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NATIONAL RESEARCH COUNCIL  
CANADA  
DIVISION OF BUILDING RESEARCH

EXTERIOR EXPOSURE OF CLEAR ORGANIC  
COATINGS ON WOOD

(A Progress Report)

by

**ANALYZED**

J. Harris, H. E. Ashton and G. A. O'Doherty

Internal Report No. 295  
of the  
Division of Building Research

OTTAWA

June 1964

## PREFACE

There has been much interest for a number of years in the use of clear coatings on the wood siding of houses. This widespread interest on the part of architects, home owners, and builders has been due largely to the attractive appearance that these coatings give to the coated grain of the wood. Unfortunately their use has presented a number of problems. Failures have occurred by delamination, cracking, and peeling with some coatings before completion of one year of exterior service. Other coatings required a new coating each year to maintain a good appearance.

Studies were undertaken during 1955 to determine the relative durability of different clear coatings and to obtain a better understanding of the various factors affecting their performance. Details of the different types of coatings that were exposed are described along with the field and laboratory methods used to assist in their evaluation. The results obtained, which are now reported will serve as a guide for future studies.

Mr. John Harris, the research officer in charge of the paint laboratories, was responsible for the initial studies undertaken. He was assisted in planning the second phase of the work by Mr. H. E. Ashton, the research officer who became responsible for the study and compiled the information being reported. Mr. G. O'Doherty, senior technical officer, assisted with all of the field and laboratory work and in evaluating the results obtained this far.

Ottawa  
June 1964

N. B. Hutcheon  
Assistant Director

## TABLE OF CONTENTS

	<u>Page</u>
FIRST EXPOSURE SERIES (1955)	2
Results	3
Summary	4
SECOND EXPOSURE SERIES (1960)	4
Results	9
Phenolic Varnishes	11
Alkyd Resins	13
Urethanes	14
Epoxies	14
Ultraviolet Absorbers	14
Exposure Conditions	14
Stains	15
Summary	15
Recoating	16
REFERENCES	18
TABLES I to VIII	
Appendix A - 1955 Exposure Series	
Appendix B - 1960 Exposure Series	

# EXTERIOR EXPOSURE OF CLEAR ORGANIC COATINGS ON WOOD

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J. Harris, H. E. Ashton and G. A. O'Doherty

The Paint Laboratory of the Division of Building Research took part in the co-operative testing program that led to the development of ASTM Method D1641: Test for Exterior Durability of Varnishes. When the test method work was finished, some preliminary investigations showed a marked difference in exterior durability between varnishes applied to D1641 test panels and the same varnishes applied to exterior siding. It was therefore decided to obtain information on the length of time that the best clear finishes could be expected to last when applied in the usual manner to the type of siding used in the house-building industry.

Exterior clear coatings have had a history of poor performance or excessive maintenance on wood in comparison with pigmented coatings. The more durable materials usually need a new coat every year or two until the thickness of the film leads to cracking across the grain. The poorer materials generally fail after 1 year by delamination or by cracking along the grain followed by peeling. In all cases the type of failure leaves a very poor surface for recoating.

In spite of their drawbacks there is widespread interest in exterior clear coatings because of the attractive appearance of the coated wood. The Division of Building Research has been approached many times for advice on this subject by architects, builders and homeowners. In order that information provided by the Division should be on a sound, unbiased basis, a project was set up to determine the durabilities of clear coatings. The project at first consisted only of exterior exposures but at a later date laboratory investigations designed to provide a better understanding of the materials were included.

A broad range of alkyd and phenolic varnishes was exposed at Ottawa in 1955. Based on these results, selected alkyds and phenolics were exposed in 1960, together with other types such as urethanes, epoxies and pigmented stains. The results of these exposures are included in this report and from them the materials with the best durability can be selected. The panels were examined at regular intervals and rated according to state of degradation, designated as follows:

10	no change
8	slight change
6	moderate change

4	marked change
2	severe change
0	complete failure

The aim of the laboratory work is to find which properties contribute the most to their durability. Ultimately it is hoped that if the paramount properties can be determined, it will be possible to predict from laboratory tests alone which coatings will be the most durable.

### FIRST EXPOSURE SERIES (1955)

The initial program included only conventional clear coatings which were in use or had potential use at that time. The 28 materials exposed included 16 pure phenolic varnishes, 9 alkyd finishes and 3 epoxy resin-fatty acid esters. The general descriptions are given in Table I and the complete formulae in Appendix A.

The alkyds and epoxy esters were prepared by diluting commercially available resin solutions to a Gardner-Holdt viscosity of approximately D and adding driers in the proportions of 0.4 per cent lead and 0.04 per cent cobalt, based on the solids content. The phenolic varnishes were prepared in the laboratory by cooking a pure para-phenylphenolic resin with the selected oils in a stainless steel beaker. After dilution to approximately 50 per cent solids, about 1/2 gal of varnish was obtained. Lead and cobalt driers in the same proportions as above were added to a part of the varnish sufficient for the coating program. The remainder was stored without driers. A portion of each material was diluted with mineral spirits to a Gardner-Holdt viscosity of A-2 for use as the first or sealer coat.

For the exposure tests two different woods which are commonly used on homes were selected, i. e. white pine and western red cedar. Three pieces of each in the form of drop (or cove) siding were cut to 30-in. lengths for each material. The edges and backs of the test panels were first sealed with sealer and aluminum paint. After coating, the six boards of each sample were mounted by brass screws to frames which could be attached to exposure racks. The screw holes were countersunk and carefully protected with aluminum paint.

For each material the complete system consisted of one sealer coat and two coats of normal viscosity applied by brush at intervals of about 24 hours. Each coat was applied to produce a full, wet coat and the amount was determined by weighing the panels. The weights and the corresponding spreading rates are given in Appendix A while the information is summarized in Table II. It can thus be seen that there was considerable variation in coverage between different panels of the same material and between different materials. The variations do not appear

to be related to differences in viscosity or in the solids content of the varnishes. Generally the coverage was greater on cedar than on pine.

## Results

Beginning 16 August 1955, the panels were exposed at the Ottawa exposure site of the National Research Council. They were mounted vertically facing south. Observations were made at intervals and are recorded in Appendix A. A summary of the results appears in Table III.

The kind of wood and its shape have an effect on the life of the coating. Generally the coatings showed poorer durability on red cedar than on white pine. This might be related to the fact that the materials, on the average, were applied at a greater coverage to the cedar thus yielding slightly thinner films. Drop siding was used in these tests and initial breakdown occurred in almost all cases at the bottom edge of the cove or in the hollow immediately above it.

The alkyd and epoxy-ester coatings failed much earlier than the pure phenolic varnishes. After one year only the long soya alkyd had a rating as high as 9. At the same time all the varnishes except three were in excellent condition. After 27 months only five varnishes and the one alkyd had no more than slight defects which did not detract from their appearance or would not interfere with recoating. The only recoatable surfaces after 3 years were the 30- and 40-gal tung oil varnishes.

The effect of oil content and type of oil on the durability of the phenolic varnishes is shown in Table IV. With one exception the tung oil varnishes were superior to the linseed oil varnishes and both were better than the dehydrated castor and soya varnishes. The latter were generally the poorest. The tung results at 20-gal oil length appear anomalous since the ratings as well as being below the corresponding linseed, are also lower than tung varnishes with both more and less oil. Better durability would be expected as the proportion of phenolic resin increases until the point is reached when the resin makes the film too brittle. The linseed varnishes illustrate this quite well. The soya and dehydrated castor varnishes, although on a more limited composition basis, also exhibit peaks in durability around 30 gal. The variation in ratings of the short oil varnishes, especially the low soya ratings, was rather surprising. One would have expected that at the highest possible resin content the durability of the resin would be the controlling factor and that the ratings would all be similar.

In Table V the ratings of the alkyd coatings are compared with their oil type and content. In contrast to the phenolics, the soya alkyds were much better than the linseed alkyds. There may be several reasons for this reversal in durability. Linseed oil is more functional than soyabean oil because of its greater unsaturation which leads to more

crosslinking during resin synthesis and in the drying process. The resulting film should be less flexible than that of a soya alkyd and therefore might fail sooner on a wood substrate. Another possibility is that alkyds fail in a different manner from phenolics when used as clear coatings on wood. Hence the effect of the type of oil could be expected to be different in alkyds. In addition, the proportion of oil in alkyds is not the same as in phenolic varnishes. An alkyd containing 60 per cent oil is considered long in oil whereas a varnish with the same oil content is short (ca. 18 gal). The most successful phenolics had 67 to 80 per cent oil while those with less had lower ratings. Possibly alkyds with this amount of oil might be more durable than the ones tested in this series. Finally it can be seen that the phenolic-modified linseed alkyd was not an improvement over the corresponding linseed alkyd. This could be due to the film being more brittle or the alkyd might contain a different phenol from the para-phenylphenol used to make Bakelite BR254.

The last observation from these results is that the summer months are more severe than the winter months. Table III shows that in the nine predominantly winter months to June 1957, 8 coatings dropped from the acceptable category and 4 were rated especially poor. In the next 5 months, which were mostly in the summer, 7 more became unacceptable and 3 more entered the poor group. Clear coatings would be expected to degrade more in the summer because of increased light and heat and these exposures confirm this assumption.

## Summary

Medium to long tung and linseed phenolic varnishes and a long soya alkyd provided 2 years of service as clear coatings on red cedar and white pine. Only two tung oil varnishes were acceptable after 3 years. At the end of these exposure periods, recoating is possible but it is not known whether the durability of new additional coats would be equal to the original coats or whether they would suffer from incipient failures in the previous coats. If left longer than 2 years in the Ottawa climate the other 22 coatings degrade to such an extent that considerable surface preparation is necessary before refinishing. In this group, short and medium length alkyds and the epoxy esters were very poor as clear coatings. It is evident from the exposure results obtained that a limited life only may be expected with conventional clear coatings on exterior wood.

## SECOND EXPOSURE SERIES (1960)

The second series of clear finish exposures was designed to recheck some of the earlier findings and to investigate newer materials. The original exposures had shown the superiority of several types of coatings and by eliminating many of the less successful ones it was possible



to examine in more detail further aspects of both phenolics and alkyds. Some of the new materials had been developed since 1955 while others were tested because they were claimed to be superior to the conventional finishes.

In the phenolic class, tung and linseed varnishes had been more durable than soya and dehydrated castor varnishes so the last two oils were dropped. The very long (50 gal) tung and linseed varnishes were eliminated because durability had decreased at this oil content. Durability had also been poorer at the short oil end so only the 10-gal tung varnish was used. All the varnishes that were retested were cooked again with closer control over the viscosity and solids content so that any differences in performance would not be due to variations in these variables.

One factor that was examined with the phenolics was the effect of varnish viscosity. An increase in viscosity is related to an increase in mean molecular weight of the oil-resin molecule. It was considered of interest to determine whether high molecular weight would be an advantage or if there would be an optimum viscosity range. Varnish specifications require the viscosity to fall within certain limits. Because the 30-gal tung phenolic had given about the best performance, it was selected for the study. Different batches of the oil and resin were held at the cooking temperature for various times to obtain a range of viscosities. The first sample was not cooked at all but the oil was heated only enough to dissolve the resin. The resulting mixture had a viscosity of B-C at 100 per cent solids. The solids content was reduced to 65 per cent so that it would be closer to the cooked varnishes and any difference in durability would not be due to film thickness. Fifty per cent butyl acetate had to be added to xylene to keep the resin in solution. There is thus evidence that in varnish cooking the resin reacts with the oil and is not merely dispersed since even the undercooked varnishes were soluble in mineral spirits containing only 10 per cent xylene.

The phenolic resin used in all the previous varnishes was made from para-phenylphenol. Although this resin was for many years considered to be the industry standard, it could not be assumed that other types of phenolic resin would not have equal or better durability. Consequently, three other resins were used to make four varnishes, one of which was known to duplicate closely a commercially available product. One resin was a reactive type while the others were of the non-reactive para-tertiary-butyl phenol kind.

In the first series all the alkyds had been reduced to the same viscosity so that the solids content differed by as much as 25 per cent total solids. It was thought possible that the poor durability rating of the short and medium alkyds could have been related to the low non-volatile vehicle which would yield thinner films. In reformulating the alkyd solutions the solids were kept as close as possible to 50 per cent without making the

viscosity abnormally high. To check the effect of oil content more thoroughly, a complete range of soya alkyds was used. One linseed alkyd was also tested and to eliminate at least one variable, all were purchased from the same manufacturer.

Most alkyd resins are based on ortho-phthalic anhydride. In recent years alkyds have also been made with the meta isomer, isophthalic acid. The Golden Gate Production Club (1) has reported that this type of alkyd had good durability when used as an exterior clear finish on wood. One very long oil isophthalic alkyd corresponding to an oil length of 50 gal was therefore included in the second series. It was intended to test one with an oil content equal to the most durable varnishes but the sample was rather old and would not dry.

Urethanes are relatively new materials in the coatings industry. They have been promoted on the basis of excellent exterior durability when used as clear coatings on wood. As a result three urethanes were included in the exposure series. One was a two-component type in which a polyisocyanate is crosslinked with castor oil. The other two were oil-modified urethanes where the drying occurs through the oil portion. One of these was a commercial clear exterior wood finish supplied by a paint manufacturer. It had been intended to have a third type in which a urethane prepolymer is crosslinked with an amine curing agent. Unfortunately, the only amine on hand when the panels were prepared was not soluble in the resin solvents and the film did not dry.

Although epoxy resins were introduced several years before the urethanes, they are not as old as phenolics and alkyds. In the first series, three epoxy esters had been tested and found to have poor exterior durability. To produce the esters, oil acids are reacted with epoxy resins and drying occurs through the oil portion. Whether such an ester is more like an oil or an epoxy depends upon the proportions of the constituents. To obtain a satisfactory film that is mainly epoxy it is necessary to crosslink the resin with a curing agent. In the second series of exposures three epoxy formulations were included to see if they would outperform the esters. One sample was cured with an amine, one with an amine-adduct and the third with a polyamide resin.

The use of ultraviolet absorbers for improving the durability of clear coatings has been suggested in commercial literature. Much of the degradation of coatings and plastics is attributed to the ultraviolet portion of daylight. One reason given for the poor durability of clear finishes in relation to pigmented finishes is that there is no pigment to absorb the light and protect the vehicle. If a material which can absorb UV and dissipate it harmlessly is added to a clear organic polymer, its exterior durability is said to be markedly improved. With the second series there was not sufficient exposure space to make more than a brief study on the absorbers. One UV absorber was added to three coatings -

an alkyd, a phenolic and a urethane - in the proportion of 0.5 per cent of the solids content. This amount had been suggested in formulae for lacquers to prevent bleached wood from darkening and was considered a good starting point for future work.

The panels for both exposure series were prepared in the laboratory using siding which had been kept indoors. Houses, of course, are not erected under such ideal conditions. Occasionally the siding may be exposed to the weather for a considerable time before it is coated. To determine if there is any effect on durability an alkyd and a phenolic were applied to panels which had first been exposed to the weather for several days.

Frequently in discussions on exterior durability testing it is suggested that panels should always be exposed at the same time of year. The idea is that films that are put out in the autumn cure under mild conditions and will be more able to resist the summer sun than those that are exposed in the late spring or early summer. Because the second series was exposed in November 1960, another set of two of the finishes was exposed in July 1961. In addition, a third material was subjected to summer weather immediately by applying it in July to siding which had already been mounted on the test fence, thus duplicating normal house application.

Three sets of panels were included as a matter of interest. One material was a water repellent sealer of the type used on lumber, which cannot be painted immediately but requires some protection. The U.S. Forest Products Laboratory strongly recommends it for back priming siding to prevent water wicking behind the siding. A raw material supplier had suggested an emulsion of a cellulose acetate-butyrate lacquer since cellulose acetate compounds are resistant to degradation by ultraviolet light. Two pieces of siding were given two coats of the emulsion.

Many people have enquired about the use of linseed oil as a clear coating for exterior wood. Although some paint dealers appear to have recommended it, the Paint Laboratory has had reservations about this treatment. It was therefore decided to determine its exterior durability. For direct comparison with the two main conventional coatings, boiled linseed oil was applied to the centre of three panels and an alkyd and a phenolic were applied on either side. In this way variations due to the wood were eliminated. All three finishes were applied in three coats with the first coat of the alkyd and of the phenolic reduced for sealing.

Finally it was decided to obtain information on the durability of exterior pigmented stains. This type of coating is classified as being in between a clear finish and a paint. The pigmented stains

are designed for use on wood and contain sufficient pigment to colour the substrate but usually not enough to observe the grain of the wood. Added durability is claimed because of the pigment content. Based on results of the 1955 exposure series, the Paint Laboratory had been recommending stains in preference to clear finishes for exterior wood. Nevertheless, it was not known from actual exposures whether their performance would be more like a clear coating or a paint. Two commercial stains, one with an alkyd vehicle and the other with refined creosote, were used as standards. The Forest Products Laboratories of both Canada (2) and the United States (3) have published formulations for stains which can be made by the homeowner and which are claimed to have very good durabilities. Coatings similar to both these materials were included in the program. Lastly, a stain was formulated in the Paint Laboratory to meet CGSB Specification 1-GP-145: Stain; Pigmented, Exterior and Interior, based on information obtained when the specification was being written. The vehicle consisted of an alkyd resin plus linseed oil.

The composition of all test materials is summarized in Table VI and the complete formulae, where known, are given in Appendix B. Except for the stains and the water-repellent sealer all materials were applied in three coats. The first coat was diluted with the appropriate thinner to a Gardner-Holdt viscosity of A-2 except for the cold-cured epoxies and those materials which already had a low viscosity. The stains and the sealer were applied in two coats with the exception of the Forest Products' formulations. The U.S. Forest Products Laboratory recommends one coat while the Canadian Forest Products Research Branch suggests two with wiping for each coat. To compromise, half of each panel received one coat and half two coats with wiping for the Canadian formula. A full coat of each stain was applied but the coverage varied from 550 to 685 sq ft per gal because of brushing characteristics. The weight applied and the resulting dry-film thickness are given in Appendix B. The clear finishes were applied to yield a total dry-film thickness close to 2.5 mils.

Two species of wood had been used in the first exposure series. Because the failure rate appeared to be slightly higher on red cedar than on white pine it was decided to use only the former in order to reduce the number of panels required by one-half. Bevelled siding was selected because the cove siding previously used had accentuated failures on the upper exposed edge. In the second series the panels were not back-primed because this is rarely practised in home building. The ends, however, were sealed to reduce their influence on the relatively short lengths. Plywood sheets covered with building paper were used to support the panels on the exposure racks. Nails were used for fasteners and were driven from the back of the plywood so that the test surfaces remained

unbroken. To protect the ends and to duplicate house construction more closely, strips were fastened to the ends of each assembly of 6 panels and caulking compound was injected between the panel ends and the strips.

A cap is generally placed on top of vertical test fences to prevent rain water from getting behind the panels. In the 1955 series it was noted that the top panel had received considerable protection from this cap. In 1960 a piece of wood was inserted to increase the distance from the top panel to the cap. It had been decided that the test panels would be mounted in a random order to eliminate possible localized effects and to help ensure unbiased ratings. Unfortunately, the first 12 of the 46 sets had all three panels placed together as in the 1955 series before the error was discovered. They were left as sets but were mixed in with the individual panel assemblies.

The panels were placed on the exposure racks at the National Research Council on 21 November 1960. As before, exposure was vertical facing south. The panels were observed periodically during the test. In November 1962 the assemblies were removed to the laboratory and examined independently by two observers. These final ratings were combined and are shown in Appendix B. The exposure period was of shorter duration in the second series because it was desired to recoat most of the panels before failure became too extensive. It had been intended to recoat them on the test fence but the early onset of winter in 1962 prevented this.

## Results

After the first 7 months of weathering only five materials showed any effects besides the expected yellowing of the phenolic varnishes. The butyrate lacquer had turned white and started to flake and the panels with water repellent sealer were beginning to look white. There was slight grain raising on the creosote stain panels while stain 870 was exhibiting some gloss over the summer wood due to the use of unbodied linseed oil. The boiled linseed oil was sweating or frosting.

The condition of the materials at the end of 1 year and 7 months is given in Table A.

Table A

In excellent condition:

893	20 gal Tung-para-phenylphenolic	
894	30 " "	" Normal cooked
894SE	30 " "	" Exposed in July 1961
894 F	30 " "	" Applied on test fence 1961
896	30 " "	" Undercooked
897	30 " "	" Slightly undercooked
898	30 " "	" Slightly overcooked
899	30 " "	" Moderately overcooked
901	40 " "	"
934	40 " "	" With UV absorber
902	20 " Linseed	"
906	TT-V-119	"
910	Cold mix varnish	
850	Castor-oil-cured urethane	
848	U.S. F.P. L. stain	
870	1-GP-145	"
11505	Rez	"

In poor condition:

846	Water repellent sealer
907	30 gal Tung-reactive phenolic
917W	Medium linseed alkyd applied to weathered boards
-	Cellulose acetate-butyrate lacquer.

Most of the remainder of the materials rated good to very good. The alkyd films were generally in good condition but there were white spots or areas underneath the film as though air were getting between the wood and the coating. This usually occurred over the spring wood only. Except for one panel the oil-modified urethanes were very good, ranking slightly below the first group. The alkyd and the phenolics that had been applied to weathered panels were in a significantly poorer condition than the same coatings on non-weathered panels. The films exposed in July were about the same or slightly better than those put out 7 months earlier.

When the final observations were compared with those made in June 1962, it was again obvious that the summer months are most destructive to clear finishes. The mean of all the ratings had decreased in 5 months from 7.7 to 5.3 (Table VII). The rate of decrease is five times greater than in the previous year. At the end of 2 years there were only 8 clear finishes and 2 stains that could be classified as good or very good and out of this group 6 panels that were rated as excellent. The materials are arranged in order of rank in Table B.

Table B

<u>Number</u>	<u>Type</u>	<u>Mean Rating</u>	<u>Lowest Rating</u>
848	U. S. F. P. L. stain	9	9
870	NRC 1-GP-145 "	8.7	8
896	30 gal tung-para-phenylphenolic	8.2	7.5
898	30 " " "	8	8
893	20 " " "	8	8
897	30 " " "	7.5	7
910	Cold mix varnish	7.5	7
906	TT-V-119 para-phenylphenolic	7.5	6
894F	30 gal tung	7.3	6.5
850	Castor-oil-cured urethane	7.3	6

There is, of course, no definite line of demarcation between "good" coatings and those of slightly lower ratings but the above materials appeared to be superior to the others. Another complicating factor in comparing materials is the variation between different panels of the same coating. Some, such as 893 and 898, performed the same on all three panels; others, such as 906, 851 and 844 were good or even excellent on one panel but fairly good to very poor on another. In some cases the poorer durability resulted from the wood panel having a lot of flat grain. Where there was no obvious explanation for the difference, the material was reduced in rank compared to those that had performed more consistently.

Phenolic Varnishes - It can be seen that phenolic varnishes generally had the highest ratings. Of the eight best clear finishes, seven belong to this category. None of the newer materials in this exposure series equalled the performance of the better tung-para-phenylphenolic varnishes. It may yet be possible that the castor-cured urethane will fail in a manner more suitable for recoating since it loses gloss rapidly but does not exhibit too many other defects. Proof of this will have to await the conclusion of the exposure test. The first signs of failure usually shown by phenolic varnishes are spots of light yellow which contrasts with the normal deep yellow colour. On close inspection the spots are found to be associated with small craters. It is not known which form first. As time progresses the craters open up into small cracks running in the same direction on the grain lines. When the cracks get larger the film peels back from the edges. If the film is brittle it may flake off in pieces rather than peel. If allowed to progress too far, this type of failure requires removal of most of the film. Such removal is very difficult to carry out on the siding of a building.

The effect of oil content and type of oil on the durability of the para-phenylphenolic varnishes is shown in Figure 1. Tung varnishes outperformed the linseed varnishes at all oil lengths. At 20 gal the difference was slight but as the oil content increased the superiority was more marked. In agreement with theory but in contrast to the 1955 series, the tung varnishes showed a peak in durability around 20 gal as did the linseed varnishes in both series. TT-V-119 and the cold mix varnish both of which contain a high proportion of tung oil were also durable varnishes.

Figure 2 shows the effect of the viscosity of the varnish on the durability rating. There appears to be a trend to better durability with lower viscosity although the results from 898 are not in agreement with the others. It had been expected that the varnishes with medium or high viscosities would be more durable. The superiority of the low viscosity varnishes might be due to the ability of the lower molecular weight material to penetrate into and reinforce the top layer of the wood. There is also the fact that the first coat of the lighter varnishes contained more non-volatile vehicle at equal viscosity and there would thus be more material available to bind the wood fibers. Work is now planned to find which property is the more important. In either case there is an indication that instead of reducing a normal viscosity varnish with solvent to prepare the first coat, a low viscosity-high solids sealer might give better results.

It is also evident, however, that at least with the para-phenylphenolic resin some cooking of the ingredients is required because the simple mixture had the poorest durability of the seven in this set. Bakelite BR 254 cannot be substituted for Bakelite BR 9400 in the cold-mix formula because it is only soluble in strong solvents. BR 9400 which is a butylphenolic resin gave good results but varnishes made with the other two alkyl phenolic resins had poor durability. The reactive phenolic varnish was in poor condition after only 19 months. At the same time formulae 908 and 909 were in good condition but deteriorated markedly during the second summer of exposure.

The above results make clear what ingredients are needed in the normal cooked varnish. The resin should be para-phenylphenolic and the oil should consist mostly of tung oil and comprise 65 to 75 per cent of the solids. This kind of information is of little assistance to the average user because neither he nor the paint dealer knows the composition of the varnish. The name "spar" varnish does not help because of misuse in the trade and even "pure phenolic" is not specific enough since failures occurred with two phenolic resins. The only recourse for the buyer or specifier is to ask whether the varnish complies with CGSB Specification 1-GP-99 which requires the use of para-phenylphenolic resin.



Alkyd Resins - The alkyds were inferior to the para-phenyl-phenolic varnishes as clear finishes for exterior wood. This finding confirms the results of the first exposure series. The typical alkyd failure starts as small craters and white spots over the spring wood. The spots grow into areas stretching in the direction of the grain. A crack may develop in which case there is peeling over a small area but usually adhesion is lost over the adjacent summer wood and large areas delaminate from the surface. This procedure is in marked contrast to pigmented coatings which first fail over the summer wood. Even after delamination the outer surface of the alkyd film appears to be in good condition. This together with laboratory studies that show that the alkyd films by themselves are very durable indicates that it is not the film but the wood substrate that has deteriorated. It is believed that the top layer of spring wood is degraded by ultraviolet light leaving the alkyd film without support. Other investigators (4) have shown that when uncoated wood is exposed, the lignin is attacked first leaving a layer of cellulose fiber. Perhaps phenolic varnishes, which inherently have less weather resistance than alkyds, show better durability on wood because they transmit less ultraviolet light. Materials such as UV absorbers or a small amount of pigment which would reduce the amount of UV light reaching the wood might markedly improve performance since the alkyds themselves appear quite durable.

There was no clear connection between oil content and durability but any relationship would be difficult to detect because the viscosity of the alkyds, hence the solids content of the first coat, varied with changing oil content. In the one case where alkyds of different viscosities had the same oil content, the lower viscosity material had the better rating. As with the phenolics it is not known whether this is due to higher solids in or better penetration of the first coat. The durability ratings are plotted against oil content in Figure 3. For comparison the tung-para-phenylphenolics are included. It can be seen that there were no alkyds in the range of 65 to 75 per cent oil where the phenolics showed their best durability.

The two best alkyds were the long soya, low viscosity and the medium soya, medium viscosity samples but after 2 years they could only be classed as fairly good. Comparisons between the two series are difficult but the shorter alkyds did not appear to fail as badly as on the first exposures. The higher solids content may have been responsible for this somewhat better durability. The isophthalic and orthophthalic alkyds could not be compared directly because of the large difference in oil content. Due to the high oil content the isophthalic retained considerable dirt on the film and a somewhat shorter resin might be better in this respect since it would not be so soft. The linseed alkyd had the best gloss retention of all clear finishes. Its performance on wood was about the same as the soya alkyds in the same oil content range. In spite of their mediocre durability, all alkyds were much better than the linseed oil treatment.

Urethanes - The performance of the urethanes was rather disappointing considering the claims made for them by the raw material suppliers. The oil-modified urethane both with and without UV absorbers showed great variation between different panels with ratings ranging from very bad to good. The commercial oil-modified urethane and the castor-cured type had smaller ranges of 3 and 2 respectively. The variability appeared to be connected with the high tensile strength of the urethanes. As long as there was no break in the surface, the film remained in quite good condition but once it was ruptured pronounced peeling followed. The castor-oil polyisocyanate was the only clear material that seemed to fail more at the air interface than at the wood interface. It lost gloss rapidly but otherwise remained in quite good condition. One urethane resin manufacturer has claimed that clear urethanes fail in a manner that leaves them suitable for recoating. This type of failure would have to occur at the air interface. The loss in gloss is the only evidence so far noted that would substantiate the claims. A higher castor oil content might improve the flexibility of the coating.

Epoxies - The two amine-cured epoxies had only fair durability ratings which were comparable to the alkyds. The type of failure, however, was entirely different in that the epoxy film degraded. Once a break occurred, extensive flaking followed. The polyamide-epoxy was rated as very bad. This is surprising since the polyamide is resinous itself and it was thought that it would confer greater flexibility than the short chained amines. Polyamides have been reported to be unstable towards UV light in the presence of air and this could explain the film degradation. The only possibility for improved epoxy performance appears to lie with curing agents which would cause less crosslinking than that obtained with the highly functional amines previously used.

Ultraviolet Absorbers - The UV absorbers when used at a concentration of 0.5 per cent were not effective in slowing the exterior degradation of an alkyd, an oil-modified urethane and a phenolic. According to information received since 1960 about 4 per cent based on solids content is required for many materials and some need up to 10 per cent. The latter level is impractical since the raw material cost would be doubled. The weatherometer is to be used for screening tests to determine the level of absorber required for clear coatings tested in the future.

Exposure Conditions - Whether panels were exposed in the spring or the fall appeared to make little difference, at least according to the results obtained with the rather small sample of two materials. An amine-cured epoxy had also been exposed but the curing agent had deteriorated and proper films were not prepared. What does appear to be important is the number of summers to which a coating has been exposed. Panels put out in autumn appear to be more durable than spring panels because there is an extra 7 months before much degradation occurs.

The period of exposure of the wood before coating is also very important. The three materials applied to boards that had been weathered for only 1 week had an average decrease in rating of about 2 from the same materials applied to panels kept in the laboratory. These results would favour factory coating of lumber since the siding on a new house is usually left for at least 1 month before it is coated. Weatherometer tests are now being carried out to see if longer exposures of the uncoated wood to light and to light and water will promote failures.

Stains - Two of the stains had the best ratings of all the materials exposed. That pigment is not the complete answer is shown by the fact that five types of clear coatings were better than the next lower stain. The creosote stain was only rated as fair and the wiped stain poor. One reason for the good durability of the U. S. Forest Product's formulation is the very dark colour, two coats of the material resembling a paint more than a stain. The NRP849 formula which is similar to the Canadian Forest Products Laboratory stain, was applied by brush and wiped after each application. The two coats applied still leave a relatively thin coating that requires renewal in about a year when the water repellent qualities have deteriorated. The maintenance would therefore be excessive. The creosote stain could be ranked lower than the Canadian material because it had two full coats as against two wiped coats. All except the wiped stain hid most of the grain pattern which defeats one of the reasons for using a stain. It is not known whether the same good results of 848 and 870 would be obtained if less pigment or a light coloured pigment were used to make the wood more distinguishable. The pigmented stains should fail by erosion which would leave a better surface for recoating than a flaked, checked or peeled clear coating.

### Summary

In carrying out this work a number of details have been mentioned concerning the preparation of the panels and exposure conditions. These details included back priming as was done with the first group of panels, the sealing of end grain and use of caulking, the choice of wood siding used and observation of the performance of different coatings to southern exposure only. Because of this, the question could be raised as to the applicability of this information to normal building practice. The intent was to remove those conditions that might have an extraneous effect on the coating performance. It is on the basis of the results obtained that the following evaluations were made and conclusions drawn.

Two pigmented stains performed the best in the second exposure series. One contained linseed oil fortified with wax and preservative and the other was based on an alkyd with additional linseed oil. Of the clear finishes, 20 to 30 gal tung-para-phenyl-phenolic varnishes provided at least 2 years of good service. A cold-

mix varnish and a castor oil-cured urethane was also good. With phenolic varnishes the type of oil and the type of resin are both important if adequate durability is to be obtained. The other clear finishes were generally inferior and could not be recommended for exterior wood. Two of the stains were also inadequate.

The weathering of wood before coating affected the durability of clear finishes. This effect must be ascribed to wood degradation which occurs much faster when wood is not coated. Because the effect of such a short time was marked it is believed that some portion of the failures of all the clear coatings is also due to this degradation. It is, in fact, considered to be the chief cause of the failure of alkyds that suffer from delamination although the films themselves are usually in good condition. The best hope for developing an excellent exterior clear finish for wood appears to lie in finding ways for stopping or slowing down the degradation at the wood surface. Coatings with the best inherent durability, such as alkyds and acrylics, could then be used satisfactorily on wood.

### Recoating

Part of the program of the second exposure series has been concerned with the problem of recoating clear finishes. Actually there are two different questions involved: how do materials which have shown good original durability perform when recoated before failure commences and what is the best way to treat surfaces on which failure has occurred because an inadequate material was used. Refinishing large areas that have deteriorated through weathering is not an easy task since the common clear finishes do not lend themselves to recoating when their useful life has ended. The types of failure range from tiny cracks or checks to large white patches or peeled and flaking areas. For refinishing, the surface must be free from all loose film and as smooth as possible with no sharp edges. Coatings do not cling well to edges and the film thickness is always reduced at these locations. Feathering the edges of stripped areas with sandpaper reduces the sharpness and also helps to blend the repaired area with the surrounding surface.

The clear finishes that had been exposed for 2 years were divided into four categories as follows:

1. Materials requiring little or no touch-up;
2. Materials starting to fail;
3. Materials with more serious failure;
4. Materials completely failed.

Those in the last group were discarded since in actual practice the coatings would seldom be allowed to deteriorate to such a degree. The first group included all the 20- and 30-gal para-phenylphenolic

varnishes, the cold mix varnish, the castor-cured urethane and the commercial oil-modified urethane. The best panel of each material was left untouched to determine the ultimate durability of the original coating system. On another panel any defective areas were hand-sanded to bare wood and the edges of the area feathered. On the third panel hand scraping was followed by light sanding and feathering. These spots were then touched up with two coats, the second coat being spread over a slightly larger area than the first. Each panel then received a coat over the entire face. For all panels in this group the same material as originally applied was used for recoating.

In the second category hand sanding was compared with scraping and sanding and with wire brushing and sanding. The coating procedure was the same except for the epoxy in which case all three panels were refinished with the 20-gal tung-para-phenylphenolic and the two alkyds each of which had one panel refinished with the same varnish. Only one material had all three panels in the category of more serious failures. It was a 40-gal linseed phenolic and was recoated with the more durable 20-gal linseed phenolic. For preparing the surface a paint remover, scraping and sanding were used on one panel, a reciprocating power sander on another panel and a circular disc sander on the third. The one oil-modified urethane panel which had failed rather badly was also prepared with the disc sander.

Four of the stains were also touched up. All three of the Canadian Forest Products panels received a fresh coat of stain. With the remaining three stains one panel of each was not recoated and one panel received a full coat. Half of the third panels of the commercial alkyd stain and the NRC modified alkyd stain were recoated. The commercial creosote stain was in poorer condition than the others so the third panel had to be given a full coat. It had been intended to re-expose the U. S. Forest Products stain without refinishing since half of each panel already had two coats. Unfortunately, the panels were left in the laboratory with the discards and were not discovered until after the first summer of re-exposure had ended.

The complete refinishing schedule is given in Table VIII. All preparation and recoating had to be carried out in the laboratory because of the early arrival of winter in 1962. The effectiveness of the different methods of preparation will not be known until the exposure studies are completed but comments can be made on the ease of preparation.

Hand sanding is effective in cases where failure is limited to small or scattered areas of lifting, peeling or light-coloured streaks. A medium grit garnet paper should be used and feathering can be done with the same paper that has lost its initial sharpness.

Scraping with a hoe-type scraper is more feasible than sanding for materials that have a greater degree of failure. It reduces the thick-

ness of the coating thus facilitating feathering. Scraping was most effective with the phenolic varnishes and urethanes.

Wire brushing easily removes very loose material but is not as effective as scraping for most coatings. The alkyds are readily wire brushed because they fail by delamination but the harder films resist the steel bristles remarkably well. Subsequent sanding and feathering take longer after wire brushing because the wood is often scored, with some spring wood removed.

The common reciprocating sander is rather ineffective, particularly on the harder materials. The sandpaper quickly gums up because the sanding dust fills the voids in the paper, reducing its abrasiveness. The disc sander does a better job since the paper stays cleaner. There is, however, some scoring caused by sanding across the grain but after refinishing close inspection revealed only slight visual defects. The chief drawback is the weight of the machine which makes it difficult to control on a vertical surface. The sanding attachment for a 1/4-in. electric drill is light but rather awkward to handle.

Paint and varnish remover is effective but very laborious. Two applications are often required and scraping with at least a putty knife followed by sanding is necessary for complete removal. Most paint removers contain wax to retard solvent evaporation so that wood surfaces must be thoroughly cleaned or subsequent coats may not dry. Another consideration is that on exterior work the wind can often increase solvent evaporation thus reducing the effectiveness of the material. In general, paint removers would not seem to be practical for use on buildings.

To summarize, scraping with finishing by sandpaper produces the best results with the least work on surfaces with moderate failure. For more serious defects the disc sander is required since most of the coating has to be removed to bare wood.

The untouched and the refinished panels were re-exposed on 19 March 1963. They will be examined periodically and the results compiled when the stage is reached where definite conclusions can be drawn. The laboratory investigations will be the subject of separate reports.

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TABLE I

COMPOSITION OF MATERIALS EXPOSED IN 1955

<u>Formula No.</u>	<u>Oil Type</u>	<u>Oil Length</u>	<u>% Solids</u>	<u>Viscosity</u>
<u>Para-phenylphenolic varnishes</u>				
372	Linseed	10 gal	51.3	G
373	"	20 "	52	C
374	"	30 "	50	E
375	"	40 "	48.5	C
376	"	50 "	46.2	F
371	Tung	10 "	54.6	A
430	"	20 "	51	C-D
429	"	30 "	52.3	F
428	"	40 "	51.8	G
427	"	50 "	48	C-D
403	Soya	10 "	53	F
402	"	35 "	49.5	C-D
401	"	50 "	55	J
407	Dehydrated Castor(D. C. O.)	10 "	53.8	P
406	"	30 "	53	E
404	"	50 "	47	B
<u>Alkyd solutions</u>				
362	Linseed	Very Short	28	D
355	"	Short	38	D
356	"	Medium	38	D
358	"	Long	52	D
363	Linseed Phenolated	Medium	39	D
359	Soya	Short	41	D
360	"	Medium	45	D
357	"	Long	53	D
361	Dehydrated Castor	Short	32	D
<u>Epoxy esters</u>				
365	Linseed	Long	38	C-D
364	Soya	Short	37	C-D
367	Dehydrated Castor	Short	32	D



TABLE II

SPREADING RATES - 1955 EXPOSURE SERIES

NRP Material No.	Mean Spreading Rate Red Cedar		(sq ft per gal) White Pine	
	<u>2nd coat</u>	<u>3rd coat</u>	<u>2nd coat</u>	<u>3rd coat</u>
<u>Phenolic varnishes</u>				
372	393	429	391	408
373	732	679	720	567
374	535	623	462	532
375	644	1068	656	744
376	856	914	560	631
371	631	475	547	538
430	612	540	566	468
429	522	422	455	399
428	661	471	576	473
427	575	500	607	383
403	368	322	365	303
402	511	521	493	455
401	531	348	409	272
407	400	331	340	305
406	531	427	465	419
404	580	646	654	459
<u>Alkyds</u>				
362	700	646	805	631
355	583	518	581	421
356	629	631	579	439
358	720	515	621	474
363	1007	648	1013	513
359	467	447	392	450
360	619	456	407	347
357	423	505	439	371
361	725	580	546	515
<u>Epoxy esters</u>				
365	713	729	493	860
364	595	699	645	556
367	701	621	615	562

TABLE III

CLASSIFICATION OF COATINGS AT VARIOUS INTERVALS

<u>Time</u>	<u>Acceptable</u>	<u>Especially Poor Conditions</u>
13 months 19 Sept. 1956	All acceptable except the seven coatings listed below *	None
22 months 19 June 1957	357 Long soya alkyd 373 20 gal linseed phenolic 374 30 " " " 375 40 " " " 376 50 " " " 402 35 " soya " 406 30 " D. C. O. " 404 50 " " " 371 10 " tung " 430 20 " " " 429 30 " " " 428 40 " " " 427 50 " " "	356 Medium linseed alkyd 363 Phenolated linseed alkyd 365 Long linseed epoxy ester 403 10 gal soya phenolic
27 months 13 Nov. 1957	357, 375, 406 429, 428, 427	356, 363, 365, 403 and 362 Very short linseed alkyd 358 Long linseed alkyd 364 Short soya epoxy ester
36 months 14 Aug. 1958	429 30 gal tung phenolic 428 40 " tung phenolic	356, 358, 362, 363 364, 365, 403 and 355 Short linseed alkyd 359 Short soya alkyd 361 Short D. C. O. alkyd 367 Short D. C. O. epoxy 376 50 gal linseed phenolic 401 50 gal soya phenolic

\* Unacceptable after 13 months' exposure:

356 Medium linseed alkyd  
363 Phenolated linseed alkyd  
364 Short soya epoxy ester  
365 Long linseed epoxy ester  
403 10 gal soya phenolic on both woods and  
362 Very short linseed alkyd  
355 Short linseed alkyd on red cedar

TABLE IV

DURABILITY RATINGS OF PURE PHENOLIC VARNISHES  
VS OIL CONTENT AND TYPE OF OIL

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<u>Oil Length</u> <u>Approx.</u>	<u>Oil Content</u> <u>% by wt</u>	<u>Ratings at end of 27 and 36 months</u>							
		<u>Tung oil</u>		<u>Linseed</u>		<u>Soya oil</u>		<u>D. C. O</u>	
		27	36	27	36	27	36	27	36
10	50	6.5	5.5	5.5	4.5	0	0	6	3
20	66.7	6	4.5	9	7	-	-	-	-
30	75	8.5	7.5	7.5	6.5	-	-	8	5.5
35	77.8	- -	- -	- -	- -	6	4.5	-	- -
40	80	8	7.5	8	6	-	- -	-	- -
50	83.3	8.5	6	5.5	3	4	0	6	4

TABLE V

DURABILITY RATINGS OF ALKYD RESINS  
VS OIL CONTENT AND TYPE OF OIL

<u>Oil Content</u> <u>(% by wt )</u>	<u>Rating after</u> <u>27 and 36 months</u>	
<u>Linseed</u>		
29	2.5	0
39.6	4	2
51	2.5	0
58.3	2.5	0
<u>Soya</u>		
41.7	5.5	4
56.3	6	5
62.5	8	5.5
<u>Dehydrated Castor Oil</u>		
37.5	4.5	2
<u>Phenolated Linseed</u>		
55	2	0

TABLE VI

## COMPOSITION OF MATERIALS EXPOSED IN 1960

NRP No.		Composition		Properties			Remarks
Series		Resin	Oil	%	% Viscosity	Sealer	
II	I	Type	Type	Oil	Solids (G-H)	Solids	
<u>Phenolic Varnishes</u>							
892	371	p-Phenyl	Tung	50	50.0	C-D	37.5
893	430	"	"	66.7	51.0	B	42.5
894	429	"	"	75	50.0	C-D	38.2
895	-	"	"	"	65.0	A-4	65.0
896	-	"	"	"	49.6	A-1	44.5
897	-	"	"	"	49.5	A-B	40.0
898	-	"	"	"	50.0	F	34.4
899	-	"	"	"	50.0	I-J	28.6
900	-	"	"	"	50.4	M	27.0
901	428	"	"	80	50.0	C-D	40.0
902	373	"	Linseed	66.7	52.8	C	41.2
903	374	"	"	75	49.8	B-C	39.0
904	-	"	"	75	50.0	J	31.8
905	375	"	"	80	50.0	D-E	41.8
906	-	"	{ Tung	46	53.8	C	40.0
			{ Linseed	23.75			
			{ Castor	2.25			
				72.			
907	-	Reactive	Tung	73.8	53.2	C	42.0
908	-	Non Reactive	"	73.8	49.8	C-D	37.2
909	-	" "	{ Tung	66.3	50.5	D	38.2
			{ Linseed	7.6			
				73.9			
<u>Alkyd Solutions</u>							
911	-	Isophthalic	{ Soya	85	55.0	A-3	55.0
			{ Linseed				
912	357	Phthalic	Soya	62.5	50.2	C	40.5
913	-	"	"	62.5	50.2	G	37.5
914	355	"	"	56	50.2	F	37.5
915	-	"	"	48	42.0	E	32.4
916	-	"	"	38.5	40.0	F	30.0
917	356	"	Linseed	51	43.2	E	33.2
844	Urethane, Oil-modified				50.0	B	(2)
11459	"	"	"	"	62.0	A-1	
850	"	"	Castor-oil-cured	"	50.0	A-2	
851	Epoxy	"	Amine-cured	"	50.0	D	
852	"	"	Amine-adduct-cured	"	50.0	G	
853	"	"	Polyamide cured	"	50.0	E	
846	Sealer,	Water Repellent			16.3	A-4	
848	Stain,	U.S. Forest Products			77.0	28.8 sec	*
849	"	Canadian Forest Products			100.0	30.6 "	
870	"	1-GP-145 Type I			35.6	23.4 "	
11505	"	Alkyd, Commercial			35.6	27.0 "	
11506	"	Creosote, Commercial			45	23.5 "	

(1) Believed to be para-tert. Butyl Phenolic.

(2) These materials were not reduced for the first coat.

\* Krebs-Stormer, time for 100 revolutions with 50 g. weight.

TABLE VII

AVERAGE RATINGS AT VARIOUS INTERVALS

	<u>June</u> <u>1961</u>	<u>June</u> <u>1962</u>	<u>Nov.</u> <u>1962</u>		<u>June</u> <u>1961</u>	<u>June</u> <u>1962</u>	<u>Nov.</u> <u>1962</u>
<u>Phenolics</u>				<u>Alkyds</u>			
892	9.7	7.7	6	911	9	6.2	4.7
893	10	10	8	912	10	7.7	6
894	10	9.7	7	913	10	6	4.7
894 F	-	9.3	7.3	913 S.E.	-	6.7	4
894 S.E.	-	9.3	7	914	10	7.3	6.3
895	10	8.3	5	915	9.5	6	4.3
896	10	9.7	8.2	916	9.7	6	3.7
897	10	9.3	7.5	917	10	7.3	4.5
898	10	10	8	917 W	8.5	5	4
899	10	9.7	6.8	936	10	6	4.3
900	10	9	6.5				
901	10	9.3	5	<u>Urethanes</u>			
901 W	10	5.5	3	844	10	8.3	5.3
902	10	9.7	7	850	9.7	10	7.3
903	10	8.3	5.5	11459	10	9	6.7
903 W	10	6.5	2.3	935	10	7.5	4.5
904	10	8.7	6.3				
905	10	6	2.5	<u>Epoxies</u>			
906	10	9.7	7.5	851	10	7	4.7
907	10	4	2.8	852	10	9	6
908	10	8.7	4.3	853	10	6.3	3
909	10	9	3.8				
910	10	9.3	7.5	<u>Stains</u>			
934	10	9.5	6.3	848	10	9.3	9
<u>Miscellaneous</u>				849	10	6.3	4
Boiled Oil	7	5	1	870	9.5	10	8.7
Cellulose				11505	10	9.3	7
Acet.- But.	5	3	0	11506	9	7	5.3
846	7	0	0				
				Mean			
				Rating	9.64	7.7	5.28
				Change			
				per month	-.05	-.10	-.48

F - applied on fence

S.E.- Summer exposure

W - Preweathered panels

TABLE VIII

REFINISHING SCHEDULE1963 Exposure Series

Group	Number	Panel Treatment		
		Left untouched	Hand sanding and feathering	Scraping and sanding
1	850	B	A	C
	893	C	B	A
	894	C	A	B
	896	A	C	B
	897	C	B	A
	898	B	A	C
	899	B	A	C
	900	A	C	B
	902	C	B	A
	903	C	A	B
	904	B	A	C
	906	A	B	C
	910	C	A	B
	934	B	A	-
	11,459	C	B	A
2		Wire brushing and sanding	Hand sanding and feathering	Scraping and sanding
	844	-	B	A
	852	C	B	A all panels recoated 893
	892	C	A	B
	901	B	C	A
	912-	C	A	B recoated with 893
	914	B recoated with 893	A	C
3		Paint remover, Scraping and sanding	Flat reciprocating sander	Circular disc sander
	844	-	-	C
	905	A	B	C all panels recoated 902
Stains		Left untouched	$\frac{1}{2}$ Panel coated	All panels coated
	849	-	-	A, B, C
	870	A-	B	C
	11,505	C	B	A
	11,506	B	-	A, C

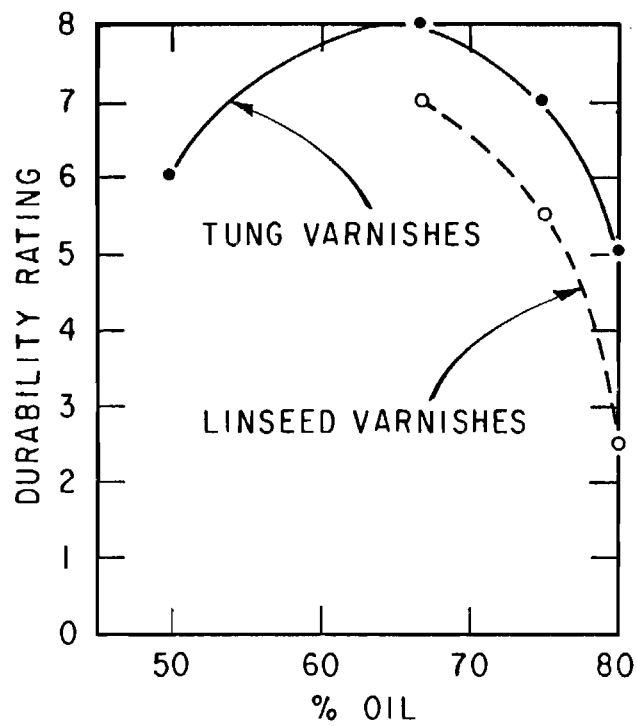


FIGURE I  
OIL CONTENT VS DURABILITY  
PHENOLIC VARNISHES

BR 2955-4



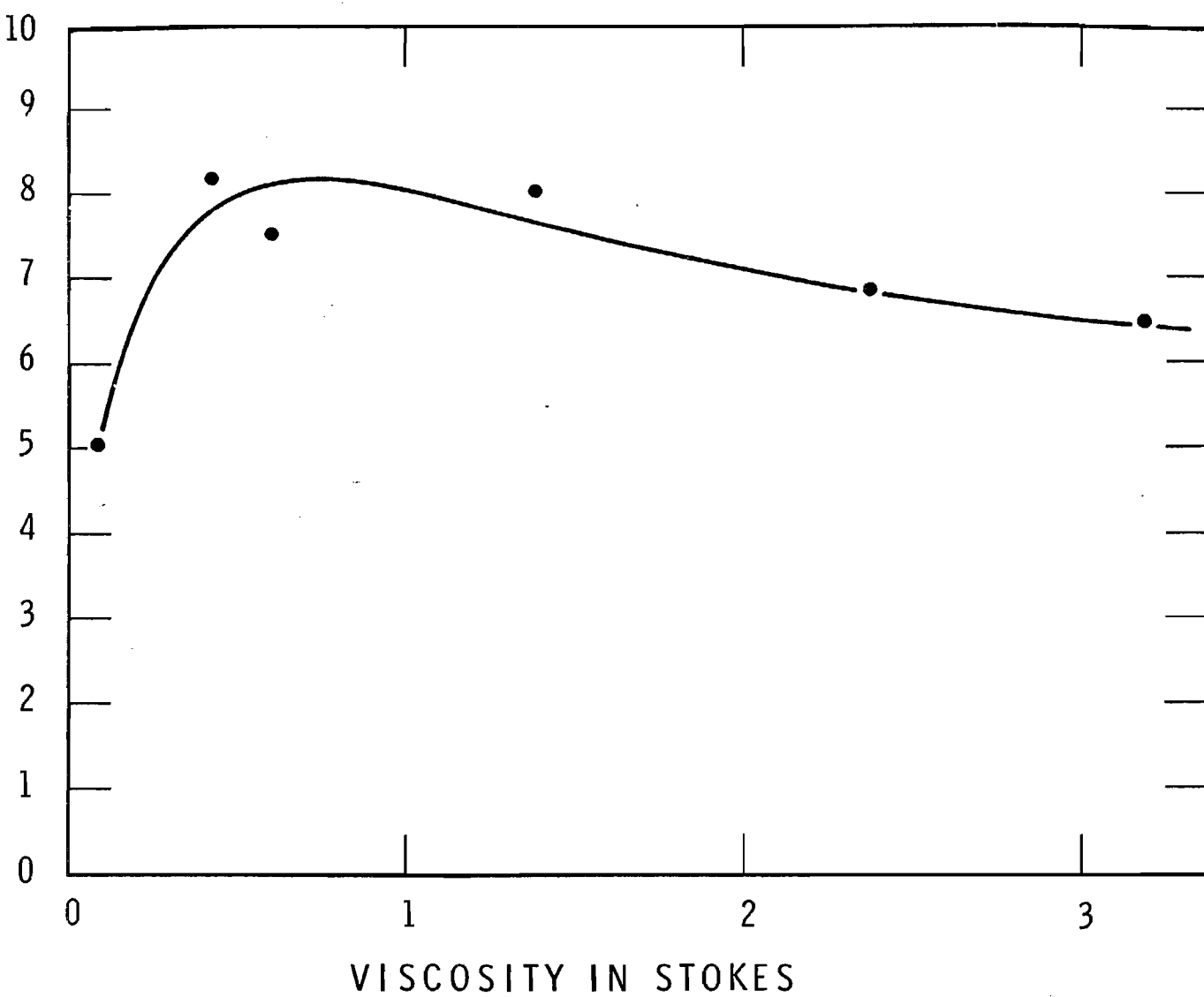


FIGURE 2

VISCOSITY VS DURABILITY OF 30 GAL TUNG-PHENOLIC  
VARNISH

Tung-Phenolic Varnishes:

NRP No.	371	430	429	428	427
Ingredients					
Bakelite BR 254	261	154	116	91	69.5
Tung oil	261	308	348	364	347.5
Mineral spirits	-	330	381	424	452
Xylene	435	110	43	-	-
24% lead naphthenate	8.7	7.7	7.7	7.6	7.0
6% cobalt naphthenate	3.5	3.1	3.1	3.0	2.8
Up-heat time, min	30	38	44	27	33
Cooking temp, °C	238	205-210	232	232	232
Holding time, min	7	22	15	22	36
Viscosity, Gardner-Holdt	A	C-D	F	G	D-E
% solids	54.6	51	52.3	51.8	48
Oil length, Imp gal	10.6	21.25	31.8	42.5	53.1
% oil on solids	50	66.7	75	80	83.3
Specific gravity	0.95	0.9	0.88	0.87	0.87

Soya-Phenolic Varnishes:

NRP No.	403	402	401
Ingredients			
Bakelite BR 254	250	96	80
Refined soya oil	250	336	400
Mineral spirits	-	397	393
Xylene	444	44	-
24% lead naphthenate	8.3	7.2	8
6% cobalt naphthenate	3.3	2.9	3.2
Up-heat time, min	50	50	50
Cooking temperature, °C	290-295	290-296	290-295
Holding time, hr: min.	2:10	3:25	4:50
Viscosity, Gardner-Holdt	F	C-D	J
% solids	53	49.5	55
Oil length, Imp gal	10.8	37.8	54
% oil on solids	50	77.8	83.3
Specific gravity	0.9	0.88	0.86

## Appendix A

### 1955 Exposure Series

#### 1. Formulae

All formulae are given in lb/100 gal unless otherwise indicated.

Para-phenylphenolic Varnishes were all cooked by the same general procedure: the oil and resin TOGETHER were heated with stirring under a blanket of nitrogen gas to the cooking temperature. The mixture was held at the top temperature until the required viscosity was reached. The batch was then cooled and thinned. Driers were added at a later date. The solids content varied in many cases from the desired 50 per cent because solvent was left out or added to obtain the desired viscosity.

#### Linseed-Phenolic Varnishes:

NRP No.	372	373	374	375	376
Ingredients					
Bakelite BR 254	243	157	110	84	66.5
Alkali refined linseed oil	243	314	330	336	332.5
Mineral spirits	-	324	396	446	464
Xylene	461	108	44	-	-
24% lead naphthenate	7.9	7.8	7.3	7.0	6.6
6% cobalt naphthenate	3.2	3.1	2.9	2.8	2.7
Up-heat time, min	40	50	45	45	45
Cooking temperature, °C	250-275	290	288-295	290-300	290-300
Holding time, hr: min	3:10	1:15	1:40	2:00	2:45
Viscosity, Gardner-Holdt	G	C	E+	C+	F
% solids	51.3	52.2	50	48.5	46.2
Oil length, Imp gal	10.75	21.5	32.25	43	53.8
% oil on solids	50	66.7	75	80	83.3
Specific gravity	0.93	0.89	0.88	0.86	0.86

Tung-Phenolic Varnishes:

NRP No.	371	430	429	428	427
Ingredients					
Bakelite BR 254	261	154	116	91	69.5
Tung oil	261	308	348	364	347.5
Mineral spirits	-	330	381	424	452
Xylene	435	110	43	-	-
24% lead naphthenate	8.7	7.7	7.7	7.6	7.0
6% cobalt naphthenate	3.5	3.1	3.1	3.0	2.8
Up-heat time, min	30	38	44	27	33
Cooking temp, °C	238	205-210	232	232	232
Holding time, min	7	22	15	22	36
Viscosity, Gardner-Holdt	A	C-D	F	G	D-E
% solids	54.6	51	52.3	51.8	48
Oil length, Imp gal	10.6	21.25	31.8	42.5	53.1
% oil on solids	50	66.7	75	80	83.3
Specific gravity	0.95	0.9	0.88	0.87	0.87

Soya-Phenolic Varnishes:

NRP No.	403	402	401
Ingredients			
Bakelite BR 254	250	96	80
Refined soya oil	250	336	400
Mineral spirits	-	397	393
Xylene	444	44	-
24% lead naphthenate	8.3	7.2	8
6% cobalt naphthenate	3.3	2.9	3.2
Up-heat time, min	50	50	50
Cooking temperature, °C	290-295	290-296	290-295
Holding time, hr: min.	2:10	3:25	4:50
Viscosity, Gardner-Holdt	F	C-D	J
% solids	53	49.5	55
Oil length, Imp gal	10.8	37.8	54
% oil on solids	50	77.8	83.3
Specific gravity	0.9	0.88	0.86

Dehydrated Castor-Phenolic Varnishes:

NRP No.	407	406	404
Ingredients			
Bakelite BR 254	256	118	67.5
D.C.O. viscosity G-H	256	354	337.5
Mineral spirits	-	376	459
Xylene	441	41.5	-
24% lead naphthenate	8.5	7.9	6.8
6% cobalt naphthenate	3.4	3.1	2.7
Up-heat time, min	50	40	50
Cooking temperature, °C	290	280-290	290
Holding time, hr: min	1:00	1:00	4:50
Viscosity, Gardner-Holdt	P	E	B
% solids	53.8	53.1	46.9
Oil length, Imp gal	10.7	32	53.3
% oil on solids	50	75	83.3
Specific gravity	0.96	0.88	0.86

Linseed Alkyd Solutions:

NRP No.	362	355	356	358	363
Ingredients					
Rezyl 1102-5 (40%)	656	-	-	-	-
Glyptal G2452 (50%)	-	713	-	-	-
Glyptal G2458 (50%)	-	-	696	-	-
Rezyl 869-1 (70%)	-	-	-	680	-
Glyptal G 7360 (60%)	-	-	-	-	568
Mineral spirits	-	-	196	230	305
Xylene	281	225	-	-	-
24% lead naphthenate	4.3	4.6	5.8	7.9	5.7
6% cobalt naphthenate	1.7	2.5	2.3	3.1	2.2
Viscosity, Gardner-Holdt	D	D	D	D	D
% solids	28	38	39	52.3	39
% oil on solids *	29	39.6	51	58.3	55
Specific gravity	0.94	0.95	0.9	0.91	0.88

Soya and Castor Alkyd Solutions:

NRP No.	359	360	357	361
Ingredients				
Glyptal G2462 (50%)	782	-	-	-
Glyptal G2475 (60%)	-	667	-	-
Glyptal G2466 (70%)	-	-	688	-
Glyptal G2480 (50%)	-	-	-	602
Mineral Spirits	-	223	220	-
Xylene	172	-	-	338
24% lead naphthenate	6.5	6.7	8	5
6% cobalt naphthenate	2.6	2.7	3.1	2
Viscosity, Gardner-Holdt	D	D	D	D
% solids	41	45	53	32
Type of oil	Soya	Soya	Soya	D. C. O
% oil on solids *	41.7	56.3	62.5	37.5
Specific gravity	0.96	0.89	0.91	0.94

Epoxy Ester Solutions:

NRP No.	365	364	367
Ingredients			
TPN 653	552	-	-
TPN 805	-	686	-
TPN 504	-	-	593
Mineral spirits	312	-	-
Xylene	-	240	322
24% lead naphthenate	4.6	5.6	4.8
6% cobalt naphthenate	1.8	2.2	1.9
Viscosity, Gardner-Holdt	C-D	C-D	D
% solids	38.3	37	32.4
Type of oil	Linseed	Soya	D. C. O.
% oil on solids *	57.5	ca45	ca46
Specific gravity	0.87	0.93	0.91

\* Note: The oil content was calculated from the reported fatty acid content according to method of Payne (6)

Rate of Application of Varnishes  
Amount Applied to Each Board\* and Average for Panel\*\*

PINE PANELS

Varnish Formula No.	Weight (lb/gal)	Sealer	Second Coat, Full Body		Third Coat Full Body		Averages Spreading Rate for each Panel	
		Weight Applied (gm)	Weight Applied (gm)	Spreading Rate (sq ft/gal)	Weight Applied (gm)	Spreading Rate (sq ft/gal)	Second Coat	Third Coat
355	9.5	5.5	7.6	568	11.3	382	581	421
		5.5	7.6	568	10.1	427		
		8.5	7.1	608	9.5	454		
356	9.1	4.8	7.2	574	9.2	449	579	439
		4.8	6.6	626	8.2	504		
		3.6	7.7	537	11.4	363		
357	9.1	6.5	11.2	369	11.7	353	439	371
		8.0	11.3	366	11.7	353		
		6.1	12.2	339	10.2	405		
358	9.0	4.5	5.6	732	9.5	431	621	474
		3.7	7.5	546	7.5	546		
		4.9	7.0	585	9.2	445		
359	9.6	7.4	10.3	423	9.7	450	392	450
		6.7	10.9	400	11.1	393		
		6.8	12.4	352	8.6	507		

\* Each board: 180 sq in. in area

\*\* Each panel consists of three boards

360	8.8	7.3	11.5	348	10.5	381	407	347
		6.0	9.0	444	11.9	336		
		6.4	9.3	430	12.3	325		
361	9.4	5.1	8.4	508	8.8	485	546	515
		4.1	8.1	527	8.2	521		
		4.2	7.1	601	7.9	541		
362	9.3	3.2	5.2	822	8.1	522	805	631
		3.9	5.3	797	5.7	741		
		5.0	5.3	797	6.7	631		
363	9.1	7.2	3.9	1060	8.0	517	1013	513
		8.4	4.3	962	8.2	504		
		7.2	3.7	1117	8.0	517		
364	9.3	6.0	7.9	535	8.5	497	645	556
		2.0	5.0	845	6.8	621		
		1.7	7.6	556	7.7	549		
365	8.7	1.3	7.6	520	5.5	719	493	860
		-	8.2	482	3.5	1129		
		1.8	8.3	476	5.4	732		
367	9.1	7.3	6.3	656	7.2	574	615	562
		6.2	6.2	667	6.6	626		
		6.0	7.9	523	8.5	486		
371	9.5	8.1	7.2	599	10.9	396	547	538
		6.7	8.2	526	9.1	474		
		8.5	8.4	514	6.7	644		
372	9.5	4.1	10.3	419	9.7	445	391	408
		5.2	11.8	366	12.0	360		
		5.6	11.1	389	10.3	419		
373	8.9	8.2	9.5	426	9.9	408	720	567
		5.2	7.5	639	6.2	652		
		7.3	3.7	1093	6.3	642		



374	8.8	2.1	8.9	449	8.5	470	462	532
		2.2	8.3	482	7.2	555		
		4.2	8.8	454	7.0	571		
375	8.6	5.0	5.9	662	6.2	630	656	744
		5.7	6.7	583	5.2	751		
		6.9	5.4	724	4.6	849		
376	9.1	3.1	7.9	523	6.0	689	560	631
		4.3	7.8	530	6.0	689		
		6.0	6.3	656	8.0	517		
401	8.65	6.0	11.4	345	14.6	269	409	272
		7.8	9.5	414	13.5	291		
		6.7	8.4	468	15.3	257		
402	8.82	7.4	8.4	478	8.4	478	493	455
		6.4	8.1	495	9.1	441		
		8.6	7.9	508	9.0	446		
403	9.0	15.8	12.2	335	13.2	310	365	303
		16.3	9.7	422	13.4	305		
		17.1	12.1	338	13.7	298		
404	8.69	8.8	5.5	718	7.9	500	654	459
		9.7	6.4	617	9.1	434		
		8.3	6.3	627	8.0	493		
406	8.84	5.0	9.4	427	8.9	451	465	419
		4.0	10.6	479	8.7	461		
		4.2	8.2	489	11.6	346		
407	9.57	7.9	12.8	340	13.9	313	340	305
		8.3	13.4	324	14.3	304		
		5.7	12.2	356	14.6	298		

427	8.67	7.8	6.8	579	11.1	355	607	383
		5.3	6.4	615	8.6	458		
		10.9	6.3	625	11.7	337		
428	8.7	8.4	7.1	557	6.5	608	576	473
		7.7	6.7	590	10.5	376		
		10.2	6.8	581	9.1	434		
429	8.8	12.5	8.6	465	9.7	412	435	399
		14.4	9.6	416	9.4	425		
		11.2	9.4	425	10.1	396		
430	8.98	4.9	9.4	434	8.2	498	566	468
		7.6	6.4	637	8.8	464		
		9.8	6.5	628	9.2	443		

Grand Average    2nd coat   543  
                          3rd coat   478

Rate of Application of Varnishes  
Amount Applied to Each Board\* and Average for Panel\*\*

CEDAR PANELS

Varnish Formula No.	Weight (lb/gal)	Sealer	Second Coat, Full Body		Third Coat Full Body		Averages Spreading Rate for each Panel	
		Weight Applied (gm)	Weight Applied (gm)	Spreading Rate (sq ft/gal)	Weight Applied (gm)	Spreading Rate (sq ft/gal)	Second Coat	Third Coat
355	9.5	4.9	7.5	575	8.3	520	583	518
		4.1	6.5	664	9.6	450		
		5.3	8.5	508	7.4	583		
356	9.1	4.0	5.9	701	6.9	699	629	631
		5.9	6.6	626	6.6	626		
		4.3	6.9	599	7.3	566		
357	9.1	6.6	10.9	379	8.5	486	423	505
		6.6	8.9	465	9.1	454		
		6.5	9.7	426	7.2	574		
358	9.02	2.2	4.0	1025	8.2	500	720	515
		6.8	6.4	640	8.6	476		
		5.6	8.3	494	7.2	569		
359	9.6	6.1	9.7	450	10.6	411	467	447
		8.7	8.2	532	9.5	459		
		4.9	10.4	419	9.3	469		

\* Each board: 180 sq in. in area

\*\* Each panel consists of three boards

360	8.8	4.1	6.5	615	9.6	416	619	456
		5.0	6.2	645	10.3	388		
		3.5	6.7	597	7.1	563		
361	9.4	3.7	6.5	657	6.0	712	725	580
		4.7	4.8	899	9.5	450		
		4.1	6.8	628	7.4	577		
362	9.3	3.6	6.7	631	6.7	631	700	646
		4.2	5.1	829	7.1	695		
		3.8	6.6	640	6.9	612		
363	9.1	4.9	4.9	844	8.4	492	1007	648
		4.9	3.4	1216	5.2	795		
		4.1	4.3	962	6.3	656		
364	9.3	2.5	7.7	549	5.8	729	595	699
		1.9	6.3	656	7.4	571		
		3.8	7.3	579	5.3	797		
365	8.7	1.6	5.9	670	5.2	760	713	728
		1.5	5.7	693	5.4	732		
		1.8	5.1	775	5.7	693		
367	9.1	6.0	6.0	689	7.2	574	701	621
		5.8	6.0	689	6.9	599		
		6.9	5.7	725	6.0	689		
371	9.5	8.5	7.2	599	9.3	464	631	475
		8.5	6.3	685	9.2	469		
		7.2	7.1	608	8.8	490		
372	9.5	5.6	11.3	382	10.1	427	393	428
		5.8	12.3	351	9.2	469		
		5.5	9.7	445	11.1	389		

373	8.9	4.5	4.9	825	5.4	749	732	679
		4.8	4.9	825	5.5	735		
		8.8	7.4	546	7.3	554		
374	8.8	6.8	7.0	571	5.0	800	535	623
		5.6	8.5	470	9.2	434		
		6.7	7.1	563	6.3	635		
375	8.6	5.1	5.0	781	2.4	1628	644	1068
		6.8	8.4	465	6.8	575		
			5.7	685	3.9	1002		
376	9.1	3.3	6.0	689	5.9	701	856	914
		3.4	3.7	1117	4.0	1034		
			4.3	962	4.1	1008		
401	8.65	7.5	7.2	546	9.5	414	531	347
		7.7	7.4	531	12.3	319		
		6.6	7.6	517	12.7	309		
402	8.82	5.6	8.3	483	7.2	557	511	521
		7.3	7.6	529	8.5	472		
		7.0	7.7	521	7.5	535		
403	9.0	10.0	10.4	393	15.0	273	368	322
		10.2	11.6	352	12.2	335		
		9.4	11.4	359	11.4	359		
404	8.69	6.4	7.6	519	5.4	731	580	646
		6.3	5.8	681	7.5	526		
		6.7	7.3	541	5.8	681		
406	8.84	5.1	6.8	590	9.9	405	531	427
		4.9	8.2	489	10.7	375		
		3.8	7.8	514	8.0	501		

407	9.57	6.7	9.8	444	13.3	327	400	331
		8.0	11.4	381	11.8	368		
		3.1	11.6	375	14.5	300		
427	8.67	9.1	6.6	597	8.1	486	575	500
		9.7	6.6	597	8.9	443		
		8.5	7.4	532	6.9	571		
428	8.70	10.2	5.5	719	9.2	430	661	471
		9.8	6.2	638	8.1	488		
		9.4	6.3	627	8.0	494		
429	8.8	10.2	7.6	526	10.0	400	522	422
		9.3	8.4	476	8.6	465		
		9.7	7.1	563	10.0	400		
430	8.98	8.6	6.6	618	7.6	537	612	540
		7.2	6.5	628	7.3	559		
		6.5	6.9	591	7.8	523		

Grand Average    2nd coat    606  
                          3rd coat    561

Exposure Record of Clear Coatings  
1955 Series

NRP No.	Wood Substrate	13 months		27 months		36 months		
		Rating	Effect	Rating	Effect	Rating	Effect	
355	WP	8	Tr Cr	5	Cr and P	40%	2	P and Ad
	RC	6	Mod Cr	3	Ad	60%	2	Cr and P
356	WP	6	Mod Cr	3	Ad	60%	Panels removed previously	
	RC	6	Min Cr	2	Ad	70%		
357	WP	9	Tr Cr	8	Tr Cr		6	Cr and Ad
	RC	10	None	8	Tr Cr		5	Cr and P
358	WP	8	Sl Cr	3	L and P	75%	Panels removed	
	RC	7	Sl P	2	Cr and P	85%		
359	WP	8	Min Cr	6	Tr P		6	P and Ad
	RC	8	Min Cr	5	Cr and P	25%	2	Sc and P
360	WP	8	Tr Cr	6	Ad	10%	5	Cr and P
	RC	8	Tr Cr	6	Cr and P	20%	5	Cr and P
361	WP	8	Tr Cr	5	Ad and Cr	40%	2	Cr and Ad
	RC	8	Tr Cr	4	Ch Cr and P	75%	2	P and Ad
362	WP	8	Tr Cr	3	P and Ad	75%	Panels removed	
	RC	6	Mod Cr and P	2	Ad	90%		
363	WP	6	Mod Cr	2	Ad	90%	"	
	RC	6	Mod Cr	2	Ad	90%		
364	WP	6	P	2	Ad	100%	"	
	RC	6	P	2	Ad	90%		
365	WP	6	Cr and Sl P	2	Ad	90%	"	
	RC	4	Ad	2	Ad	90%		
367	WP	8	Sl Cr	3	Cr and P	60%	"	
	RC	8	Sl Cr	4	Cr and P	60%		
371	WP	8	Tr Cr and L	7	Tr L		6	Cr and L
	RC	10	None	6	Cr and P	20%	5	Cr and L
372	WP	9	Tr Cr and P	6	Cr and P	20%	5	P and L
	RC	8	Tr Cr	5	Fl and P	60%	4	Cr and P
373	WP	10	None	9	Sl L		7	Cr and Sl L
	RC	10	None	9	Tr Cr		7	Cr and L
374	WP	10	None	8	Sm Cr		6	Cr and L
	RC	10	None	7	3 w Cr		7	Cr and L
375	WP	10	None	8	Min Cr	10%	6	Min Cr
	RC	10	None	8	Sl L		6	Cr and P
376	WP	10	None	7	Min Cr		4	Sl P
	RC	10	None	4	Min Cr	80%	2	Cr and P
401	WP	8	Min Ch	4	Sev Ch	100%	Panels removed	
	RC	8	Min Ch	4	Mar Cr	100%		
402	WP	8	Min Cr	6	Ad	20%	4	Cr and P
	RC	10	None	6	Cr	30%	4	Cr and P
403	WP	4	Cr and P	Panels removed due to failure			Panels removed	
	RC	4	Cr and P					
404	WP	10	None	7	Min Cr	100%	4	Cr and L
	RC	10	None	5	Min Cr	100%	4	Cr and L
406	WP	10	None	8	Min Cr	10%	5	Min Cr
	RC	10	None	8	Min Cr	10%	6	Min Cr
407	WP	8	Sl Cr and P	6	Cr and P	20%	4	Ad and Cr
	RC	8	Long Cr	6	Long Cr		2	All 100%
427	WP	10	None	8	Tr Cr and P		6	Cr and Tr L
	RC	10	None	9	Tr Cr		6	Cr and P
428	WP	10	None	8	Tr Cr and L		8	Cr and L
	RC	10	None	8	Min Cr		7	1 - Cr and P
429	WP	10	None	8	Sl L		7	Cr and L
	RC	10	None	9	Tr L		8	Cr and L
430	WP	8	Sl P	6	Mod P		5	Ch and P
	RC	10	None	6	Cr and P	35%	4	Sm Cr

Min - Minute  
Sm - Small  
Tr - Trace  
Sl - Slight

Mod - Moderate  
Mar - Marked  
Sev - Severe  
Ad - Loss of Adhesion

Cr - Cracking  
Ch - Checking  
L - Lifting  
P - Peeling  
Fl - Flaking

Appendix B

1960 Exposure Series

All formula in lb per 100 gal

Tung-para-phenylphenolic Varnishes:

NRP No.	<u>892</u>	<u>893</u>	<u>894</u>	<u>895</u>	<u>896</u>
Ingredients					
Bakelite BR 254*	239	153	110	153	109
Tung oil	239	306	330	459	327
Mineral spirits	-	331	396	-	398.5
Xylene	478	110	44	165	44.5
n Butyl acetate	-	-	-	165	-
24% lead naphthenate	2	7.7	7.3	10.2	7.2
6% cobalt naphthenate	0.8	3.1	2.9	4.1	2.9
Up-heat time, min	28	29	22	22	18
Cooking temp, °C	233	233	233	180	234
Holding time, min	25	13	18	0	16
Viscosity, Gardner-Holdt	C-D	B	C-D	A-4	A-1
% solids	50.0	51.0	50.0	65.0	49.6
Oil length, Imp gal	10.6	21.25	31.8	31.8	31.8
% oil on solids	50	66.7	75	75	75
Specific gravity	0.96	0.92	0.88	0.91	0.88

NRP No.	<u>897</u>	<u>898</u>	<u>899</u>	<u>900</u>	<u>901</u>
Bakelite BR 254*	109	110	110	111	87.5
Tung oil	327	330	330	333	350
Mineral spirits	400	396	396	393	437.5
Xylene	44.5	44	44	44	-
24% lead naphthenate	7.2	7.3	7.3	7.4	7.3
6% cobalt naphthenate	2.9	2.9	2.9	3.0	2.9
Up-heat time, min	21	29	19	30	36
Cooking temp, °C	236	234	235	235	235
Holding time, min	20	33	31	30	24
Viscosity, Gardner-Holdt	A-B	F	I-J	M	C
% solids	49.5	50.0	50.0	50.4	50.0
Oil length, Imp gal	31.8	31.8	31.8	31.8	42.5
% oil on solids	75	75	75	75	80
Specific gravity	0.89	0.89	0.89	0.89	0.88

\* Also coded at different times as TR 254 and CKR 5254.



Linseed-para-phenylphenolic Varnishes:

NRP No.	<u>902</u>	<u>903</u>	<u>904</u>	<u>905</u>
Ingredients				
Bakelite BR 254	154	106	106	84
Alkali refined linseed oil	308	318	318	336
Mineral spirits	309	384	381	420
Xylene	103	43	43	-
5% calcium naphthenate	37	33.9	33.9	33.6
6% manganese naphthenate	3.1	2.8	2.8	2.8
Up-heat time, min	56	51	43	70
Cooking temp, °C	292	292-300	290-295	292-298
Holding time, hr:min	1:22	1:52	2:50	2:20
Viscosity, Gardner-Holdt	C	B-C	J	D-E
% solids	52.8	49.8	50.0	50.0
Oil length, Imp gal	21.5	32.25	32.25	43
% oil on solids	66.7	75	75	80
Specific gravity	0.91	0.89	0.9	0.88

Phenolic Varnishes:

NRP No.	<u>906</u>	<u>907</u>	<u>908</u>	<u>909</u>
Ingredients				
Bakelite BR 254	136	-	-	-
Amberol ST-137	-	121	-	-
Amberol ST-137x	-	-	113	114
Tung oil	223	341	319	290
Alkali refined linseed oil	115.5	-	-	-
Boiled linseed oil Z-Z <sub>2</sub>	-	-	-	33
Refined castor oil	11	-	-	-
Mineral spirits	312	406	436	428
Dipentene	42	-	-	-
Bronoco Hi-Sol 102	42	-	-	-
n Butenol	21	-	-	-
24% lead naphthenate	1.5	7.7	5.4	7.3
6% cobalt naphthenate	0.6	3.1	2.2	2.9
6% manganese naphthenate	0.3	-	-	-
Up-heat time, min	34	26	19	26
Cooking temp, °C	295 233	248	240-250	232-242
Holding time, min	30 22	21	25	21
Viscosity, Gardner-Holdt	C	C	D	D
% solids	53.8	53.2	49.8	50.5
Oil length, Imp gal	27.4	30	30	30
% oil on solids	72	73.8	73.8	73.9
Specific gravity	0.9	0.88	0.86	0.86

NRP 910 - Cold-Mix Varnish:

173 lb Bakelite BR 9400

233 " Mineral spirits

26 " n Butenol

Dissolve the resin in the solvents. Add slowly with stirring

254 lb Tung oil.

When thoroughly dispersed add

86.5 lb Boiled linseed oil Z-9

120 " Mineral spirits

3.4 " 6% zirconium octoate

1.7 " 6% cobalt naphthenate

1.7 " 4% calcium naphthenate

Soya Phthalic Alkyd Solutions:

NRP No.	<u>912</u>	<u>913</u>	<u>914</u>	<u>915</u>	<u>916</u>
Ingredients					
Glyptal G2466 (70.2%)	645	-	-	-	-
Glyptal G2504 (70.3%)	-	660	-	-	-
Glyptal G2475 (60%)	-	-	770	-	-
Glyptal G2509 (50%)	-	-	-	771	-
Glyptal G6250 (50%)	-	-	-	-	750
Mineral spirits	258	-	-	-	-
Xylene	-	264	154	147	188
24% lead naphthenate	7.5	7.7	7.7	6.4	6.3
6% cobalt naphthenate	3	3.1	3.1	2.6	2.5
Viscosity, Gardner-Holdt	C	G	F	E	I
% solids	50.2	50.2	50.0	42.0	40.0
% oil on solids*	62.5	62.5	56.0	48.0	38.5
Specific gravity	0.9	0.93	0.92	0.91	0.93

\* The oil content of alkyds was calculated from the reported fatty acid content according to Payne (6) except for the isophthalic alkyd which was reported as oil content.

Alkyd Solutions:

NRP No.	<u>917</u>	<u>911</u>
Ingredients		
Glyptal G2458	795	-
Super becosol L-116	-	476
Mineral spirits	-	390
Xylene	124	-
24% lead naphthenate	6.6	-
6% cobalt naphthenate	2.7	-
6% manganese naphthenate	-	4.0
5% calcium naphthenate	-	19.0
Viscosity, Gardner-Holdt	E	A-3
% solids	43.2	55.0
Dibasic acid	Phthalic	Isophthalic
Type of oil	Linseed	Linseed-Soya
% oil on solids*	51	85
Specific gravity	0.92	0.88

Urethanes:

NRP No.	844	850
Type	Oil Modified	Polyisocyanate and Polyol
Spengel F77-60 M S	770	-
Xylene	154	-
6% cobalt naphthenate	2.3	2.5
Spengel castor oil 1066	-	238
Amyl acetate	-	204
Bronoco Hi-Sol 102	-	204
	-	1 hour before use add:
Spengel P23-75 S	-	343
NCO/OH	-	1:1
Viscosity, Gardner-Holdt	B	A-2
% solids	50.0	50.1
Specific gravity	0.91	0.99

\* The oil content of alkyds was calculated from the reported fatty acid content according to Payne (6) except for the isophthalic alkyd which was reported as oil content.

Epoxyes:

NRP No.	<u>851</u>	<u>852</u>	<u>853</u>
<u>Epoxy Solution</u>			
Epox 1001	460	390	345
Diacetone alcohol	94	79.6	68.7
Methyl isobutyl ketone	70	59.3	51.1
Cellosolve	150	127	109.5
Xylene	150	127	109.5
Beetle 216-8	23	19.5	16.8

Curing Solution

Epox 1001	-	70	-
Methyl isobutyl ketone	-	25	40
Cellosolve	-	36.5	51
Xylene	13.5	36	50
n Butanol	13.5	-	-
Diethylene triamine	27	25	-
Versomid 125	-	-	144

Mixed Solution Properties

Viscosity, Gardner-Holdt	D	G	E
% solids	50.0	50.0	50.2
Specific gravity	1.0	1.0	0.97

NRP 846 Water Repellent Sealer

44 lb Pentachlorophenol	Dissolve pentachlorophenol in methanol and xylene to make 50 per cent solution. Add 250 lb TS-28. Melt wax and resin together and dissolve in remainder of TS-28. Add this to penta solution using mineral spirits as wash.
22 " Methanol	
22 " Xylene	
83 " Pentalyn G	
14 " Paraffin wax	
318 " Shell TS-28	
362 " Mineral spirits	

Viscosity, Gardner-Holdt	A-4
% solids	16.3
Specific gravity	0.87

Forest Products' Stains

	NRP 848		NRP 849	
	<u>U. S.</u>	<u>F. P. L.</u>	<u>Can.</u>	<u>F. P. R. B.</u>
Refined linseed oil	570		835	
Mineral spirits	162		-	
Paraffin wax	25		17	
Zinc stearate	3.2		-	
Pentachlorophenol	59		45	
Methanol	29.5		-	
Xylene	29.5		-	
24% lead naphthenate	-		7	
6% cobalt naphthenate	-		3.5	
Burnt sienna in oil	40		40	
Raw umber in oil	40		40	
Viscosity, Krebs-Stormer				
sec with 50 gm wt	28.8		30.6	
% solids	77		100	
Specific gravity	0.96		0.98	

Preparation and Use

Prepare (or buy) 50 per cent penta solution. Melt wax and stearate and pour into most of mineral spirits, stirring vigorously. Use remainder of solvent as wash. Add oil followed by penta solution and colour-in-oil.

Apply one coat on smooth wood. Warm oil to 150° F, add penta and stir until dissolved. Similarly add the wax. Cool and add drier and colour-in-oil.

Apply a good wet coat and after 20 to 30 min remove excess with clean rags. On new wood apply a second coat in the same way.

NRP 870 Exterior Stain, 1-GP-145, Type I

36 lb Ferrite yellow norpico 310  
 10 " Ferrite red norpico 403  
 2 " Lampblack B-14  
 40 " Micro-mica C-3000  
 100 " Alkali refined linseed oil  
 82 " Glyptal G2504 (70%)  
     Grind to 5 and add  
 28 lb Linseed oil  
 50 " G2504  
 3.6 lb 24% Lead naphthenate  
 1.5 " 6% Lead naphthenate  
 13.5 " U. V. Absorber No. 9 (33 1/3% solution in Shell TS-28)  
 516 " Mineral spirits

Viscosity           23.4 sec  
 % solids           35.6  
 Specific gravity    0.89

Clear Finishes with Ultraviolet Light Absorber

U. V. Absorber No. 9 dissolved in xylene and added at the rate of 0.5 per cent of the solids content, as follows:

934 - added to NRP 901, 40 gal Tung-para-phenylphenolic  
 935 - " " " 844, Oil-modified urethane  
 936 - " " " 913, Long soya alkyd

Commercial Materials

Lab No.	Name	Supplier	Type	% Solids	Visc.	5.6
11459	No. 30 Redwood Finish	The Glidden Co. Ltd.	Clear Urethane	62.0	A-1	0.9
11505	Rez Cedar Stain	Monsanto (Canada) Ltd.	Pigmented Stain	35.6	27.0	0.93
11506	Cedar Creosote Stain	John Cabot Co.	Pigmented Stain	45.0	23.5	0.97
-	Boiled Linseed Oil	Sherwin Williams Co.	-	100.0	-	-

Cellulose Acetate-Butyrate

Lacquer Emulsion

Composition (reported)

Part A

204	lb	Cellulose acetate-butyrate 1/2 sec
78	"	Dimethyl phthalate
234	"	Toluene
58.6	"	Denatured ethanol
97.5	"	2-Ethylhexyl acetate
9.7	"	Alipal CO-436 surfactant
9.7	"	Igepal CO-630 "

Part B

243	"	Water	% solids	31.0
			Specific gravity	0.97

Part C

4.8	"	Denatured ethanol
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Application Rates of Pigmented Stains

<u>NRP No.</u>	<u>Coat</u>	<u>Weight Applied (gm)</u>	<u>Film Thickness, mil</u>	
			<u>Wet</u>	<u>Dry</u>
848	First	11	3.0	2.3
	Second (half panel)	4	2.2	1.6
849	First	10	2.8	Wipe off excess " " "
	Second (half panel)	10		
870	First	12	3.5	1.3
	Second	12	3.5	1.3
11505	First	12	3.4	1.2
	Second	9	2.5	0.9
11506	First	12	3.2	1.4
	Second	11	3.0	1.4