THE PRESERVATIVE TREATED UTILITY POLE IN SERVICE

RESEARCH AND EXPERIENCES IN SWEDEN

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INTRODUCTION AND BACKGROUND

The industrial impregnation of utility poles in Sweden started in 1859 when two plants for Boucherie-treatment were opened. In 1900 creosote treatment of poles started. Creosote treatment increased gradually while the Boucherie treatment with copper sulphate decreased, the last plant closing in 1944.

Initially a full cell process was used for creosote, but later during the 1920's the Rüping process took over. During the 1930's the Scandinavian specifications for creosote were introduced to standardize the earlier formulations which were of a varying undefined quality. Subsequently in the 1930's various shale oils replaced creosote to some extent.

Water soluble preservatives for vacuum/pressure treatment of poles were used only to a limited extent before World War II, with certain preservative salts of the U- and UA-type imported from Germany. However, after the outbreak of World War II the import of these was restricted or completely blocked, so neither creosote nor imported salt preservatives were available for some time.

Development of a domestic wood preservative was intensified and the Boliden BIS was soon marketed. This preservative contained zinc, chrome and arsenic. Between 1941 and 1945 Boliden BIS was almost the only preservative used in Sweden. After the war creosote treatment of poles was restarted. However, from then on creosote had to compete with the water soluble "salt" preservatives.

The BIS-salt was replaced in 1954-57 by three other Boliden preservatives, S, S25 and K33. These were all oxide formulations - S contained zinc/chrome/arsenic, S25 zinc/copper/chrome/arsenic and K33 copper/chrome/arsenic. S and S25 were only used to a limited extent and Boliden K33 soon became the dominating waterborne preservative for the treatment of poles. However, other CCA-preservatives as well as the copper/chrome/boron types have been and are in current use for poles (Figure 1).

It is estimated that approximately nine million utility poles are in service in Sweden at present. Of these four million are creosoted, three million BIS treated and two million CCA-treated. A relatively small number of poles are treated with CC and CBC or with S25 and S,

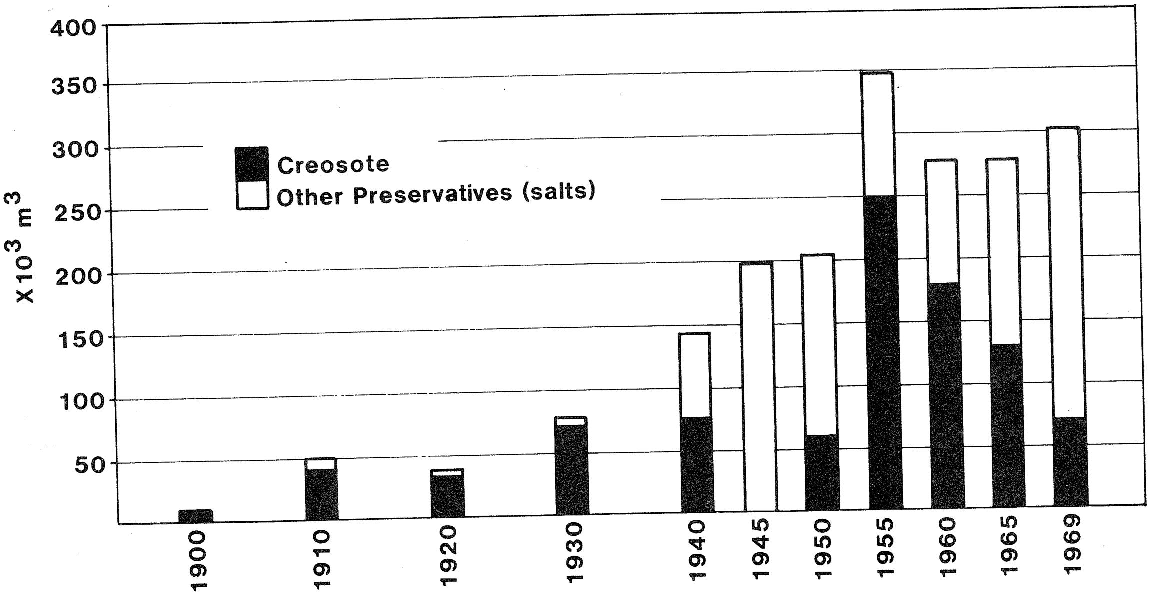

Figure 1. Quantities of Pressure Treated Wood 1900-1969

while a very limited number treated in the early 1940's with U- and UA-salts are still in service.

Of the four million creosoted poles in service approximately one third are from the period before 1940. A few full cell treated creosote poles from the early 20th century are also still found in some lines.

As regards wood species the Swedish situation is simple: Baltic redwood (<u>Pinus sylvestris</u> L.) has almost exclusively been used for poles. This wood species has a very permeable sapwood and a fairly impermeable but moderately resistant heartwood. In broad terms the relation between sap and heart is 50:50 on a volume basis.

The Swedish wood preservation industry has produced between 80,000 and 100,000 m^3 utility poles per year in the last 15-year period. Of this quantity between 10 - 20,000 m^3 have been exported annually. So, for a long period there has been a constant domestic need for 60 - 80,000 m^3 of preservative treated utility poles.

In 1981 the impregnation of poles reached 86,000 m^3 of which 49,000 m^3 were treated with creosote and 37,000 m^3 with waterborne preservatives (Swedish Wood Preservation Institute, 1982). In recent years an increasing interest for creosote has been observed among the major pole users. It is claimed that a longer average life is achieved with creosoted rather than CCA-treated poles. Further, from an occupational safety point of view old creosoted poles are safer to climb than "salt" treated poles. The reason is that "salt" treated poles are ultimately attacked by mainly soft rot. At bending, a soft rotted pole will break suddenly and without warning resulting in a "carrot-type fracture" (Figure 2). In contrast creosoted poles will most likely be attacked in the inner parts by traditional rot fungi (Basidiomycetes) and will therefore break slowly with a lot of "warning" noise, resulting in a very split fracture.

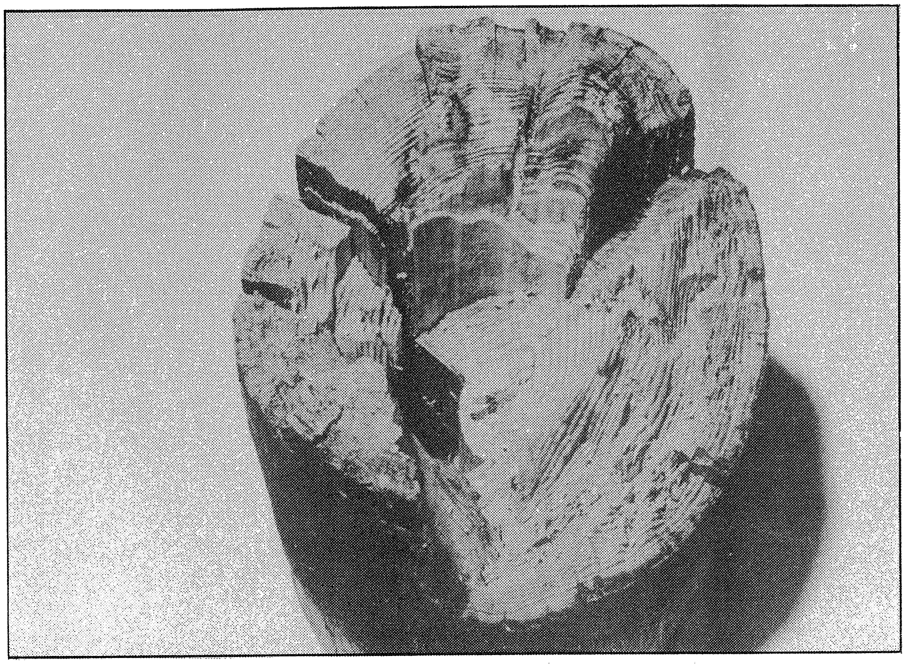

Figure 2. Fracture of a Broken BIS-Pole After 25 Years in Service

SOFT ROT IN POLES IN SERVICE

It became evident at the beginning of the 1970's that the BIS-treated poles installed during World War II were suffering from severe soft rot decay. A comprehensive co-operative investigation was presented in 1976 (Henningsson et al.), after a number of aspects from the problem had been thoroughly studied and discussed.

One aim of the study was to obtain a clearer understanding of how the soft rot attack proceeded and which organisms were responsible. It was of further interest to try to find climatic and environmental factors that influenced the development of soft rot in salt treated poles. By correlating microscopic observations, laboratory strength tests, and full scale strength tests of poles in service, it was also possible to find a method and a formula for determining the residual strength of a soft rot attacked utility pole. Guidelines for the inspection of salt-treated poles were finally worked out. A prototype of a new instrument to measure the depth of soft rot in standing poles was also tested.

The most frequently occurring soft rot fungi proved to be certain *Phialophora* species especially *Phialophora hoffmannii* (Table 1). This group has been shown repeatedly to contain the most important soft rot fungi in preservative treated wood, both in ground contact and elsewhere (Henningsson and Nilsson, 1976; Nilsson and Henningsson, 1978; Fougerousse, 1976 and Gersonde and Kerner-Gang, 1976). The *Phialophora*'s attack softwoods as well as hardwoods and certain species have also shown a significant resistance to wood preservative chemicals.

Table 1

Frequency of *Phialophora* Species and other Fungal Isolates in Pine and Beech Posts Exposed at Bogesund for Two Years

Post No.	Treatment (% CCA)	Wood Species	Number of Samples	Total Number of Fungal isolates	Total Number of *Phialophora* spp.	Total Number of other fungal isolates
153	Control	Pine	77	119	15 (12.6%)	104 (87.4%)
3	0.5	Pine	77	68	29 (42.6%)	39 (57.4%)
42	1.0	Pine	57	68	42 (61.8%)	26 (38.2%)
72	2.0	Pine	69	76	17 (22.4%)	59 (77.6%)
288	Control	Beech	79	136	29 (21.3%)	107 (78.7%)
258	0.5	Beech	88	169	113 (66.9%)	56 (33.1%)
234	1.0	Beech	70	144	110 (76.4%)	34 (23.6%)
212	2.0	Beech	71	140	105 (75.0%)	35 (25.0%)

The combined laboratory strength tests and microscopic studies of BIS-poles showed that progressive soft rot decay of wood caused decreasing strength properties and elasticity which eventually resulted in a reduction of its tensile strength of 88 - 92 percent (Figure 3). It was further demonstrated that a five percent reduction of the secondary wall substance as seen under the microscope - corresponding to a one percent weight loss - resulted in a 25 percent reduction in tensile strength.

A formula for predicting the modulus of rupture for soft rot attacked pine poles was also presented. The formula requires information concerning 1) the average modulus of rupture of a non-decayed pole and 2) the soft rot situation in the worst cross section of the decayed pole as observed under the microscope. The results obtained by using the formula were compared with the actual moduli of rupture determined in full scale strength tests on the poles. Surprisingly good correlations were found.

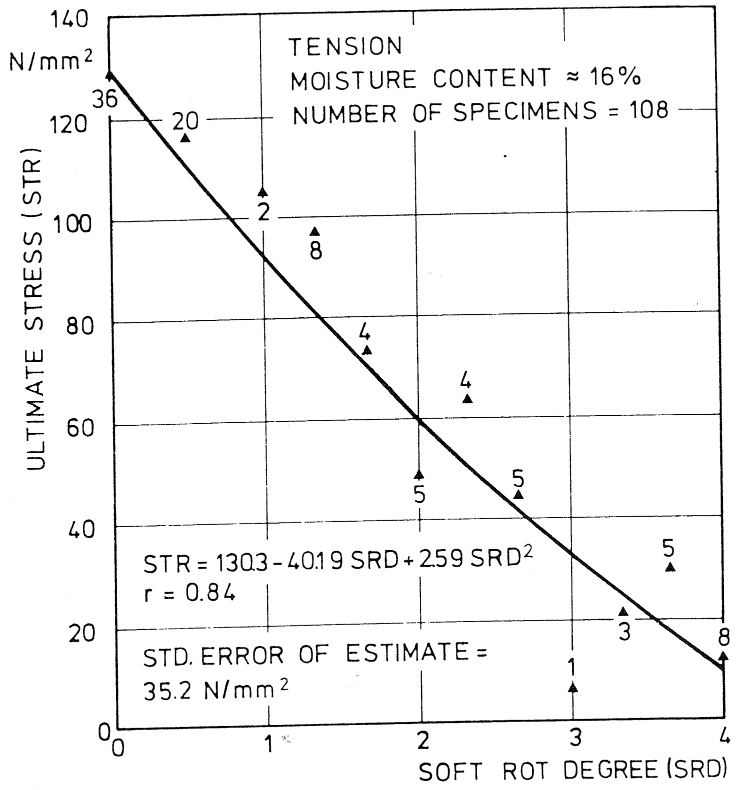

Figure 3. Regression of Soft Rot Degree on Ultimate Tensile Stress

Since soft rot advances from the periphery inwards, the effect of attack on a pole can be described in terms of diameter reduction. This measure was easily understood and accepted by pole users and has consequently been used widely since.

Of the environmental conditions influencing the development of soft rot in BIS-poles, the (nutrient) status of the soil has proved to have a major influence. Soft rot proceeded much faster in cultivated soil than in woodland or in moors (Table 2).

Table 2.

Average Diameter Reduction in Salt-Treated Poles from the years 1944 - 1946 (after Friis-Hansen, 1976)

Environment	Number of poles	Average diameter (mm)	Average diameter reduction (mm)
Cultivated soil	283	226	49
Woodland	347	228	22
Moor	160	224	14

In a more recent study by L. Schmidt (1981) it was shown that the annual diameter reduction of old BIS-treated poles in southern Sweden was on average about two millimeters. This means that the diameter is reduced by 16 mm within an inspection period of eight years, which corresponds to a reduction in bending strength of 22 percent for a pole with a 200 mm sound diameter.

In the 1976 study, which involved nearly 700 poles, the most severe soft rot was found in a zone from the ground level down to 100 mm in poles in cultivated land, and down to 150 - 200 mm in woodland. This difference may be explained by the observation that the commonly used backfill of rock stays clean for long periods in woodland while the spaces between the rocks are soon filled with top soil in cultivated land.

There was also a correlation between the development of soft rot in poles and climate. In the northern parts of the country less than 10 percent of the inspected poles had to be rejected because of severe soft rot while the corresponding figure in the southernmost parts varied between 15 - 90 percent.

Approximately 90 poles were strength tested in the field. A line was attached to the top of the pole, the line was wound back and the failure load determined on a dynamometer inserted in the line closest to the winder. The actual failure load was then compared with calculated failure loads obtained by indirect methods including - poking, visual and microscopic examination of bore samples and Pilodyn testing. Results obtained with the poking method and Pilodyn testing corresponded fairly well with those of the actual strength test in the field.

It is generally accepted that creosoted poles do not suffer from soft rot. This is, however, not always true. Soft rot is sometimes found in creosoted poles after 20 years or more in service and in special cases can be common (Table 3). For example, in a field experiment

Table 3

		Index of Decay	
Oil No.	Type	Simlangsdalen*	Stürzelberg**
1	Heavy	0	0.7
2	Heavy	0.7	0
3		1.3	6.6
4		2.5	3.3
5	Light	20.6	9.9
6		0	0.7

*22 years exposure
**24 years exposure

with poles treated with various types of creosote oil set up by the Western European Institute for Wood Preservation, severe soft rot to depths of 20 - 30 mm from the pole surface was observed after 22 years in service with poles treated with one so-called low-boiling type of creosote. Also severe soft rot has been observed in creosoted poles placed in highly fertilized soil and when in contact with manure.

CCA-treated poles in service have been more thoroughly studied in recent years. In Sweden these poles have usually been treated with Boliden K33 from 1955 and onward. There are indications that soft rot may sometimes occur in the inner parts of the sapwood, although the outer parts may be completely free from any attack (Friis-Hansen, 1982). A certain number of these cases may be attributed to impregnation failure or poor preservative distribution as shown by chemical analyses. However, in other cases the penetration and retention of the preservative was adequate.

It is known that preservative treated wood in contact with the ground, like utility poles, is colonized by soft rot fungi shortly after installation (Figure 4). However, even if mycelia of soft rot fungi are present in the treated wood at an early stage, degradation of fibre cell walls will not take place for many years.

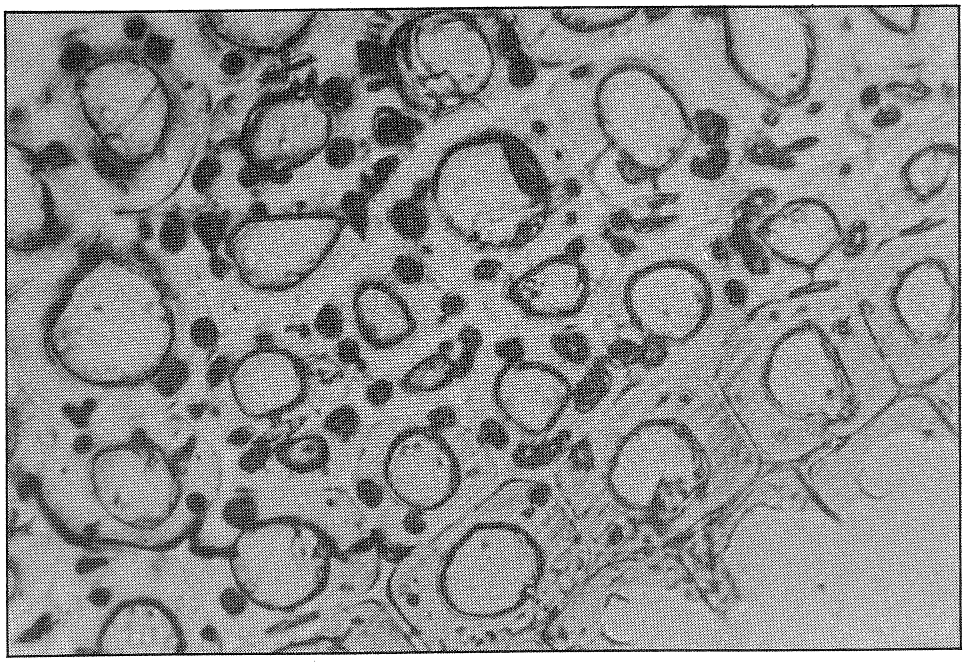

Figure 4. Soft Rot (Rhinocladiella) in Pine Sapwood After 92 Days in Test

This early colonization gives the soft rot fungi the chance to start an attack in the wood wherever the amount of preservative is below the toxic threshold. This indicates that the quality of impregnation is of great importance, particularly when highly fixed preservatives are used.

PRE-TREATMENT DECAY

This phenomenon has attracted increasing interest in recent years as a result of the intensified inspection of poles in service. In a number of cases it seems clear that poles which have failed in service, or have been rejected due to decay when inspected, must have been decayed before they were treated. It is, of course, not always possible to decide when the decay took place. However, the type of decay and the pattern in which it has advanced into the wood usually gives an experienced mycologist the necessary information.

During handling, transport and storage of poles there are several critical periods when infection can take place. The pole must not remain too long in the forest after felling with its bark on, since it will be attacked by bark beetles and even incipient decay may occur. In Scandinavia poles should be cut during the winter period, transported to the impregnation plant and debarked. Debarking in the forest or at special "barking" terminals may also be employed. Immediately before impregnation the outermost layers of the poles are turned off.

Most impregnation plants store their barked poles in open stacks for one year. During this period the poles are slowly seasoned and become "ripe" as they are referred to in the preservation industy. This "ripening" means that a sufficient number of bordered pits are open to allow for a good penetration of the preservative during the impregnation process.

To a limited extent water sprays or ponding are used to improve the permeability and reduce creosote bleeding. One month's ponding or two month's water spraying in late spring and early summer is recommended. After these "extra" water treatments the poles need to be stored until the following spring before they can be preservative treated.

During this long period of storage conditions may arise which promote decay, the hazard increasing with time. Under no circumstances should poles be stored longer than one year at the impregnation plant before preservative treatment. A second summer's storage of untreated poles may be disastrous.

As a consequence of the long period of handling and storage between the felling of trees and preservative treatment of poles cut from the trees it is necessary for the industry to be more careful and attentive than when dealing with treatment of other commodities which do not require such a long seasoning period.

THE CREOSOTE TREATED POLE

Creosoted poles have, according to experience, a long service life. In Scandinavia a creosoted pine pole is expected to last on average for 50 or more years. It is normally not significantly attacked by soft rot fungi. If it is decayed, then the attack is mainly of an interior type and caused by Basidiomycetes. The sapwood close to the heartwood, which has received less preservative than the outer sapwood, or the heartwood itself may be attacked. The most common decay fungus in these situations is the brown rot fungus Lentinus lepideus (Fr.) Fr., which is regarded to be fairly resistant to phenolic substances like pinosylvins occuring in pine heartwood or various phenolic compounds of the creosote itself. Laboratory tests have shown L. lepideus to attack sapwood and heartwood of Baltic redwood, (Pinus sylvestris) to about the same extent (Bechgaard et al., 1979; Rennerfelt, 1949). The fungus is further able to withstand dry periods without difficulties (Seehan and Liese, 1981), so it is well adapted to conditions within creosoted poles.

The internal decay often leads to a hollow pole. This affects the bending strength to a much lesser degree than if the decay had advanced inwards from the periphery, which in principle results in a reduction in pole diameter.

Once the internal cavity has been formed, further expansion has been shown to proceed very slowly. A recent investigation including a number of creosoted poles from 1930 with advanced internal decay was first presented by L. Schmidt in a seminar in Stockholm. The poles were thoroughly inspected in 1972, 1976 and 1980. During this period the decay mainly advanced inwards towards the center of the poles while the decay in the opposite direction had advanced very slowly or had stopped completely. The outer shell of sound wood was reduced somewhat in the first four-year period, indicating an inferior impregnation of the inner sapwood. The decay had then stopped on contact with wood with higher creosote retentions.

As was indicated above a creosoted pole with internal decay and an outer shell of sound wood will not break abruptly when a load is applied. The creosoted outer shell contains surprisingly tough wood which will withstand substantial bending and the pole will ultimately break as a result of a series of fractures, a process that takes considerable time. This is considered an advantage from the safety point of view for linesmen working on poles.

The major disadvantage with creosoted poles is bleeding, a process which is not fully understood. According to certain findings, however, creosote is trapped in springwood tracheids during the impregnation process. This trapped creosote may stay under pressure for long periods but will squeeze out to the pole surface when the temperature changes in the wood (Bosshard, 1965). Bleeding is especially pronounced in clear weather in early spring when temperatures in the outer wood layers change from below zero at night to 40 - 60°C in daytime, when the sun is shining intensively.

Creosote may cause skin irritation, which occasionally may be severe. Skin contact with creosote in combination with exposure to sunlight (UV-light) may result in a photo-toxic contact eczema. This is an obvious risk for workers that have to climb poles which are bleeding heavily.

To reduce creosote bleeding several measures have been tried with varying success, including: steaming before and during treatment, treatment with volatile solvents, and water spraying or ponding of the fresh poles before treatment (Lacey et al., 1957; Wells and Bordenca, 1955; Leach et al., 1957 and Banks, 1970). In Sweden several studies on the effect of water spraying or ponding before treatment were presented in the 1970's (Bergman et al., 1975 and Boutelje et al., 1977 and Bergman and Martinsson, 1979). It was shown that water storage for fresh poles for one month, or water spraying for two months before seasoning and treatment, substantially reduced creosote bleeding (Figure 5). However, bleeding could not be completely controlled, mainly because the breakdown of the bordered pits is dependent on the uncontrolled invasion and activity of a natural bacteria flora.

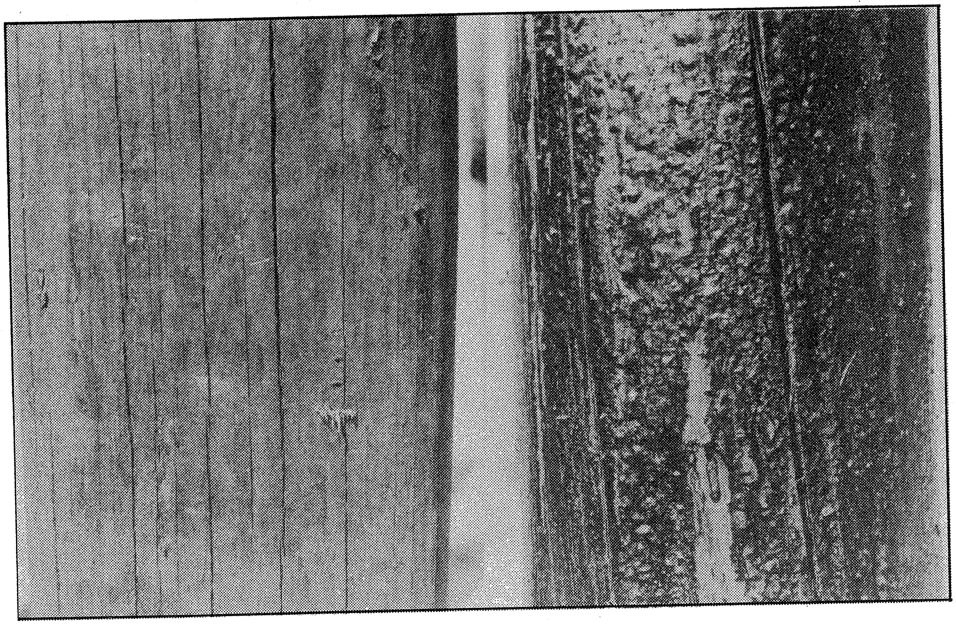

Figure 5. The Surface of Two Poles Treated with Creosote and Exposed for 6 Months in the Field. The Pole to the Left was Water Sprayed for 2 Months Immediately After Debarking and Then Dried. The Pole to the Right was Dried Immediately After Barking

The effect of water spraying on creosote bleeding was recently studied in a full scale field test. The study was made during 1979 - 1982 and included as many as 1,450 full size poles, some of which were sprayed for two months with water from a lake and then seasoned for 12 months before creosote treatment (Jermer and Severin, 1982). At final inspection, 17 months after the creosote treatment, about 70 percent of the water sprayed poles were free from bleeding while the corresponding figure for non-sprayed poles was 20 percent. This study confirmed that creosote bleeding could be substantially reduced, but not completely prevented, by water spraying.

It has also been suggested that the use of low viscosity creosote oils could be advantageous in reducing bleeding. It is, however, necessary to ensure that the wood preserving effect of these low viscosity (low boiling) creosotes is not inferior to that of creosotes traditionally used for impregnation of utility poles. There are indications that this might be the case. In 1955 the Western European Institute for Wood Preservation (WEI) started a full scale field test with Scots pine (Pinus sylvestris) poles impregnated with several different types of creosote. When these poles were inspected 23 years after installation extensive soft rot was found in poles treated with one type of low viscosity creosote. Severe soft rot had penetrated to a depth of more than 20 mm from the surface in a zone immediately below the groundline.

THE "SALT"-TREATED POLE

Poles treated with modern CCA-preservatives are also expected to have a long service life. Field tests with stakes, posts and poles indicate that a well treated CCA-pole may last as long as a treated creosote pole, even under severe conditions. However, as stated earlier, soft rot attack due to poor treatment and pre-treatment decay has recently been observed in CCA-poles.

As a result of high and rapid fixation of the active components in the wood, soft rot fungi may grow through the sapwood and start their attack on the wood fibres in the inner parts of the sapwood which received less preservative during the impregnation process (Friis-Hansen, 1982). However, these indications of internal soft rot decay in CCA-treated poles are only very preliminary and the risk must not be exaggerated at this stage.

In contrast to creosoted poles "salt" treated poles are always clean. This is greatly appreciated by workers, who have to handle and climb poles and a definite advantage when creosote and "salt" are compared and evaluated.

More recently the effect of increasing acidification on the precipitation and leaching of CCA has been under discussion in Sweden. This seems limited to a potential problem at the impregnation plants where often substantial amounts of chrome and arsenic may be deposited in the ground as a result of decades of wood preservation activity. However, the long term effect of possible excessive leaching from a treated pole on it's durability has also been considered. Results from field tests with preservative treated wood samples from areas experiencing a very low average pH of rain (pH 4.1) do not, however, give any support to such apprehensions.

In order to follow leaching from CCA-treated timber in a normal Swedish site, a field test with fence posts was started several years ago. This study is still in progress. However, chemical analyses indicate that all components of the preservative are leached to a certain extent from that part of the pole beneath the soil surface. Arsenic is leached most rapidly and arsenic leaching is also highest in quantitative terms. The chrome compounds seem to be the most effectively fixed in the wood. In the outermost layers (10 mm) of the wood the As-content had sometimes dropped to 50 percent of the original level during the first year of exposure. A significant quantity of As was also leached from layers in the interior of the poles (Figure 6).

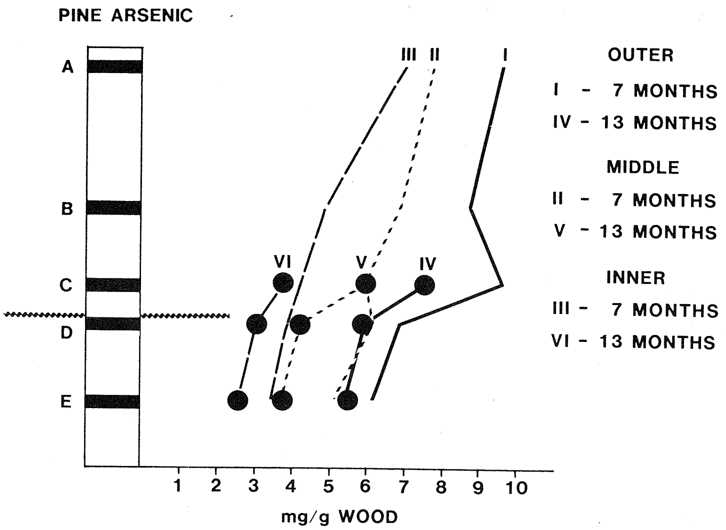

Figure 6. Diagram Showing the Arsenic Content in the Sapwood of a CCA-Treated Pine Post (Boliden K33) Exposed for 7 and 13 Months at the Simlangsdalen Test Field. Sample (discs) were cut from the Pine Post at Five Levels - Below the Ground, at the Ground Level and at the Three Levels Above Ground. The Sapwood was Divided into an Outer (I, IV) a Middle (II, V) and an Inner Layer (III, VI)

As regards copper, the quantity in the outermost parts of the wood below ground became reduced by as much as 25 percent in some examples during the same period. Usually, however, the leaching of copper was less than 15 percent.

A certain loss of chrome from the outermost layer seems also to have taken place during the first year of exposure. Indications of a later redistribution of chrome have been observed, probably as a result of the fairly heavy leaching of arsenic.

Further studies on leaching from preservative treated wood in soil are underway. The main interest concerns the possible impact on the environment of deposition in the earth of preservative treated waste material like poles which have failed or been rejected on inspection of pole lines. Both laboratory leaching tests with various preservatives and various soil types, as well as so called lysimeter tests in the open, have been conducted. Results indicate that the situation is very complicated. Different soils affect the leaching of individual components differently for different preservatives. Similarly, the re-absorption of leached components varies from one soil type to another.

Research has been carried out to find waterborne alternatives to the CCA-preservatives. However, the CCA's are very effective in protecting wood from degradation in severe situations, like contact with soil or sea-water, so the research for equally good alternatives, e.g., for pole treatment, has not yet been successful. For less severe exposure situations a number of alternatives compete successfully with the CCA's.

In recent years alkylammonium compounds (AAC's) have been tested intensively with varying results. The most extensive research on AAC's has been carried out in New Zealand by Dr. John Butcher and his group. The group presented their results at the 1980 annual convention of the American Wood Preservers' Association.

Two AAC preservatives had by that time been approved for commercial treatment of Radiata pine (*Pinus radiata*). The approval was restricted to its use in above ground situations. The two products contained benzyl ammonium chloride and alkyl dimethyl aminoacetate and the required retention of preservative for protection against decay was set to 2.5 kg/m^3 (sapwood).

For timber in ground contact the effect of AAC's against decay have not been equally good. A pronounced softening occurs at the outermost layers of timber in contact with the soil. This surface decay may be a result of bacterial attack (Nilsson, 1982). The best AAC chemicals for timber in soil contact proved to be dialkyl dimethylammonium chlorides and alkyl dimethylammonium compounds. Combinations including AAC's and copper compounds, which were tested, improved the preservation effect of wood in soil compared with the original non-metallic AAC preservatives.

In Sweden a combined AAC/TBTO preservative is also approved for ground contact situations. The required minimum retention is at present 12 kg/m^3 of the commercial product which contains 40 percent of benzyl trimethylammonium chloride and 10 percent TBTO. The product has not yet been used for the impregnation of poles.

Copper-ammoniacal preservatives have been used in the Scandinavian countries for about 20 years. At present one preservative containing 9.5 percent Cu and 4.75 percent caprylic acid is approved for use in ground contact at a minimum retention of 21 kg/m^3 sapwood (pine). It has not been used, however, for the commercial impregnation of poles.

Several preservatives which like the CCA's are dependent on the chromates for their fixation in wood are used to a limited extent for the preservation of poles in Scandinavia. These preservatives are mostly the well known copper/chrome, copper/chrome/boron and copper/chrome/fluor tupes. Among these the copper/chrome and copper/chrome/boron preservatives have been the most widely used. A preservative, which is chemically closely related to the oxide type of CCA but where the arsenic pentoxide has been replaced by phosphoric acid, has been in use for some time. Its minimum required retention for pine sapwood is 18 kg/m^3.

As regards alternatives to waterborne CCA's for the preservation of utility poles, it may be concluded that there are in Scandinavia some older type preservatives based mainly on chrome and copper. New developments based on alkylammonium compounds in combination with copper as a second active ingredient and used in an ammoniacal system may reach a mature stage within the not too distant future.

POLE INSPECTION

Regulations for the inspection of utility poles have recently been issued by the Swedish National Board of Occupational Safety. In principle, poles have to be inspected initially within 20 years from the date of installation with a following inspection within the next eight years. The inspector has to be specially trained for this type of work and has to have the necessary knowledge. Results of the inspection are recorded. The inspector has to record the extent of decay and to determine whether reinforcement or exchange is necessary before the next inspection. If a dangerous pole is found, it is marked with a special sign and instructions are given to the linesmen on how to proceed when a dangerous pole has to be climbed.

Instructions for the inspection of utility poles in service have been issued by EBR, a common organization for producers and distributors of electricity in Sweden. Separate instructions are given for "salt" treated poles and creosote treated poles. One major difference is that salt treated poles always have to be uncovered, from the soil surface down to 15 - 30 cm depth depending on soil type, while creosoted poles only have to be uncovered in special cases or if it is considered necessary for a proper evaluation of the condition of the pole. The inspection of salt treated poles includes hammering to find the softest area of the uncovered parts. At these regions the depth of the decay is determined either by the use of a special instrument (Pilodyn (R)) or by the use of a strong pricker or awl (= poking method). The depth of decayed wood is also measured on the diametrically opposite side. The diameter reduction of the pole is achieved by adding the two measured depths of decay. The remaining sound diameter of the pole is then calculated. The inspector also has to judge whether the sound pole diameter corresponds to the minimum diameter required for a pole in that situation. If not, or if the inspector expects the sound diameter to decrease below the required minimum diameter within the next inspection interval, the pole is marked with a special sign. By the use of the inspector's report it is later decided if the pole should be exchanged, reinforced or chemically treated.

Creosoted poles are normally hammered from 2 mm above down to ground level. If the hammering sounds indicate internal decay, bore samples are taken from that part which is regarded most severely attacked. Should the first bore sample indicate severe decay (hole) several borings have to be made to determine the greatest width of the hole and the minimum thickness of the outer sound shell. The remaining sound shell can be related to the required minimum diameter of the pole in question. Tables on this relationship are available and the inspector can then decide what further measures are necessary.

It has to be emphasized that the compulsory inspection scheme is fairly new (from 1980) so our experience is limited. It soon became evident, however, that certain exemptions had to be made since the new regulations concerned so many poles. There is also a lack of well trained and skilled inspectors. Even though several of the great electricity producers and distributors have started courses for their staff these are often too short and do not always cover the most important items. A lot more practical training than given at present is also necessary before a person should be given the responsibility of inspecting poles. His work is of extreme importance for the safety of the linesmen. However, from an economical point of view it is also very important to have detailed information on the condition of poles in a line so optimal planning can be made by the company. It can be very expensive to exchange a pole too late. However, there is also money to save if poles are not rejected prematurely.

REINFORCEMENT AND REMEDIAL TREATMENT OF DECAYED POLES

Remedial treatment of poles in Sweden is almost exclusively performed by the Cobra injection technique. Bandages are not used at present. The Cobra treatments are usually done in conjunction with contracted inspections. Our experiences with these treatments are that a temporary sterilization of the critical part of a pole is required. The duration of the sterilization is of course dependent on the prevailing climatic and soil conditions. A complete sterilization, which means that the existing flora of wood destroyers are killed and no wood destroying activity or invasion of new microorganisms can take place, lasts for more than one but less than nine years (Henningsson *et al*., 1976). Comparative studies have been made by the Cobra company, where development of soft rot in more than 2,000 old BIS-treated poles with and without a Cobra-treatment was followed over an 11-year period. The soft rot development (measured as diameter reduction) was significantly reduced in cultivated soils by as much as 50 percent on average.

Several companies have introduced various systems for the reinforcement of decayed poles. The common principle is to force beams or other profiles of steel into the ground close to the pole and to join the individual beams or plates so that they carry the full load applied on the pole in the ground-line (Figure 7). Some companies offer a combination of services including inspection as well as reinforcement.

GLUE-LAM POLES

The round wooden pole is extremely well suited for it's purpose. It is produced almost in its final shape by nature itself so there is very little need for further processing or machining. Wood species like various pines usually have permeable sapwood which is easy to impregnate with preserving chemicals. Adequately treated, such poles will have a service life in world temperate regions of 40 - 60 years, or even more.

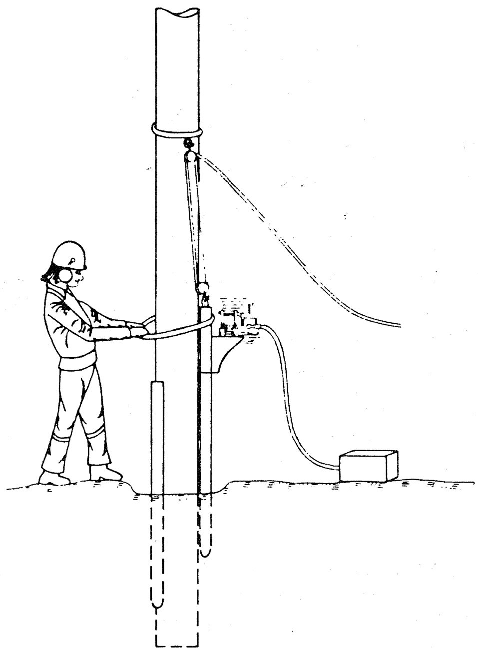

Figure 7. Reinforcement of a Pole by Forcing Down Steel Profiles Close to the Pole

However, in Scandinavia modern forestry is producing less and less large trees. As a result there are now significant difficulties in finding the raw material necessary for poles above 18 m in length. Steel is therefore being used more frequently for transmission structures.

Laminated wooden construction for these steel structures and also their use as an alternative to the normal wooden pole has only recently been considered seriously in the Scandinavian countries. Studies have been made (Jermer and Omér, 1980) and field tests with laminated structures have been set up. The studies resulted in a "norm" issued by SEK (Swedish Electrical Commission). According to the "norm" the individual pieces have to be preservative treated to the Nordic wood preservation class A before planing and glueing. After glueing the assembled structure has to be retreated, according to the Nordic class to a minimum depth of 20 mm, even in the heartwood.

Normally the first impregnation is made with a waterborne CCA preservative. Drying, planing and gluing are followed by incising and creosote impregnation. The 18 mm long incising needle used in the experiments gave an average creosote penetration of 23 mm and the minimum penetration was seldom less than 20 mm.

Recently, attempts have been made to make tube-formed laminated poles of pine wood. This construction needs less wood than the solid construction and the total weight is of course substantially reduced. The individual pieces have to be profiled and have a wedge-shaped cross section. It is also intended to make the construction in sections which can be later combined to form the final length.

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