High Pressure Sap Displacement For Treating Green Timber Poles

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ABSTRACT

The main problem in the practical application of the high pressure sap displacement impregnation (HPSD) has been in devising a satisfactory cap. Such a cap must be easily fitted to different size log ends and tolerable eccentricities to give a leak proof seal. The present paper describes a new type of cap and sealing system designed to meet these requirements.

The principle of design has been "leak proof" and "adjustability". These mean forces tending to create leakage must be resisted by stresses in the system so that the cap retention on the log and the tightness of the rubber "D" ring increases with increasing pressure. An essential feature of the cap is the design of the contour of natural round timber surfaces. This also keeps the rubber seal from bulging out. Application of pressure to the impregnating preservative tends to force the rubber seal to press the area of contact on the log thus increasing the tightness of the rubber seal.

Results of test on 15 mahogany Swietenia macrophylla King) poles indicated that the system of operation is workable and that an adequate retention of preservative could be obtained in the treatable sapwood to control decay and insect attack under tropical conditions.

Having regard to the results as well as those obtained by previous workers on its technical and economic aspects, HPSD technology have been transferred to the electric cooperatives of Kalinga-Apayao

(KAELCO), North Cotabato (COTELCO), Ilocos Norte (INEC), Camarines Sur (CASURECO I and CASURECO IV), Zambales (ZAMECO I), Palawan (PALECO), Zamboanga del Sur (ZAMSURECO I and ZAMSURECO II), Agusan del Sur (ASELCO), Quirino (QUIRELCO), Maguindanao (MAGELCO), Camarines Norte (CANORECO), ASIAN AGRO Aquatic Resource Development, Inc., (Calauag, Quezon), and Unson Industries (Pagsanjan, Laguna) serving Quezon II Electric Cooperative (Infanta, Quezon).

INTRODUCTION

Wood preservation is one of the most important ways to conserve our forest resources by enabling us to obtain the longest practical life from wood in its various applications. This has been recognized since the early decades of this century and since then complex wood treating facilities and organizations have developed especially in more industrialized countries such as Europe, Australia, and the United States of America. These developments were brought about by the growing consciousness of end-users of the benefits derived from the use of preserved wood.

In the Philippines, the bulk of treatment is confined to poles for power and telecommunication lines. The present government program of rural electrification being implemented by the National Electrification Administration (NEA) requires 216,000 poles during its first 4 years of operation, to initially energize 36 districts. Latest NEA report indicated that 120 electric cooperatives have already been organized and more cooperatives are being formed in areas where electricity is inadequate or nonexistent. This broad program for electrification network definitely requires substantial number of poles for expansion and replacement.

Owing to the archipelagic nature of the Philippines, the transport of materials is costly. . The present practice of transporting poles from one island to another is not uncommon. Ordinarily, poles cut in one island are transported to another where a pressure treating plant is located and then hauled back to the former or to a third island. The cost of transportation naturally becomes double and possibly more.

Since the national electrification broad program for development definitely requires a large number of poles, especially for the distribution system to reach the remotest barangay, the production of poles will be difficult unless they are to be obtained in the areas where the treating plants are to be installed. Since the cost of transport becomes prohibitive when poles are involved, or the cost of putting up a preserving plant would have to be economically justified, the need of instituting a new method of treating poles that can provide the immediate and future needs of any pole-using entity and for that matter, the much needed electricity in the rural areas, is imperative. The treatment of poles therefore, by High Pressure Sap Displacement (HPSD) method has been adopted.

The HPSD process represents modern technology applied to a simple process called the "Boucherie" process. The basic principles of HPSD and the "Boucherie" process are the same, that is, the sap is forced from the living sapwood of a freshly-felled tree or bamboo by a water-borne preservative solution introduced under pressure through a cap which is fitted over one end of the tree.

Unfortunately, previous methods have not been successful due to the problems associated with making a leak-proof seal for pressure caps, that can be fitted and detached with relative ease to conform to the eccentricities and irregularities often found at the butt end of post or pole of any size. This cap was developed to overcome the problem.

Among its chief advantages towards its application to fit into development programmes for developing countries are:

Geographical Advantages

It is conveniently mobile and can readily be taken over any kind of terrain to either in the forest where the trees, bamboos, and palms are to be felled or to the construction site. Whereas, vacuum/pressure plants by their size and nature are usually fixed installations, that materials to be treated must be with in the economic radius for transporting raw and finished products.

Technical Advantages

There is enough savings in cost, due to the reduction in time between felling the tree and placing the treated material in service. This is because no predrying is required before treatment such that treating can be carried out after felling. With vaccum/pressure treatment, the wood must be debarked, stacked in a seasoning yard and dried for several months.

Economic Advantages

- Absence of debarking costs;
- Absence of handling and stacking costs for predrying;
- Lower transport costs from forest to construction site since materials may be treated at the point of use or any point between;
- Absence of interest costs on capital tied up in predrying stocks; and
- Absence of interest costs on capital tied up in land for predrying yard.

Applications

- Electricity and telephone poles
- Civil engineering construction - bridges for secondary and feeder roads/wharves, piers and ramps for barges; hydro-electric works; and mining operation.
- Fish pens
- Farm development - fence posts; farm buildings, dwellings, etc.; and dams for irrigations, small scale hydro-electric generation.
- Building construction utilizing pole type designs - urban and rural dwellings, industrial and commercial buildings; warehouses, factories, public utilities, markets, schools, parks and playground facilities, and resorts.

RESEARCH OBJECTIVE

General Objective

This study generally aimed to design a workable pressure cap that fits the eccentricities and irregularities of a pole of varying diameters.

Specific Objectives

Specifically, this study aimed to:

- Design a cap that is leak-proof at permissible working pressure ranges and that it can be fitted and detached with relative ease;
- Demonstrate how the system works;

- Analyze the amount of toxic chemical present in the treated zone;
- Determine unit cost to treat a standard electric pole; and
- Pilot and transfer the technology generated.

REVIEW OF LITERATURE

Known so far as one of the oldest preservation processes is sap displacement impregnation of timber. However, previous methods have not been truly successful due to the problem of making a leak-proof seal for pressure caps that can be fitted and detached with relative ease and which conforms to the eccentricities and irregularities often found at the butt top ends of a post or pole of any size.

This process of treating green or freshly-felled poles described by Hunt (1953) which was originally developed by Boucherie in 1838, is still used in Switzerland, Argentina, Israel, Japan and to some extent in France and Germany. This method makes use of a tight fitting cap at one end of the pole attached to a reservoir of preservative, usually copper sulphate or zinc chloride. The pressure head tank is mounted well above the pole so that the hydrostatic pressure of the liquid column forces the preservative through the sapwood. Treatment usually takes more than two weeks and efforts have been geared towards reduction of treating time. To achieve this objective the Boucherie method has been modified by applying the preservative at a pressue up to 10 kg/cm^2 (980 kPa). The major obstacles in the development of the high pressure sap displacement method include the need of preparing the end surface of the pole for the cap and the difficulty of making the seal leak-proof.

Extensive investigations were carried out by Neumark (1973) on Eucalyptus species using a modified pressure system of up to 5 kg/cm^2 (490 kPa). As a result of his work large scale treatment was carried out on plantation grown trees in Israel. Similar problem of fitting the cap was mentioned because of the eccentricities of the butt. Some tests were also carried by Johnstone and Blau (1970) in Australia on the fitting of a pressure-type cap to the butt ends of Eucalypt poles using a 4 percent solution containing Boliden K-33 (copper/chrome/arsenic salts) applied at pressures of 4.9 - 7.0 kg/cm^2 (480- 686 kPa). The poles varied in length from 6.1 - 12.2 m and from 200 - 300 mm, in butt diameter. They found the system workable and suggested that an improved method of fitting and removing the cap be designed, but since then no folow-up study was made.

The design by Dale (1969) is of simple construction being made from steel tubing which is closed at one end. The open end is sealed by means of an annular rubber seal clamped between a flange welded to the steel tube and a mating flange backed by a rubber O-ring. In this design the eccentricity of the timber is taken into consideration but the retaining steel teeth provide a wide gap as the diameter of the timber increases. This gap causes the annular rubber seal to bulge out and the pressure acting on the seal is relieved to atmospheric pressure.

Lately, Mason and Shoreland (1975) described a fiber glass cap and associated pumps to operate at working pressure at 4 kg/cm^2 (392 kPa). In the technique for fixing the cap to the pole, they cut the freshly-felled log at a place coinciding with the diameter of the split ring of the cap. They did this to do away with the invariably irregular shape of the pole so as to provide a tight seal between the cap and the log. Their design, therefore, was limited to more or less round butt or top ends.

In their design fourteen species of hardwoods were examined for response to HPSD treatment using a copper-chrome-arsenate type preservative. All 14 hardwood species treated readily and satisfactorily, with the treating time ranging from 20 to 80 minutes for logs 6 m in length and 127 mm average top diameter. Several types of pressure caps including the original Boucherie process are illustrated in Figs. 1, 2 and 3.

MATERIALS AND METHODS

Materials

Pressure cap. The materials used for the fabrication and accessories of the pressure cap consisted of 3 mm steel plate; eight sets 12 mm diameter by 50 mm long bolt including nuts and washers; one piece 19 mm coupling and two pieces, 31 mm couplings; steel rod, 16 mm diameter by 35 mm long; pressure gage, 0 - 21 kg/cm^2 range; 3000 mm high pressure rubber hose, 19 mm diameter retaining steel rod, complete with fittings; relief value and four 50-liter capacity plastic containers.

Preservative. The water-borne preservative used was a copper-chrome-boron (CCB) type.

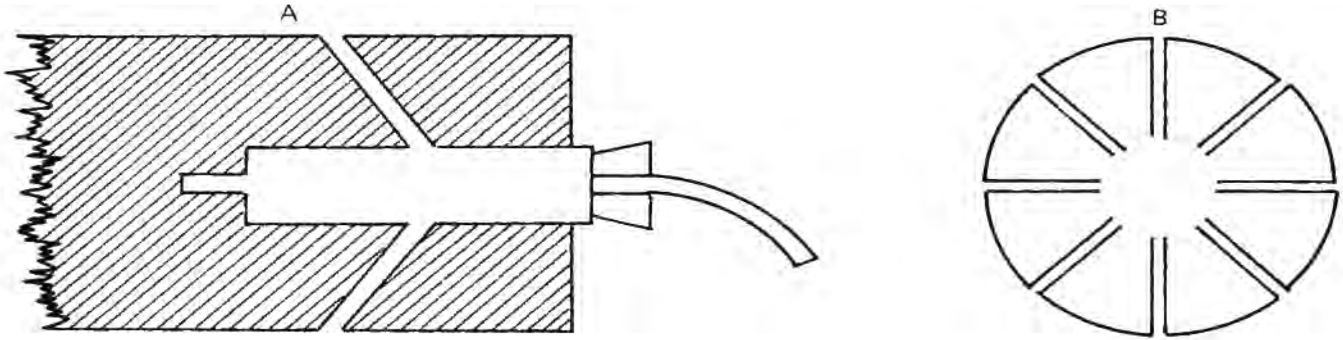

Fig. 1. Boucherie method of treating. A - longitudinal section of pole butt showing detail of end connections, B - Section showing distribution holes which must be plugged after boring.

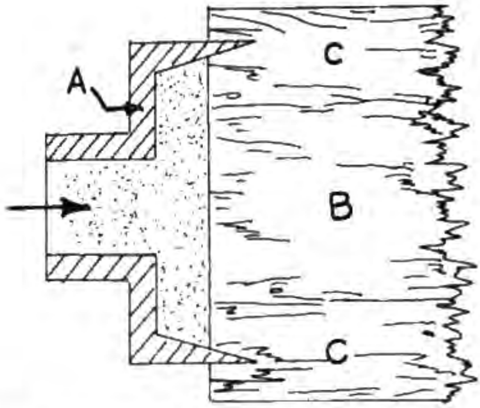

Fig. 2. A - Drive in cap, B - heartwood, C - sapwood.

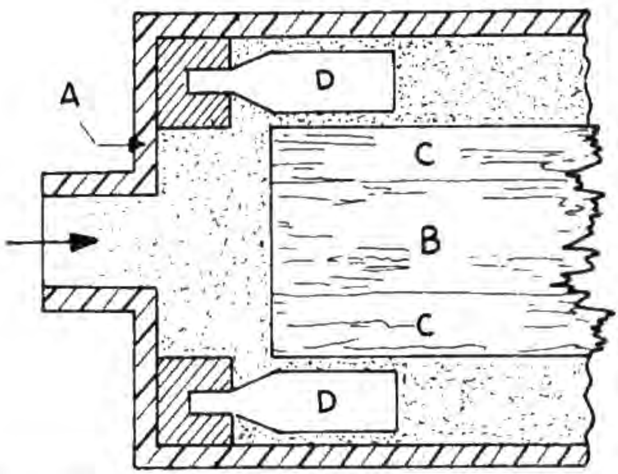

Fig. 3. Self sealing cap with self sealing rubber tube (D). A, B, and C as in Fig. 2.

Timber species. The specimens were freshly-cut mahogany (*Swietenia macrophylla* King) poles of varying butt diameter ranging from 100 to 280 mm with lengths from 5500 - 7600 mm.

Equipment. The pressure used was a reciprocating pump with a displacement capacity of 18.9 liters per minute driven by a 7-1/2 horsepower portable gas engine or a 1/3 HP electric motor.

Methods

Fabrication. The HPSD cap that was fabricated consisted mainly of a cylindrical pressure cap with one end open and the other end had a dished head welded inwardly. The open end was flanged with equally-spaced bolt holes for holding the rubber seal and the adjustable steel fingers to keep the rubber from bulging out under operating pressures.

The pressure cap was designed and fabricated as detailed in Section "B"–"B" in Fig. 4. The design stress of the tank was not taken into account because the rubber seal will serve as a safety valve, being the weakest part of the system while in operation.

The adjustable finger retainers (8 pieces) were fabricated as shown in Fig. 5, in an imaginary position of the adjustable fingers to accommodate a 279 mm butt diameter log.

Treatment. The necessary pole specimens were collected from the College of Forestry mahogany plantation. The specimens had their bark intact and were brought to FPRDI compound.

Before treatment, each pole was debarked one at a time approximately about 450 mm from the butt or top end. The peeled portion was tapered so that it will fit with ease into the rubber seal. Before fitting the pole, a 19 mm hole was drilled transversely about 10 cm from the butt or top end. This was used for inserting the retaining steel rod which kept the pole fixed while the cylinder was under pressure.

Three intensities of pressure were investigated, namely, 1.4, 2.8 and 4.2 kg/cm^2. Fifteen mahogany poles were treated, five each under three treating pressures.

Measurement of results. The moisture content of each pole was determined prior to treatment by taking 25 mm disc, 75 mm from the top and 150 mm from the butt end. Butt and top diameter, length and sapwood thickness were measured and heartwood/sapwood volume calculated.

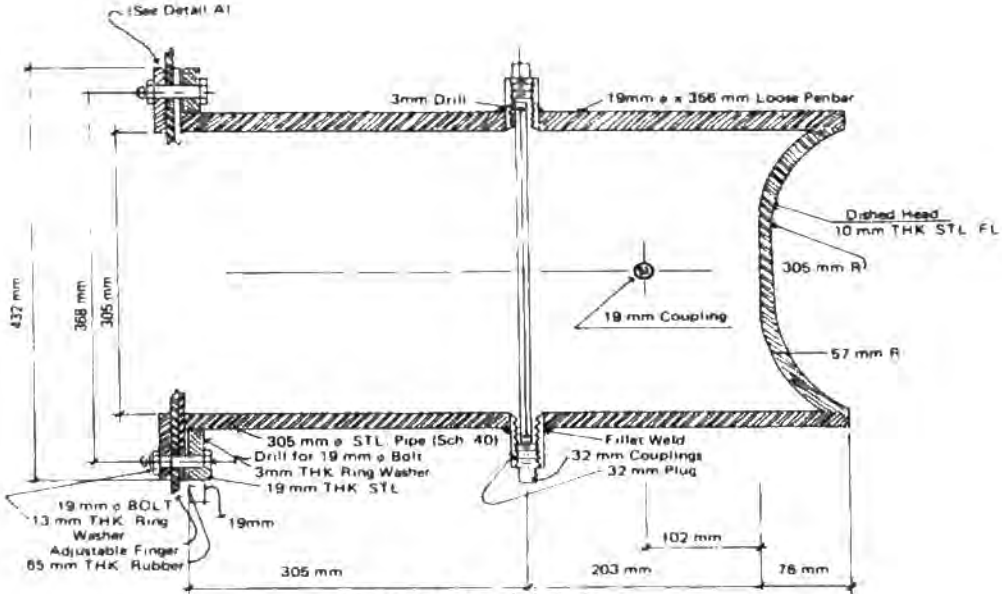

Fig. 4. Cross-section of pressure cap.

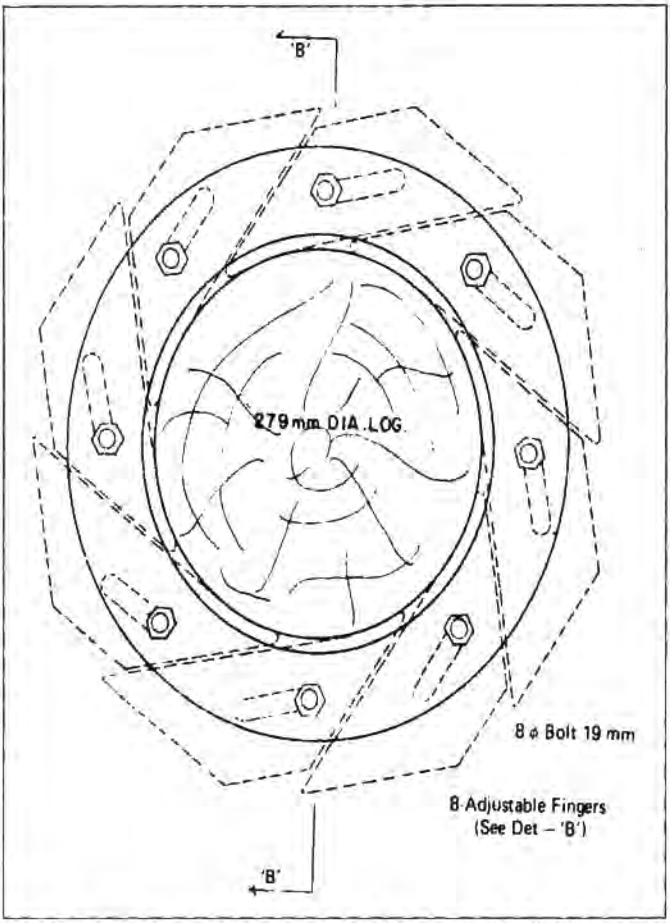

Fig. 5. Imaginary position of retaining fingers to fit a 279 mm pole diameter.

The rate of sap preservative flow from the free end was measured at regular intervals of 10, 15, and 30 minutes depending on the speed of flow. At the same time the specific gravity of the final effluent was compared with that of the preservative solution. Pressure treatment was stopped as soon as the specific gravity of the effluent was approximately the same as the preservative solution or at some pre-determined values depending on the concentrations used. The volume of the sap and inflowing preservative was measured as well as the volume of the effluent.

Discs measuring about 25 mm were taken 1000 mm from the top and butt ends and the middle from each of three poles for quantitative analyses of copper using an atomic absorption spectrophotometer.

RESULTS AND DISCUSSION

Testing the HPSD Cap

The high pressure sap displacement cap was fabricated as drawn with its corresponding attachments and accessories. This was tested to fulfill the objectives of this study and the pertinent results are summarized in Table 1. Mahogany (*Swietenia macrophylla* King) was selected to test the equipment on because pole size trees abound in the UPLB College of Forestry and the eccentricity of the butt or top of the pole was ideal for evaluating the effectiveness of the retaining fingers to seal against leaks. In the treatment conducted, the biggest diameter fitted was 250 mm as shown in Fig. 6, and the smallest diameter was 104 mm. As designed, the cap can accommodate up to 279 mm pole diameter.

Three pressure levels were tested, e.g., 1.4, 2.8 and 4.2 kg/cm^2 The same rubber material, however, had been tested by Dale (1969) to a pressure of 14 kg/cm^2 and mentioned that there is probably not much to be gained by using pressures over 7 kg/cm^2

It was noted that the sealing became more positve as the pressure is increased. Higher pressure causes the rubber seal to stretch and follow the irregular contour of the pole surface. The rubber seal has sufficient elasticity to conform to the shape of the area to be sealed when compressed and return to its original shape when removed from the pole. Based from the 65 mm diameter of the rubber seal hole, the maximum pole diameter inserted in was 250 mm.

Retaining Fingers

The most salient part of the pressure cap notwithstanding the rubber seal, is the design of the retaining fingers. The retaining fingers were so designed and dove-tailed to fit the eccentricities and irregularities in the form of the poles within the effective contact area of the rubber seal. Each retaining finger can be positioned to rest on the peeled surface of the pole, such that an irregular form is more or less seated on to prevent the seal from bulging out under pressure. This is an improvement of Dale's (1969) retaining gadget made of 19 mm thick plywood cut to follow the shape of the pole, such that each pole to be treated requires a separate retaining plywood.

Table 1. Data obtained on testing the high pressure sap displacement cap (HPSD) using freshly felled mahogany (*Swietenia macrophylla* King) Poles.

POLE NO.	LENGTH (mm)	DIAMETER Butt (mm)	DIAMETER Top (mm)	AVE. SAP-WOOD VOL. cm³ x 104	AVE. NC %	PRESSURE APPLIED kg/cm²	PRESERVATIVE	SP. GR. Pres.	SP. GR. Effl.	TIME TO FLOW Sap	TIME TO FLOW Effl.	FLOW RATE Sap	FLOW RATE Effl.	COLLECTED cm³ Sap	COLLECTED cm³ Effl.	TREATING TIME (Min)
1	6850	244	177	11.50	72.8	1.4	8%, CCB	1.0483	1.0258	75	15	53	103/72	1200	8850	95
2	7135	154	77	3.38	69.0	1.4	8%, CCB	1.0483	1.0152	170	65	34	40/14	800	8000	275
3	7137	185	108	5.03	61.5	1.4	8%, CCB	1.0483	1.0229	90	23	70	74/48	650	7000	163
4	7630	181	102	5.20	65.1	1.4	8%, CCB	1.0483	1.0215	105	25	52	64/27	7000	10120	245
5	7106	109	102	4.93	67.5	1.4	8%, CCB	1.0483	1.0142	100	40	24	30/5	780	2000	230
6	5460	181	104	4.91	66.1	2.8	8%, CCB	1.0489	1.0309	90	12	90	98/43	575	5500	86
7	7480	196	120	7.57	63.7	2.8	8%, CCB	1.0489	1.0244	85	16	51	69/48	1036	7100	120
8	7570	224	134	8.15	70.3	2.8	8%, CCB	1.0489	1.0233	70	19	62	67/50	1000	7575	120
9	7630	221	142	9.67	71.8	2.8	8%, CCB	1.0489	1.0246	50	14	120	120/75	1400	9890	100
10	6600	228	112	8.75	63.0	2.8	8%, CCB	1.0489	1.0211	155	25	30	40/18	1500	8350	135
11	7220	175	110	6.69	64.6	4.2	8%, CCB	1.0489	1.0254	39	16	66	69/56	1060	4850	40
12	6880	174	96	4.60	59.2	4.2	8%, CCB	1.0489	1.0252	24	9	110	115/10	850	3650	70
13	7530	184	109	7.47	66.4	4.2	8%, CCB	1.0489	1.0252	33	12	96	97/81	1000	4280	20
14	7320	208	123	5.45	65.9	4.2	8%, CCB	1.0489	1.0254	39	16	66	69/56	1060	4950	70
15	7310	250	195	13.39	67.2	4.2	8%, CCB	1.0489	1.0275	35	10	100	530/172	2000	12300	40

[a]CCB (Copper-Chrome-Boron) a water-borne preservative.

[b]Figures above the slash refr to preservative intial flow, while below refer to final preservative flow.

Fig. 6. Front view of pressure cap showing position of retaining teeth on the largest diameter (250 mm) of pole being treated.

Treating Time

The data obtained as summarized in Table 1 were statistically analyzed to determine their respective attributes to the dependent variables.

As shown in the matrix of correlation coefficents, Table 2, the variables, namely: applied pressure, time for sap to flow out, time for effluent to flow out, and sap flow rate were significantly related to treating time. Expectedly, the applied pressure and sap flow rate were inversely related to treating time while the time for the sap and effluent to flow out were directly related to treating time. The applied pressure had a pronounced effect on treating time, the time for sap and effluent to flow out and sap flow rate. While applied pressure significantly influenced sap flow rate, it did not affect to a significant degree effluent flow rate. This could have been due to the accumulation of particulate matter from the undissolved portion of the preservative, in the wood capillaries, and/or due to the formulation of air bubbles. In the treatment process no system fo prefiltration of the solution was made. Kelso, et al. (1963) reported that prefiltering of the liquid enhanced flow rate.

Table 2. Matrix of simple correlation coefficient

VARIABLE	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11
X1	1.000	0.189	0.062	-0.252	0.056	0.017	0.071	0.112	-0.310	0.283	0.225
X2		1.000	0.228	-0.308	-0.478	0.261	0.666**	-0.441	0.397	0.868**	0.624*
X3			1.000	-0.717**	-0.614*	0.589*	0.399	-0.816**	-0.629*	-0.214	0.178
X4				1.000	0.783**	-0.746**	-0.411	0.816**	-0.629*	-0.214	0.178
X5					1.000	-0.673**	-0.365	0.850**	-0.868**	-0.305	-0.045
X6						1.000	0.484	-0.698**	0.694**	0.211	0.114
X7							1.000	-0.415	0.415	0.717**	0.537*
X8								1.000	-0.806**	-0.362	0.119
X9									1.000	0.215	0.168
X10										1.000	0.641**
X11											1.000

* - Significant at the 5% probability level.
** - Significant at the 1% probability level.
X1 - Pole length, mm.
X2 - Sapwood volume, cm^3
X3 - Applied pressure, kg/cm^2
X4 - Time for sap to flow out, min.
X5 - Time for effluent to flow out, min.
X6 - Sap flow rate, ml/min.
X7 - Effluent flow rate, ml/min.
X8 - Treating time, min.
X9 - Effluent specific gravity.
X10 - Volume of sap collected, ml.
X11 - Volume of effluent collected, ml.

The predicting equations derived for treating time, time for sap to flow out, volume of sap collected, time for effluent to flow out and volume of effluent collected are shown in Table. 3.

Volume and Flow Rate of Sap Effluent

The volume of sap collected was markedly influenced by sapwood volume (r = 0.868**) and sap flow rate (r = 0.717**). Similarly, the volume of effluent collected was appreciably influenced by sapwood volume (r = 0.624*), effluent flow rate (r = 0.537*) and volume of sap collected (r = 0.641*). On the other hand, the effluent flow rate was directly influenced by the volume of sapwood (r = 0.666***).

In general, the flow rate in all poles fell off gradually even when a constant pressure was being maintained. This phenomenon has been reported by Muskat (1946) and that the common cause of the deterioration of flow rate of liquids through a porous medium is the evolution of air or dissolved gas in the liquid which is trapped in the pores. Substantial evidence has already been presented that accumulation of air within a wood sample was responsible for the observed decrease in rate of flow. Kelso, et. al. (1963) who studied the effect of air blockage upon the permeability of wood to liquids demonstrated the phenomenon that when liquid passes through a fine capillary and a gas bubble is caused to flow through it, the bubble would not pass unless a critical force is exerted on it. They also found that fresh distilled water will not pass through wood at constant rate unless precautions are taken to remove the dissolved air or to prevent any of it to evolve and be deposited as bubbles in the wood.

The problem of enhancing the passage of the preservative during the HPSD treatment has been investigated by Hudson and Shelton (1969) and they found that cutting a second disc after application of high pressure enhanced the rate of flow in conifer woods under 14 kg/cm^2. Zimmermann (1963-1964) has described and explained this phenomenon as due to a "wall of air" present in the ends of cut off cells. Once the flow of liquid passes the "wall of air" negative pressure condition inside the pole is quickly relieved and when a second disc 20-50 mm is cut the "wall of air" is releated with it. The author, during his fellowship in the Division of Forest Products, C.S.I.R.O., Melbourne, Australia has also experienced bringing back on Eucalyptus the rate of flow to the original by cutting a disc the following day after treatment.

Table 3. Predicting equations derived for treating time, time for sap to flow out, volume of sap collected, time for effluent to flow out, and volume of effluent collected.

DEPENDENT VARIABLE										R²
X8	-78.5299	+	0.03517X1	-	5.1252X2	- 30.8089X3	+ 35.901X4	+ 1.14134X5		0.947**
X4	4.4339	-	0.000247X1		0.03057X2	- 0.4139X3				0.570*
X10	-408.491X1	+	40.0787X1	+	103.5669X2	+ 58.538X3				0.570*
X5	-42.3583	-	0.0079X1	-	1.5405X2	- 0.3608X3	+ 14.829X4			0.762**
X11	2573.458	+	616.864X2		0.390*					

*	:	Significant at the 5% probability level.
**	-	Significant at the 1% probability level.
X8	-	Time to treat a pole.
X4	-	Time for sap to flow out, min.
X10	-	Collected volume of sap, ml.
X5	-	Time for effluent to flow out, min
X11	:	Collected volume of effluent, ml.

Krier (1951) demonstrated that most blockage occurs near the inflow surface. Resurgence of flow obtained by reversing the sample supports their conclusion. However, as Krier noted, reversing direction of flow did not produce the expected great response when the sample was more completely blocked. This effect suggests that some blockage must occur downstream of the first pit where it passed through pores in pit membranes or by growth of existing air nuclei within a tracheid. Other than cutting a second disc, no procedure has so far been described which will maintain flow rate. Hudson and Shelton (1969) also tested the effects of (1) brushing the butt with a steel wire brush, (2) pouring isoprophyl alcohol on the surface of the butt, and (3) treating the surface of the butt with powerful wetting agents. None of these treatments was effective.

Results of atomic absorption spectrophotometry analyses on poles representing each of the pressure periods used are shown in Table 4.

In the foregoing analyses no attention has been directed towards the radial distribution of the toxic radicals. Apparently, by inspection of the surface of the disc cut at various sections, the penetration in the sapwood was deemed complete as manifested by the cross section of the treated sapwood. No evidence of preservative penetration was noted in the heartwood.

Only the copper oxide of the preservative, i.e., copper-chrome boron (CCB) was analyzed because only copper cath-

Table 4. Chemical analysis of copper in treated mahogany (*Swietenia macrophylla* King) poles by atomic absorption spectrophometry.

POLE NO.	LOCATION	BASED ON ONE GRAME TREATED SAPWOOD SAMPLE AT 12% M.C.					
		Density cm³	Vol. g/cm³	CuO g	Oxide Retention		
					g/cm³	kg/m³	lb/ft³
1	Top	0.562	1.84	0.0226	0.01229	11.29	0.767
	Mid	0.429	2.33	0.0189	0.00810	8.10	0.505
	Butt	0.457	2.18	0.0114	0.00521	5.21	0.325
6	Top	0.541	1.85	0.0204	0.01103	11.03	0.688
	Mid	0.536	1.87	0.0163	0.00873	8.73	0.545
	Butt	0.502	1.99	0.0113	0.00567	5.67	0.354
14	Top	0.510	1.96	0.0153	0.00780	7.80	0.487
	Mid	0.509	1.96	0.0140	0.00712	7.12	0.444
	Butt	0.562	1.78	0.0079	0.00444	4.44	0.277

*Pressure cap was placed at the top end in the three samples.

ode lamp was available at the time of the analyses. However, copper analyses in treated wood could serve as an index of retention measurement in CCB treated wood (Johnstone and Blau, 1970). In Table 4, the oxide retention of the top, middle and buttsection of each pole sampled is expressed in appropriate units.

The analysis showed that there is an uneven distribution of the preservative between the butt and the top end of the pole. The longitudinal preservative gradient from top to butt end sections analyzed agrees with the findings of Mason and Shoreland (1972) on *Pinus radiata* and of Fougerouses (1976) on *Eucalyptus robusta, E. tereticornis, Pinus patula* and a large number of 82 hardwood species from the forest of Madagascar. However, Johnstone and Blau (1970) claimed that no significant difference in retention was evident when treated was from the butt-end in the direction of the top and when reversed. This may be explained by the high pressure they used, 5.4 kg/cm^2 - 8.9 kg/cm^2 (75-100 psi). On the other hand, they maintained that it is undesirable to treat from top to butt because of the effect of reverse treatment on branch stubs which showed poor treatment and also of the need to have a maximum loading of preservative in the butt end.

Based on the copper oxide retention, the values obtained could surpass the standard of 16 kg/m^3 oxide retention of the three elements combined required in poles under Philippine conditions, (PHILSA 1976) not withstanding the toxic radicals of hexavalent chromium (CrO_3) and boric oxide (B_2O_3) which were not included in the calculations.

Cost Estimate of HPSD Unit

Table 5 shows the cost estimate of an HPSD treating unit as of January 1986.

Cost of Treatment per Pole

The cost of treating a standard 10,670 millimeter (35 ft) long pole using the HPSD device is P949.37 (Table 6).

The average buying price of the Electric Cooperative of the National Electrification Administration (NEA) pick up at plant is about P2,000 for a 10,670 mm long pole, complete with papers and other requirements. If the HPSD treating device will be used, the savings, excluding administration (overhead) cost and taxes, will be P1,050.63 per pole.

Table 5. Bill of materials.

QTY.	UNIT	SPECIFICATION	COST
1	set	Materials and fabrication of pressure cap	P5,000
1	unit	Reciprocating piston pump, 1000 liters/hr	18,000
1	unit	Prime mover, Briggs and Stratton gasoline engine, 5 HP	8,000
5	pcs.	Rubber seal, 3 mm thick	300
6	m.	High pressure rubber hose	300
1	pc.	Pressure gauge, 20 kg/cm^2 capacity	200
1	pc.	12 mm check valve, ball type	150
4	pcs.	13 mm Ball valve	600
4	pcs.	Elbow, 19 mm G.I.	40
4	pcs.	Union, brass seated, 19 mm	60
2	pcs.	Reducer 13 x 6 mm	30
20	pcs.	Short & close nipples w/ mixed sizes	150
10	pcs.	Fittings (tee, couplings, etc.)	50
2	pcs.	Plastic pails with lide (50-li. cap.)	150
2	pcs.	Plastic pails with lid (100-li. cap.)	400
1	pc.	Pipe wrench 203 mm long	200
1	pc.	Pipe wrench 305 mm long	300
2	pcs.	Box wrenches 305 mm long	150
1	pc.	Crescent wrench 305 mm long	200
1	set	Bow saw with blades	800
1	set	Power drill with bits (25 mm maximum bit size)	3,000
		Subtotal	P 38,080
		Plus 15% Contingency	5,712
		Total	P 43,792

Table 6. Total input and operating cost per pole of standard pole length using the HPSD treating unit.

TREATMENT OPERATION INPUT	TREATMENT COST/POLE	
Raw pole material	P400.00	
Preservative (copper-chrome-arsenate)	250.00	
Labor (three hours)	150.00	
Fuel (electric power)	22.50	(7.50)
Depreciation	3.04	
Contingency (15%)	123.83	
Total	P949.37	

THE APPLICATION OF HPSD TO OTHER FIELDS OF SCIENCE AND TECHNOLOGY

With the equipment described in this paper, it is possible to remove rapidly and completely the sap from freshly-felled trees of plantation thinnings size, i.e., of the order of 6 m by 130 mm top diameter. This opens up the scientific study. For instance, metabolic studies of the sap in living trees could be made on liter quantities within minutes of removal from the tree. If collected under suitable conditions, enzymatic and oxidative changes could be prevented and the constituents of the sap thus studied under conditions more nearly pertaining to those existing within the sapwood tissues. It would also offer the possibility of studying other constituents of the sap while avoiding the changes that take place in the traditional process of chipping the wood and extracting with solvent liquids.

Again, water insoluble extractives could be removed from the sapwood by pumping suitable solvents through the log. They could thus be obtained and studied in a form more closely related to the conditions in which they exist in the wood tissues.

When it is considered that flow rates of up to 2 liters per minute of sap can be obtained from a 6 m by 130 mm Hoop Pine log and that 60 liters of pure sap can be collected before any preservative solution appears, the potential for this technique can be appreciated. In the case of Hoop Pine, a water soluble gum was removed with the sap. After 24 hours standing a colorless resin separated on the surface of the sap.

The use of HPSD equipment thus opens up the possibility of the recovery from the living tree and the exploitation on a commercial scale of wood extractives, without destroying the tree.

CONCLUSION

The use of sap displacement methods of treating freshly-felled natural round timbers, using caps and pumps specially designed for the purpose, and applying high hydraulic pressures, opens up an entirely new field in the utilization of wood as an engineering material in tropical developing countries.

Since so often the first requirements in developing an area are communication systems calling for engineering projects of roads, bridges, railways, posts, telephone and electricity services, and since many of these areas have extensive forest resources, a system which can utilize these resources on the spot, provide treating facilities to give long-term protection against severe decay and insect hazards, and make structural members available for civil engineering works in a matter of days, must be regarded as extremely attractive.

Such a system has tremendous potential. It makes possible a reduction in construction time on projects and offers the opportunity to effect substantial savings in foreign exchange. It is considered that the introduction of HPSD treatment in tropical developing countries and the development of its full potential for civil engineering projects could be the most important advances in wood preservation in many years.

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