in aromatics. You must consider that aromaticity has a relationship to toxicity against marine borers, not directly proportional, but approximately proportional in accordance with the square of the aromatics present. Because it does have a relation, this is recognized by requiring, for marine use, the particular Grade 3 creosote defined by our Federal Specifications.

Dr. Gardner: In the case of these marine organisms, is the protection provided by creosote a mechanical one, a fouling one, or is it toxicity?

Mr. Bramhall: Toxicity.

Mr. Christerson: There are various views, we have had people from our Gulf States that have indicated that a good preservative that has proven well is creosote mixed with coal tar solutions. The contention, shared by Ralph Mann, who was cited earlier as being an authority, was that the added mechanical advantage brought about by mixing coal tar with creosote was helpful in addition to the toxicity.

Dr. Gardner: I am thinking about research and what should and what shouldn't be done. Has there been any work done to establish which fraction is most toxic?

Mr. Bramhall: The U.S. Forest Products Laboratory has done a tremendous amount of work on that.

Dr. Gardner: It is well covered?

Mr. Bramhall: Many different compounds are responsible for toxicity, and a mixture is always better than any one separately. The large number of ingredients in creosote aids toxicity.

Mr. Dierden: Has there been any investigation into the equivalent of systemic insecticides?

Dr. Gardner: You mean feeding the tree something that would make it unpalatable?

Mr. Dierden: Yes, you would feed the tree this and it would absorb some fraction of something that would make it unpalatable. It's rather far out, but I know systemic insecticides are being investigated.

Dr. Gardner: That's an interesting possibility.

Dr. Quayle: There was an investigation conducted by a chap here at the university on the injection of sodium arsenite for debarking. However, I tested the wood at Ladysmith with the hope that perhaps there was enough remaining in the wood to inhibit marine borers, but Bankia ate it up.

Mr. B. Sivak, U.B.C. Student: This has been done in forest pathology against parasitic plants on trees. They inject the chemical into the bole of the tree and it is distributed by the water stream. It has been very successful.

Dr. Gardner: Well certainly it is theoretically possible, but I don't know whether we have at the present time a poison that would be toxic enough to get in there at appropriate levels.

Mr. Dierden: Isn't it also a change of thinking from silviculture to arborculture?

Dr. Gardner: I grant you.

Question: What is the property of gumwood that makes it so good?

Mr. Bramhall: It contains silica; to put it very crudely, the teredo wears its teeth down before it can wear the wood down.

Dr. Gardner: Several Australian species have a fairly high content of silica and you will find that practically every species grown in Australia and in that part of the world has been thoroughly examined for its silica content, hoping they would find another species with a high silica content and then have another resistant species.

Question: Could silica be used as a treatment.

Dr. Gardner: It is a case of getting it in there and then stabilizing it there. This is a problem that people interested in fire retardants are working on presently.

Dr. Walden: There were two Australian investigators by the name of Amos and Tack who tried this by sequential impregnation and it worked reasonably well, but it was never used commercially. At the Research Council, we have prepared plywood with silica in the glue-lines which also resists attack very well, but has never reached the commercial development stage.

Dr. Gardner: One thing about the silica in plywood--I can remember it was good against the teredos, but it was also good against the saws.

Question: A question about dock inspection. After the pile driving people have completed a dock, are there any efforts to inspect the piling beneath the dock under water before it is accepted by the company?

Mr. Corbett: Not usually. I have not run into it.

Question: Would it be a useful practice, because it would be the only way to tell if a pile were over-driven.

Mr. Dodge: It probably could be, but you wouldn't be very successful in finding that they had been over-driven, and also it would not be as much value as proper inspection at the top and during driving.

Question: I have a question for Mr. Corbett. You mentioned the failure of piling on which the tips had been cut off--driven into quarried rock, which I understand has very sharp edges. Because a point of your paper was to avoid driving sharp objects into piles while they are at the surface. Is this not doing the same thing under water?

Mr. Corbett: Yes, I would say that it is poor practice, but there are cases where it is done. Maybe not so much in quarried rock, but quite often attempts are made to drive a pile into broken bed rock. Sometimes they haven't made any investigation of the site, and are not aware of the rock, or sometimes they just sit a post on the rock.

Dr. Gardner: I think we are all indebted to our speakers today. They have done a good deal of work to prepare material for you. They have answered your questions as best they can, and I think you have had an opportunity in the breaks and at noon to have some discussion, meet your competitors and meet your friends. Any way you look at it, it's a good idea to talk about what we're doing--the good parts about it, the bad parts about it, and what we should do in the future. So I think with this successful day behind us, we can look forward to having a similar symposium going on from here next year or the year after. I don't know what the father-organization behind this symposium has in mind, but maybe some of us can influence them to have another one if you wish it. In the meantime, thank you very much for coming.