Long-term appraisal of on-site preservative treatments for preventing decay in exterior woodwork[1]

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1. Introduction

This research was initiated in 1958 to investigate the efficacy of various preservatives and treating methods for new lumber to be used outside, particularly steps, porches, decks, and millwork. Previous work (T. L. HIGHLEY, 1980,1992; T. C. SCHEFFER and W. E. ESLYN, 1978,1982; T. C. SCHEFFER *et al.*, 1971) had shown the merit of surface application of preservatives to aboveground wood, whether by brushing, spraying, or brief soaking, as could be done at the construction site or in a routine maintenance program.

Specific research objectives were (1) to determine the relative amounts of protection provided by soak treatments that incorporate different oil carriers, (2) to compare relative amounts of protection obtained with different methods of nonpressure application, such as brushing, dipping before or after assembly, and 3- or 15-min soaking, (3) to ascertain the value of a water-repellent additive, (4) to ascertain the value of painting in connection with different preservatives and methods of application, (5) to explore whether bases of posts and columns could be protected

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through treatment with preservative incorporated in a grease-type carrier, (6) to determine the efficacy of brush treating untreated surfaces (exposed by cutting and shaping) of pressure-treated lumber, and (7) to learn how and to what extent wood species affects the outcome of treatment. Pentachlorophenol (penta) formulations were used in much of this work.

Environmental concerns have now limited the use of penta, but the relative effectiveness of the treatments probably would not be greatly altered if they were replaced by alternative fungicides with comparable properties.

2. Materials and methods

2.1 Preservatives[3]

The following preservative solutions were used: (1) pentachlorophenal (penta), 5%, plus water repellent in mineral spirits, (2) penta, 5%, plus water repellent in kerosene, (3) penta, 5% in No. 2 fuel oil, (4) penta, 5% in mineral spirits, (5) penta, 10% in naphtha, (6) copper naphthenate, 1% copper, plus water repellent in mineral spirits, (7) penta-grease, 10% equivalent in a grease, (8) chemonite (ammoniacal copper arsenite), (9) Tanalith Wolman Salts (sodium fluoride, sodium chromate, disodium arsenate, and dinitrophenol).

Copper naphthenate (1% copper) was made from commercial stock consisting of 80% copper naphthenate (8% copper as metal) and 20% petroleum distillate. Paraffin wax (1%) was used as water repellent. Pine oil was incorporated as a booster solvent to insure complete solubility of penta and wax constituent. The penta-grease product was a commercial product (Pol-Nu) manufactured by Chapman Chemical Co. (Memphis, TN), which consisted of 10% penta and 90% inert ingredients.

Applicable test units were painted with Sherwin Williams Gloss no. 471 white house paint; two coats were applied with a brush in all cases,

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2.2 Construction of test units

Test units were constructed of Southern Pine sapwood (most likely consisting of loblolly (*Pinus taeda* L.), shortleaf (*P. echinata* Mill.), longleaf (*P. palustris* Mill.), and/or slash (*P. elliottii* Engelm.) pines), Douglas-fir (*Pseudotsuga menziesii* Mirb. Franco), and mill-run western hemlock (*Tsuga heterophylla* (Raf.) Sarg.). Douglas-fir heartwood is moderately resistant to decay in aboveground exposure. Southern Pine sapwood is perishable and hemlock heartwood has low decay-resistance.

Test units were made from 2- by 4-in. (5.1- by 10.2-cm) stock and consisted of two pieces, a vertical member (post) and a slanting one (rail), joined together with nails at a 45° angle (T. C. SCHEFFER and W. E. ESLYN, 1982). This construction simulated a conventional type of post and rail assembly.

Units for all but one test series were assembled after the two components had been treated. Posts and rails were matched on the basis of comparable preservative retentions. Thus, results obtained with a particular unit could be appraised with reference to a single level of treatment throughout the unit. In the test series in which the units were assembled before treatment, the two components were matched for expected equality of retention, on the basis of retentions obtained in wood from the same boards used in the other series.

Numbered aluminum identification tags were nailed on the test units after treatment but prior to painting. Units were painted approximately 15 days after treatment and then repainted periodically to maintain the finish through 1984.

2.3 Exposure of units and rating of decay

Test units were exposed outside on fences in the moderate-decay-hazard climate of Madison, WI (T. C. SCHEFFER, 1972). Units were systematically randomized for type of treatment. Decay was appraised visually and by probing. Decay was also appraised by sawing through the units at mid-positions and evaluating extent of decay by the appearance of newly exposed surfaces. The following scale was used to rate the development of decay:

0 no evidence of decay
20 decay suspected (based primarily on discoloration)
40 decay definite, but limited
60 general decay
80 decay sufficient to warrant replacement of unit
100 unit essentially destroyed; easily broken by sharp blow

2.4 Preservative treatments

Table 1 summarizes various treating variables and average retention of treating solutions for the three test species. Each entry is the average of eight post or rail pieces. The 3-min soak and 2-s dip treatments after assembly were done similarly, and comparable records for all these treatments were made. No retention record was kept for the brush treatment.

Table 1: Average retention of treating solution in nonpressure treatment of post-rail units[a].

Chemical[b]	Finish	Solution retention (g)					
		Pine		Hemlock		Douglas-fir	
		Post	Rail	Post	Rail	Post	Rail
15-min soak prior to assembly							
5% penta + WR in mineral spirits	Painted	28.5	21.9	25.6	18.6	17.2	13.9
	Unpainted	26.4	22.4	22.7	16.7	15.4	11.8
5% penta in mineral spirits	Painted	26.1	21.9	21.3	16.9	15.4	11.9
	Unpainted	26.5	21.7	21.4	17.4	14.9	12.1
5% penta + WR in kerosene	Painted	26.5	21.4	21.7	17.7	15.0	11.8
5% penta in No. 2 fuel oil	Painted	28.2	22.1	21.5	18.7	14.7	12.0
copper naphthenate[c] + WR in mineral spirits	Painted	25.0	19.2	17.8	16.3	12.9	10.6
	Unpainted	25.1	19.8	17.8	16.5	13.7	10.4
3-min soak prior to assembly							
5% penta + WR in mineral spirits	Painted	23.7	17.7	17.1	15.6	12.1	9.0
	Unpainted	22.2	16.8	17.1	15.7	12.9	10.7
10% penta + WR in naphtha	Painted	29.2	21.6	18.9	17.8	12.9	9.8
2-s dip after assembly							
5% penta + WR in kerosene	Painted	22.6	22.6	23.0	23.0	14.3	14.3
Spread on ends only[d]							
10% penta in grease	Painted	21.4	15.2	14.9	12.6	16.2	12.8

[a] Eight units per wood species. Retentions not ascertained for brush treatment with 10% penta + WR in naphtha (painted units).
[b] WR = water repellent.
[c] 1% cu.
[d] 3/8-in. (0.95-cm) layer of penta-grease applied to ends for 24 h.

For the penta-grease treatment, a 3/8-in. (0.95-cm) layer of grease was applied to the cut ends of the post and rail pieces. Surplus grease was removed after 24 h; the weight of preservative represents the absorbed oil and penta (Table 2).

T a b 1 e 2: Retention of pressure-applied preservative in test units[a].

Preservative and retention level	Pine sapwood		Mill-run hemlock		Douglas-fir heartwood	
	lb/ft^3	kg/cu^3	lb/ft^3	kg/cu^3	lb/ft^3	kg/cu^3
Chemonite						
Range	0.259 - 0.297	0.016 - 0.012	0.110 - 0.439	0.0069 - 0.027	0.094 - 0.682	0.0059 - 0.043
Average	0.282	0.018	0.264	0.012	0.334	0.021
Tanalith						
Range	0.316 - 0.353	0.021 - 0.022	0.165 - 0.621	0.010 - 0.039	0.189 - 0.721	0.012 - 0.045
Average	0.331	0.021	0.419	0.026	0.413	0.026

[a] Three to 8 units per wood species

Pressure treatment was applied to short (3- to 6-ft (91.4- to 183-cm)) lengths of 2- by 4-in. (5.1- by 12.7-cm) stock. Prior to treatment, each length was end-coated with three applications of Gaco Neoprene, N-700 Maintenance Coating, which effectively prevented end-penetration of the preservative. Retentions in the pressure-treated stock were calculated for each length individually After treatment, the stock was first kiln-dried and then cut into the post and rail pieces.

The rather wide range of retentions reflects the variation in treatability of Douglas-fir and hemlock heartwood. Hemlock showed less variability in this respect than did Douglas-fir, and pine sapwood showed approximately uniform retention. Averages and ranges of retentions obtained in the three species by pressure treatment with the two waterborne preservatives are shown in Table 2.

2.5 Bioassay of residual preservative in test units

Residual penta or copper naphthenate was estimated in the outer eighth-inch (0.3-cm) by bioassay for fungus-inhibiting chemical with *Aspergillus niger* van Tieghem (T. C. SCHEFFER and J. J. MORRELL, 1986). Bioassay samples were collected by removing surface chips, approximately 1/4-in. (0.6-cm) square, using a chisel. Chips were placed in 3.5-in. (9-cm),petri dishes on a malt-agar (2% malt extract, 1.5% agar) nutrient medium previously seeded with spores of *A. niger*. The plates were incubated at 81 °F (27 °C) and 80% relative humidity The area without black spores (zone of inhibition) near the specimen was considered an indication of inhibitory chemical, and the size of the area was considered the approximate amount of penta.

3. Results and discussion

The results presented in Tables 3 and 4 indicate that painting was an overriding factor in controlling decay in the post-rail units. Significant

Table 3: Condition of post-rail units, soaked for 15 min with 5% penta formulations, after 34-year aboveground exposure.

Wood species and carrier	Average rating[a] (% failed units[b])				Units without visible decay (%)			
	Painted		Unpainted		Painted		Unpainted	
	Post	Rail	Post	Rail	Post	Rail	Post	Rail
Southern pine sapwood								
Mineral spirits	8 (0)	8 (0)	38 (25)	48 (38)	87	87	75	75
Mineral spirits + WR	0 (0)	13 (13)	23 (25)	18 (31)	100	87	75	75
Kerosene + WR	0 (0)	15 (13)	-	-	100	75	-	-
Fuel oil	0 (0)	13 (0)	-	-	100	75	-	-
None (control)	63 (63)	67 (63)	88 (88)	88 (88)	38	25	13	13
Western hemlock, mill-run								
Mineral spirits	0 (0)	0 (0)	0 (0)	0 (0)	100	100	100	100
Mineral spirits + WR	0 (0)	0 (0)	0 (0)	0 (0)	100	100	100	100
Kerosene + WR	0 (0)	0 (0)	-	-	100	100	-	-
Fuel oil	0 (0)	0 (0)	-	-	100	100	-	-
None (control)	38 (13)	43 (13)	73 (63)	65 (38)	25	13	0	0
Douglas-fir heartwood								
Mineral spirits	0 (0)	0 (0)	0 (0)	0 (0)	100	100	100	100
Mineral spirits + WR	0 (0)	0 (0)	0 (0)	0 (0)	100	100	100	100
Kerosene + WR	0 (0)	0 (0)	-	-	100	100	-	-
Fuel oil	0 (0)	0 (0)	-	-	100	100	-	-
None (control)	0 (0)	0 (0)	48 (0)	43 (0)	100	100	0	13

[a] Average rating of eight units. See text for rating scheme; the greater the value, the poorer the condition of the units. Nearly all unpainted units were severely weathered.
[b] Failed units had individual ratings $\geq$ 80.

decay was present in painted units, with few exceptions (only in pine and hemlock controls and lightly treated pine units). A. F. VERRALL (1961, 1965) found that oil paint did not have a consistent effect on untreated pine exposed in southern Mississippi but markedly increased the effectiveness of dip treatments. He mainly attributed the salutary effect of paint to reduction in the amount of surface checking, which might expose untreated interiors, and possible reduction in the loss of toxicants through volatilization. In our study, checking and weathering were probably major factors in the poorer performance of unpainted pine units because these units were severely weathered and checked compared to painted units. With the more durable Douglas-fir heartwood, paint may reduce the loss of fungitoxic extractives.

T a b l e 4: Condition of post-rail units, treated in different ways, after 34-year aboveground exposure.

Species and chemical	Method of application[a]	Average rating[b] (% failed units[c])				Units without visible decay (%)			
		Painted		Unpainted		Painted		Unpainted	
		Post	Rail	Post	Rail	Post	Rail	Post	Rail
Southern pine sapwood									
Copper naphthenate, 1% Cu	15-min soak	10 (13)	30 (25)	88 (75)	93 (88)	87	63	0	0
Penta									
5% in kerosene + WR	2-s dip	35 (13)	53 (38)	-	-	38	38	-	-
5% in mineral spirits + WR	3-min soak	17 (13)	23 (13)	50 (38)	70 (50)	87	63	38	13
10% in naphtha + WR	3-min soak	0 (0)	0 (0)	-	-	100	100	-	-
10% in naphtha + WR	brush	38 (38)	45 (38)	-	-	50	38	-	-
in grease on cut ends only	trowel	0 (0)	8 (0)	-	-	100	87	-	-
Western hemlock, mill-run									
Copper naphthenate, 1% Cu	15-min soak	0 (0)	0 (0)	25 (0)	30 (25)	100	100	50	50
Penta									
5% in kerosene + WR	2-s dip	8 (0)	-	-	-	87	87	-	-
5% in mineral spirits + WR	3-min soak	0 (0)	0 (0)	0 (0)	5 (0)	100	100	100	100
10% in naphtha + WR	3-min soak	0 (0)	0 (0)	-	-	100	100	-	-
10% in naphtha + WR	brush	0 (0)	0 (0)	-	-	100	100	-	-
in grease on cut ends only	trowel	0 (0)	0 (0)	-	-	100	100	-	-
Douglas-fir heartwood									
Copper naphthenate, 1% Cu	15-min soak	0 (0)	0 (0)	0 (0)	5 (0)	100	100	100	87
Penta									
5% in kerosene + WR	2-s dip	0 (0)	8 (0)	0 (0)	0 (0)	100	100	100	100
5% in mineral spirits + WR	3-min soak	0 (0)	0 (0)	0 (0)	5 (0)	100	100	100	87
10% in naphtha + WR	3-min soak	0 (0)	0 (0)	-	-	100	100	-	-
10% in naphtha + WR	brush	0 (0)	0 (0)	-	-	100	100	-	-
in grease on cut ends only	trowel	0 (0)	0 (0)	-	-	100	100	-	-

[a] Units dipped for 2 s in kerosene were treated after assembly; other units were treated before assembly.
[b] Average rating of eight units. See text for rating scheme; the greater the value, the poorer the condition of the units. Nearly all unpainted units were severely weathered.
[c] Failed units had individual ratings $\geq$ 80.

Notable decay occurred only in pine post-rail units, which consisted of sapwood. Therefore, comparisons of results with different treatment variables were based mainly on observations of pine units. Data in the tables were based on external observations because external and internal ratings were generally comparable. All units pressure-treated with Tanalith or Chemonite, regardless if they were given a supplementary end-treatment with preservative, were free of decay. Therefore, these results are not included in the tables.

The results obtained by 15-min soaking in various 5% penta solutions before assembly are given in Table 3. The kind of preservative carrier (mineral spirits, kerosene, or fuel oil) did not affect preservative efficacy. Likewise, there is no evidence that incorporation of a water repellent improved effectiveness of treatment. Perhaps under more severe exposure conditions a water repellent would have improved the treatments.

Table 4 shows data from both copper naphthenate and penta treatments, different preservative solvents and preservative concentrations, and presence or absence of paint. Except for those units dipped in kerosene, all units were treated before assembly.

Comparisons of painted and unpainted units are provided only for units treated with copper naphthenate or with a 3-min soak in penta (5% in mineral spirits). Painting was beneficial for pine and hemlock units treated with copper naphthenate. Decay was moderate in painted treated pine units, but advanced to a point of causing failure in most unpainted treated pine units. No decay occurred in painted hemlock units treated with copper naphthenate, but decay was prevalent in unpainted treated units. Painting also benefited pine units soaked in 5% penta; both painted and unpainted hemlock units treated in this way were free of decay.

Copper naphthenate (1% Cu) was less effective than penta treatments for unpainted units, but it was comparable to 3-min soaking with 5% penta for painted units. A. F. VERRALL (1961) found that in-place treatment of unpainted pine units with copper naphthenate (0.5% or 2% Cu) or penta (5%) added little to the service life of units exposed aboveground in southern Mississippi. However, painting considerably increased the service life of treated units.

In an earlier study, A. F. VERRALL (1957) reported that soaking wood in preservative for 15 min provided somewhat deeper penetration than soaking for 3 min. Any benefit of such soaking was not apparent in our data; similar results were obtained with 3- or 15-min soaking in 5% penta (Tables 4 and 3, respectively). A quick dip (2 s) in 5% penta after assembly provided poor protection for pine units, even though all were

painted. This method of treatment, however, controlled decay in hemlock and Douglas-fir units to a great extent.

With one exception on pine, 10% penta in grease applied to only the component ends of painted units was fully effective. T. C. SCHEFFER and W. E. ESLYN (1982) also found that penta-grease applied to joint interfaces effectively protected painted post-rail units from decay in Mississippi. We did not include unpainted units in our study, but such treatment probably would not have been as effective in Wisconsin because of the deep weathering checks that develop in unpainted units.

Brushing units with 10% penta before assembly was fully effective on hemlock and Douglas-fir units but failed markedly on pine units, even though they were painted. However, paint alone protected Douglas-fir units from decay. A 3-min dip in 10% penta before assembly completely protected painted pine units; the 5% concentration was not as effective.

Previous studies (T. L. HIGHLEY and T. C. SCHEFFER, 1986; T. C. SCHEFFER and W. E. ESLYN, 1982) also showed that brush or dip treatments are much more effective on Douglas-fir than pine heartwood. This effectiveness is evidently due to the increased natural decay resistance of Douglas-fir. There is accumulating evidence that the benefit from simple preservative treatments of aboveground wood is mainly determined by the inherent decay resistance of the wood (T. C. SCHEFFER *et al.*, 1971). Furthermore, Douglas-fir and other western species are not easily pressure treated, and the ends of the components need to be retreated after the lumber is cut to size at the construction site. The results of our study indicate that preservative treatment of such species to be used out of ground contact might be accomplished just as well by briefly soaking cut-to-size stock in treating solution.

Previous studies had shown that penta applied by brush or soaking remains in the wood for a long time. T. L. HIGHLEY and T. C. SCHEFFER (1991) found residual penta in brush-treated Douglas-fir planks 20 years after treatment, and T. C. SCHEFFER and W. E. ESLYN (1982) detected small amounts of penta in dip-treated deck units after 22 years. In the present study, the *A. niger*, bioassay indicated the presence of trace amounts of residual penta only in units that had been soaked for 15 min in 5% penta with water repellent and painted; the one exception was in Douglas-fir units, where the bioassay indicated trace amounts of penta without water repellent. No residual copper naphthenate was indicated by the bioassay. This bioassay relies on the escape of biocide into the surrounding medium. Chemical analysis might have detected some biocide.

Of course, the effectiveness of treatments such as those described here will vary with climate. In Wisconsin, just 6 months of the year are warm enough to permit appreciable decay and the decay hazard is considered

moderate (T. C. SCHEFFER, 1972). Poorer performance was obtained in comparable studies in the high-decay-hazard climate of southern Mississippi (T. L. HIGHLEY and T. C. SCHEFFER, 1991; T. C. SCHEFFER and W. E. ESLYN, 1982). For example, 56% of painted untreated Douglas-fir post-rail units failed by 22 years after treatment in Mississippi (T. C. SCHEFFER and W. E. ESLYN, 1982). In our study, all painted Douglas-fir heartwood units were free of decay after 34 years of exposure in Wisconsin.

The results of our study lend encouragement to using simple in-place treatment of wood items not in ground contact, such as exterior trim, porch and deck components, and fence railing.

4. Summary

This research was initiated in 1958 to investigate the efficacy of various preservatives and treating methods for new lumber intended for exterior structures. Post-rail units (2 by 4 in. (5.1 cm by 12.7 cm) constructed of Southern Pine sapwood, Douglas-fir heartwood, and mill-run western hemlock were dip- or brush-treated before or after assembly. Units were treated with pentachlorophenol (penta) in various petroleum solvents or with copper naphthenate in mineral spirits. Both painted and unpainted units were exposed on a test fence in Madison, Wisconsin. Most of the painted untreated pine units (controls) failed by 34 years after treatment. Surprisingly, painting completely protected untreated Douglas-fir heartwood units from decay and afforded substantial protection to untreated hemlock. For painted treated units, significant decay was present only in lightly treated pine units (2-s dip after assembly or brush treated). Copper naphthenate (1% Cu) was markedly less effective than penta treatments on unpainted pine and hemlock units. There was no evidence that type of oil carrier or incorporation of a water repellent improved effectiveness of treatment. Three-minute and 15-minute dips in penta were equally effective. Application of penta-grease to only the ends of units was effective.

Zusammenfassung

Langzeit-Beurteilung einer in-situ-Schutzbehandlung
von Holz für den Außenbau gegen Pilzbefall

Die Forschungarbeiten wurden im Jahr 1958 mit dem Ziel begonnen, die Wirksamkeit verschiedener Schutzmittel und Schutzverfahren für neues, außen verbautes Holz zu untersuchen. Holzverbindungen (Stiel-Kopfband-Versuchskonstruktion mit den Abmessungen 5,1 cm × 12,7 cm) aus Splintholz von ‘southern pine’, Kernholz von Douglasie und ‘western hemlock’-Schnittholz wurden vor oder nach dem Zusammenfügen durch Tauchen oder Streichen behandelt. Bei den untersuchten Schutzmitteln handelte es sich um Pentachlorphenol (Penta) in verschiedenen Mineralölen oder um Kupfernaphthenat in Leichtbenzin. Die Versuchskonstruktionen mit und ohne Anstrich wurden auf einem Versuchszaun in Madison, Wisconsin, geprüft. Die meisten der unbehandelten Kiefernkonstruktio-

nen mit Anstrich (Kontrollen) waren nach 34 Jahren nach der Behandlung ausgefallen. Überraschenderweise schützte ein Anstrich die unbehandelten Konstruktionen aus Douglasien-Kernholz völlig gegen Pilzbefall, und eine erhebliche Schutzwirkung wurde ebenfalls bei unbehandelten 'western hemlock'-Konstruktionen festgestellt. Bei den behandelten Konstruktionen mit Schutzanstrich wurde erheblicher Pilzbefall nur bei den schwach behandelten Kiefern-Konstruktionen (2 Sek. Tauchbehandlung nach dem Zusammenfügen oder Streichen) beobachtet. Kupfernaphthenat (1% Cu) war erheblich weniger wirksam als Pentabehandlungen bei Kiefern- und 'hemlock'-Proben ohne Anstrich. Es gab keinen Hinweis darauf, daß das verwendete Trägermittel oder der Zusatz eines wasserabweisenden Mittels die Wirksamkeit der Behandlung verbesserte. Eine 3minütige und eine 15minütige Tauchbehandlung mit Penta waren gleich wirksam. Eine Behandlung der Kopfenden der Versuchskonstruktionen mit Penta mit einem fetthaltigen Trägermittel erwies sich als wirksam.

Résumé

Evaluation à long terme de deux sites de traitement pour prévenir les pourritures dans le bois exposé à l'extérieur

Cette recherche a commence en 1958, pour examiner l'efficacité de différents produits de preservation et de méthodes de traitements pour des bois utilisés dans des structures extérieures. Des échantillons de rails (5.1 cm par 12.7 cm) construites en aubier de pin du Sud, en coeur de sapin-de-Douglas et de la pruche de l'ouest ont été trempés ou traités à la brosse avant d'être assemblés. Les unités ont été traitées avec du pentachlorophénol (penta) dans différents solvents ou avec du naphthénate de cuivre dans des sels „spirits". Les unités peintes ou non ont été exposées dans un test de barrières à Madison, Wisconsin. La plupart des unités de pin peintes, mais non traitées (témoins) ont montré des échecs après 34 années. A notre surprise, la peinture a complètement protégé des pourritures, les unites du coeur Douglas non traitées, et a aussi protégé de façon non négligeable celles de la pruche de l'ouest. Pour les unités traitées et peintes, une pourriture non négligeable était présente seulement dans les unités de pin ayant reçu un léger traitement (2-s trempages après l'assemblage, ou traitement à la brosse) Les traitements au naphthénate de cuivre (1 % Cu) ont été moins efficaces que ceux aux penta sur les unités de pin et de hemlock non peintes. Il n'y avait pas d'évidence que l'utilisation de l'huile au lieu d'un produit antiperméable à l'eau améliore le traitement. Trois et 15 minutes de trempage dans le penta ont montré les mêmes résultats. L'application d'une graisse penta aux extrémités des unités à été très efficace.

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