DURABILITY TESTS OF SPAR VARNISHES

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ABSTRACT

Fifty commercial spar varnishes, which had been tested for conformity to Federal specification No. 18b, were exposed to several accelerated weathering cycles and outdoors. Kauri reduction values were also determined. The varnish was applied both by whirling and brushing. Sand-blasted and nonsand-blasted panels were used.

This paper correlates the tests mentioned above and also gives the results of similar tests made on experimental varnishes, prepared in the laboratory from various oils and resins.

A short bibliography pertaining to the subject matter of this paper is appended.

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I. INTRODUCTION

In determining the relative durability of varnish coatings in "accelerated weathering cycles" and outdoors many interesting questions have arisen from time to time, such as the following:

What accelerated weathering cycle, using the carbon arc light, will soonest cause the failure of varnish coatings and will give a relative order of failure for a given set of varnishes similar to that given by roof exposure?

Will a given set of varnishes exposed outdoors at different seasons of the year fail in the same relative order? It is, of course, well known that the same varnish will last considerably longer when exposed in October than when exposed in May, mainly because of the lower intensity of the sun's rays in the winter months.

How does the kauri reduction test compare with the accelerated weathering test as an indicator of the relative durability outdoors of a given set of varnishes?

Will a given set of varnishes fail in the same relative order when the coating is applied by whirling and when it is applied by brushing (assuming that the brushing is all done by one operator)? Also, is a sand-blasted panel to be preferred to a nonsand-blasted panel?

How does the relative durability outdoors of the spar varnishes meeting Federal specification No. 18b compare with the durability of spar varnishes which do not meet this specification?

How do spar varnishes made from the amberol type of resin compare in durability outdoors with varnishes made from rosin, ester gum, and kauri?

The work discussed in this paper was undertaken for the purpose of obtaining answers to the above questions.

II. DURABILITY OF 50 COMMERCIAL SPAR VARNISHES

1. ACCELERATED WEATHERING TESTS

The apparatus used for the accelerated testing is the same as described by Walker and Hickson.[1] Briefly, it is a carbon arc light operated on a 220-volt d. c. circuit, at 13 amperes, inclosed in a pyrex globe and suspended in the center of a chamber consisting of a rotating cylinder 76 cm (30 inches) in diameter and 38 cm (15 inches) high, open at both ends. The cylinder is provided with water sprays so that it is possible to expose the panels in succession to intense light and to a variety of moisture conditions. When not being sprayed, the average temperature at the surface of the panels is about 56° C. The cylinder has room for fifty-eight 7.5 by 15 cm (3 by 6 inch) panels of the size used in all of this exposure work.

The panels used in this work were of black iron of a grade known as American Russia Iron and were cleaned very carefully with benzol before applying the varnish. No primer was used. The varnish was applied directly to the bare metal, two coats in every case, and three days were allowed for drying between coats and between the application of the last coat and exposure. The backs and edges of all panels were given two coats of aluminum paint mixed in the proportion of 25 g of polished aluminum powder to 100 ml of a long-oil water-resisting spar varnish.

The first experiment was a continuous exposure (24 hours per day) to the carbon arc light alone. As was expected, with no water present, the failure of the varnish coatings was extremely slow, only the very poorest varnishes showing any signs of failure after 60 days. At the end of this period the water spray was turned on in conjunction with the light for 17 hours (overnight). The following morning all, except a few of the most durable coatings, were completely covered with fine checks. Evidently the light had some destructive effect on the coatings during the 60-day period of light alone, and only the comparatively short treatment with the light in conjunction with water was required to produce the characteristic varnish checks.

In the second experiment the varnish coatings were exposed to light alone for 21 hours, then the light was turned off and the panels exposed to the water spray from a revolving lawn sprinkler for three hours. This schedule was followed every day for four consecutive days of each week; on the three remaining days the schedule was interrupted by heating the panels for one-half hour in an oven at about 70° C., then refrigerating for one hour at −10° C. This cycle caused the coatings to fail much more rapidly than when light

[1] P. H. Walker and E. F. Hickson, Accelerated Tests of Organic Protective Coatings, B. S. Jour. Research, 1 (RP1); 1928.

alone was used, but much more slowly than they should in an accelerated cycle. It required 38 to 45 days to bring about failure of the average grade of spar varnish.

The next experiment was a continuous combination of light and spray for 24 hours each day. All coatings received the light all of the time and each coating was sprayed with water at each revolution of the cylinder, which made three revolutions per hour. A modification of this cycle was tried, by using refrigeration at −10° C. one hour a day for four days a week, but as far as could be determined this refrigeration did not accelerate the failure or change the nature of the failure to any extent. As compared with the two previous experiments, this continuous combination of light and spray greatly accelerated the failure of the varnish coatings, the average grades of spar varnish showing initial signs of failure in about 15 days. It was thought that possibly the relative order of failure of a given set of varnishes might vary if the cycle was changed somewhat, so a variation was made by using the light and spray combination continuously for 17 hours and then light alone for 7 hours each day. However, the relative order of failure of a set of 50 varnishes was just about the same for both cycles, but in most cases the continuous 24-hour combination of light and spray caused failure sooner than or in the same number of days as the other cycle. Table 1 shows in detail a comparison of the two cycles as to the number of days to failure for each varnish.

TABLE 1.—*Cycle 1 (continuous 24-hour light water) versus cycle 2 (17-hour light water +7-hour light alone)*

ACCELERATED EXPOSURE

Varnish No.	Cycle 1, days to failure	Cycle 2, days to failure	Varnish No.	Cycle 1, days to failure	Cycle 2, days to failure	Varnish No.	Cycle 1, days to failure	Cycle 2, days to failure
1	18	19	21	21	25	41	22	20
2	18	19	22	19	19	42	15	15
3	18	19	23	21	21	43	16	17
4	25	30	24	19	19	44	25	27
5	18	19	25	21	21	45	17	16
6	26	30	26	32	30	46	30	27
7	12	14	27	30	30	47	25	27
8	28	30	28	28	30	48	32	29
9	26	28	29	26	27	49	25	26
10	24	28	30	20	20	50	22	24
11	[1, 2] 10	[1, 2] 11	31	18	18			
12	20	23	32	[1, 2] 27	[1, 2] 29			
13	18	19	33	18	18			
14	27	27	34	24	24			
15	26	27	35	28	28			
16	17	17	36	20	21			
17	17	19	37	22	21			
18	16	16	38	28	27			
19	19	22	39	[1, 2] 19	[1, 2] 20			
20	14	18	40	22	22			

[1] Bad appearance.
[2] Film showed no characteristic checking and no dulling.

The continuous cycle of light and water together is the best for rapid acceleration of the failure of varnish coatings that we have so far found. First signs of failure can be seen in 8 days for the poorer grades of spar varnishes and in 18 to 20 days for the best grades of

long-oil spar varnishes. There does not seem, however, to be a very close relationship between the number of days in which checks first appear and the number of days before failure. The first appearance of dulling was taken as the end point of failure. This dulling was caused by the formation of extremely fine "honeycomb" checking. As can be seen from Table 2 the difference in days between the appearance of the first checks and initial dulling varies considerably among the 50 varnishes; that is, from a minimum of 2 to a maximum of 13 days. The end point, as Table 2 shows, varied from 10 days for the poorest varnish to from 30 to 32 days for the very best varnishes. The 50 spar varnishes used in this work were all commercial brands. The type of failure observed in the accelerated test resembles very closely the type of failure found on outdoor exposure.

TABLE 2.—*Relation between first checks and failure*

ACCELERATED EXPOSURE

Varnish No.	Days to first checks	Days to end-point of failure	Difference between columns 2 and 3	Varnish No.	Days to first checks	Days to end-point of failure	Difference between columns 2 and 3	Varnish No.	Days to first checks	Days to end-point of failure	Difference between columns 2 and 3
1	11	18	7	21	14	21	7	36	18	20	2
2	11	18	7	22	12	19	7	37	12	22	10
3	11	18	7	23	15	21	6	38	19	28	9
4	18	25	7	24	8	19	11	39	[1] 18	[2] 19	[3] 1
5	11	18	7	25	11	21	10	40	15	22	7
6	18	26	8	26	23	32	9	41	9	22	13
7	8	12	4	27	19	30	11	42	14	15	1
8	18	28	10	28	18	28	10	43	14	16	2
9	19	26	7	29	15	26	11	44	19	25	6
10	14	24	10	30	11	20	9	45	11	17	6
11	[1] 7	[2] 10	[3] 3	31	15	18	3	46	18	30	12
12	14	20	6	32	[1] 19	[2] 27	[3] 8	47	20	25	5
13	9	18	9	33	15	18	3	48	20	32	12
14	14	27	13	34	15	24	9	49	20	25	5
15	18	26	8	35	15	28	13	50	18	22	4
16	12	17	5								
17	9	17	8								
18	14	16	2								
19	14	19	5								
20	12	14	2								

[1] First cracks.
[2] Bad appearance.
[3] Film showed no characteristic checking and no dulling.

Practically 95 per cent of all the spar varnishes tested in the accelerated cycle failed in the same way. The first sign of failure was a fine checking and cracking inside of spots, on the varnish film, caused by the evaporation of drops of water left after spraying. The next step in failure was scattered checking and cracking outside of these water spots. The amount of this cracking and checking grew from day to day until finally the checks began to run together and gave the film a "honeycombed" appearance. The checks became so densely packed in small areas that the panel appeared dull in these areas. This initial dulling was easily seen by the naked eye and was taken as the end point. These dull areas gradually grew in size until finally the entire panel was extremely dull, after which the film began to peel. A small lens, magnifying about 2½ diameters, was used in studying the failure of the coatings from day to day.

Three of the 50 varnishes, Nos. 11, 32, and 39, failed differently in the accelerated test from the rest of the varnishes. Varnishes Nos. 32 and 39 proved by roof exposure to be the most durable of the entire set, and varnish No. 11 was among the best. In the accelerated test these three varnishes all failed by first showing a few scattered cracks which shortly after their appearance seemed to open up wider and wider each day exposing bare metal underneath. More and more cracks appeared each day, and these would open to expose the bare metal until finally the entire panel was covered by a large number of these cracks all exposing the bare metal and giving the panel a very bad appearance. The films, however, never showed the fine checking characteristic of most varnish failures and never exhibited any dulling. Outdoors, varnish, No. 11 failed in the usual way, and varnishes Nos. 32 and 39 did not show initial failure after seven and one-half months' exposure.

Comparisons between the accelerated weathering and roof exposure tests will be found in Table 5.

2. OUTDOOR WEATHERING TESTS

The same set of 50 spar varnishes, which were tested in the accelerated weathering apparatus, and for which data were given in Table 2, were placed outdoors on the roof of the Chemistry Building of the National Bureau of Standards on January 10, 1929, and a similar set on April 1, 1929. The panels for the set exposed on January 10 were prepared in the same manner as the panels for the accelerated tests. Two coats of each varnish were brushed on duplicate panels allowing three days' drying between coats and three days' drying after the final coating before exposure. The panels were exposed in suitable racks at an angle of 45° facing south and examined with the lens once a week for signs of failure.

The second set of the same varnishes, exposed outdoors on April 1, 1929, was on panels which had been sand blasted before applying the varnish. The sand blasting was done at about 25 pounds pressure, using a 30 to 40 mesh sand. After sanding, the panels were handled with rubber gloves to prevent any grease or perspiration from the hands from coming in contact with the panel. It was not necessary to wash these panels with benzol. The backs and edges of the panels were coated with two coats of aluminum paint. The varnishes were applied to the panel by the whirling method.[2] In this method the varnish is poured on the center of the panel, which is whirled for at least two minutes at 300 r. p. m. At the end of the 2-minute period practically all the excess varnish has been forced off the panel. The advantages of the whirling method over the brushing method for preparing varnish films for exposure work are that it tends to give a cleaner, smoother film and eliminates entirely any personal factor which might enter into the operation. Brushes collect dirt very easily, and this dirt, of course, is transmitted to the varnish coating. Two coats of varnish were applied to the panels by this method, allowing three days for drying between coats and three days after the last coat, before exposure.

[2] P. H. Walker and J. G. Thompson, Physical Properties of Paints, Proc. Am. Soc. Test. Materials, 464; 1922.

One of the most significant results of the exposure tests on these two sets of the same varnishes exposed outdoors approximately three months apart is the very good agreement in their relative order of failure. This close agreement is shown graphically in Figure 1. The number of days before failure of each varnish is shown in Table 3.

TABLE 3.—*Outdoor exposure*

[Relation between two sets of varnishes exposed Jan. 10, and Apr. 1, respectively]

Varnish No.	Days to failure		Difference between columns 2 and 3	Days to failure in accelerated weather	Equivalents; one day in accelerated equivalent approximately to, in days outdoors	
	Exposed Jan. 10	Exposed Apr. 1			Jan. 10	Apr. 1
1	177	124	53	18	10	7
2	177	124	53	18	10	7
3	177	124	53	18	10	7
4	219	159	60	25	9	6
5	170	117	53	18	9	7
6	184	131	53	26	7	5
7	55	33	22	12	5	3
8	205	145	60	28	7	5
9	191	131	60	26	7	5
10	184	131	53	24	8	5
11	219	159	60	10	(1)	(1)
12	177	124	53	20	9	6
13	170	117	53	18	9	7
14	212	152	60	27	8	6
15	198	131	67	26	8	5
16	170	117	53	17	10	7
17	170	117	53	17	10	7
18	114	61	53	16	7	4
19	191	138	53	19	10	7
20	170	110	60	14	12	8
21	219	159	60	21	10	8
22	184	131	53	19	10	7
23	177	124	53	21	8	6
24	170	117	53	19	9	6
25	198	138	60	21	9	7
26	177	131	46	32	5	4
27	219	166	53	30	7	6
28	219	166	53	28	8	6
29	205	138	67	26	8	5
30	191	131	60	20	10	7
31	114	82	32	18	6	5
32				27	(1)	(1)
33	170	117	53	18	9	7
34	177	124	53	24	7	5
35	205	152	53	28	7	5
36	184	124	60	20	9	6
37	184	124	60	22	8	6
38	198	138	60	28	7	5
39				19	(1)	(1)
40	170	117	53	22	8	5
41	205	131	74	22	9	6
42	121	61	60	15	8	4
43	114	54	60	16	7	3
44	198	145	53	25	8	6
45	107	54	53	17	6	3
46	219	159	60	30	7	5
47	170	117	53	25	7	5
48	205	152	53	32	6	5
49	170	117	53	25	7	5
50	170	117	53	22	8	5
Average					8	5.5

[1] Failed abnormally.

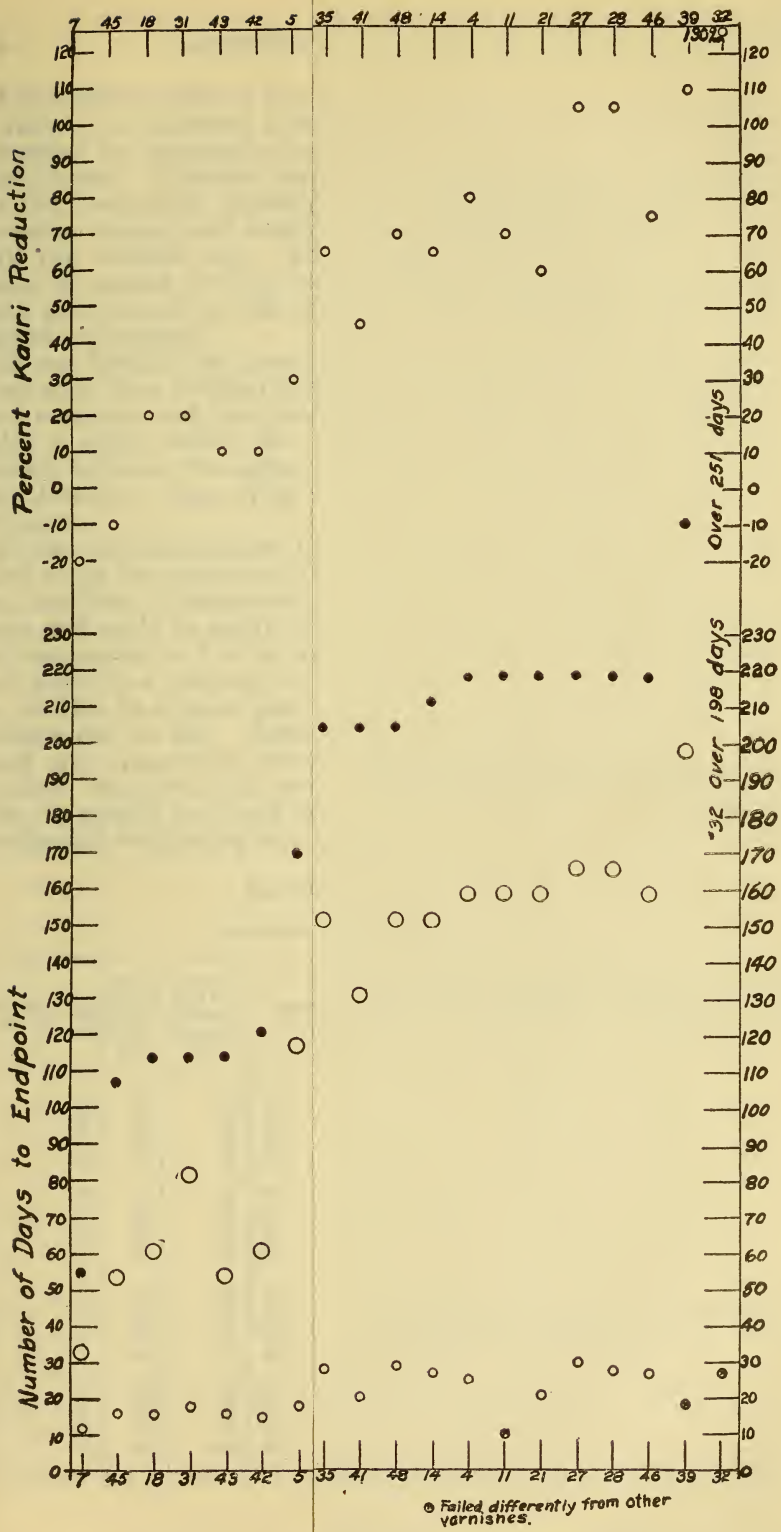

FIGURE 1.—*Comp of the year for 50 varnishes tested*

88500°—30. (Face p. 252.)

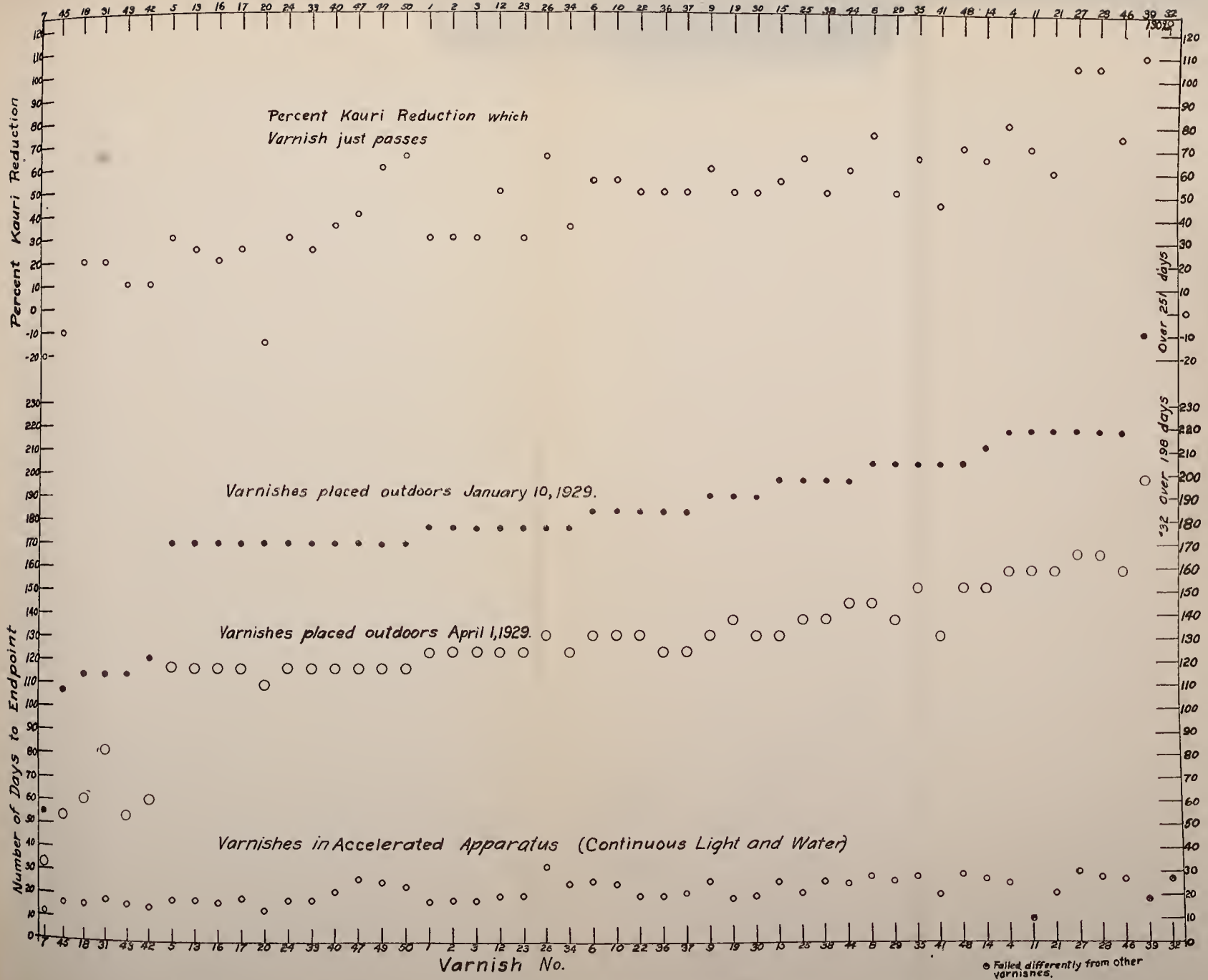

FIGURE 1.—*Comparisons of the end point in the kauri reduction test, in the accelerated cycle, and on outdoor exposure at two times of the year for 50 varnishes tested*

From these results it is apparent that as far as the relative order of failure is concerned it makes no difference whether the varnish is applied by brushing or whirling or whether or not the surface is sand blasted. However, we are strongly in favor of the panel which has not been sand blasted, mainly because of the great difficulty in seeing checks and cracks on the sand-blasted panel, especially with the unaided eye. This difficulty in seeing the checks and cracks is caused by the multiple reflection from the innumerable small pits caused by the sand blasting. This would not apply to pigmented coatings.

As was found to be true in the results of the accelerated test, there is no very close relation between first appearance of checks on outdoor exposure and complete failure. This is shown graphically in Table 4 which shows the number of days which elapsed for each varnish between the appearance of first checks and date of failure. This difference varies from a minimum of 19 days to a maximum of 100 days.

In the outside-exposure tests the samples were considered to have failed when the panels were completely covered with checks and had the resulting "honeycomb" appearance. This point was quite sharp and could be easily seen with the aid of the small lens. After the appearance of five or six small checks or cracks, the number on each panel was counted each week until there were about 100; then the number in a given area was counted until the total for the panel reached 600 to 800. After this a close watch was kept until the panel was completely covered with checks, and had the "honeycombed" appearance all over. This was regarded as the end point. This, it should be noted is not the same as the end point in the accelerated weathering test.

TABLE 4.—*Outdoor exposure*

[Relation between first checks and failure]

Varnish No.	Days to first checks	Days to end point of failure	Difference between columns 2 and 3	Varnish No.	Days to first checks	Days to end point of failure	Difference between columns 2 and 3	Varnish No.	Days to first checks	Days to end point of failure	Difference between columns 2 and 3
1	107	177	70	21	121	219	98	41	121	205	84
2	107	177	70	22	114	184	70	42	55	121	66
3	107	177	70	23	114	177	63	43	55	114	59
4	121	219	98	24	114	170	56	44	121	198	77
5	107	170	63	25	114	198	84	45	36	107	71
6	121	184	63	26	121	177	56	46	135	219	84
7	36	55	19	27	121	219	98	47	107	170	63
8	121	205	84	28	121	219	98	48	121	205	84
9	121	191	70	29	114	205	91	49	114	170	56
10	121	184	63	30	107	191	84	50	107	170	63
11	121	219	98	31	55	114	59				
12	114	177	63	32	233	-------	---------				
13	107	170	63	33	78	170	92				
14	121	212	91	34	107	177	70				
15	121	198	77	35	121	205	84				
16	107	170	63	36	121	184	63				
17	107	170	63	37	121	184	63				
18	55	114	59	38	121	198	77				
19	114	191	77	39	219	-------	---------				
20	70	170	100	40	114	170	56				

TABLE 5.—*Outdoor versus accelerated weathering versus kauri versus Federal specification No. 18b*

Varnish No.	Days to failure, outdoors	Days to failure in accelerated weathering	Kauri reduction value	When tested according to Federal specification fails on—
7	55	12	−20	Hot and cold water and kauri.
45	107	17	−10	Kauri.
18	114	16	20	Hot and cold water and kauri.
31	114	18	20	Do.
43	114	16	10	Do.
42	121	15	10	Kauri and nonvolatile.
5	170	18	30	Kauri.
13	170	18	25	Do.
16	170	17	20	Hot and cold water and kauri.
17	170	17	25	Do.
20	170	14	−5	Do.
24	170	19	30	Kauri.
33	170	18	25	Draft and kauri.
40	170	22	35	Viscosity and kauri.
47	170	25	40	Hot and cold water and kauri.
49	170	25	60	O. K.
50	170	22	65	Do.
1	177	18	30	Hot and cold water and kauri.
2	177	18	30	Do.
3	177	18	30	Do.
12	177	20	50	O. K.
23	177	21	30	Hot and cold water and kauri.
26	177	32	65	O. K.
34	177	24	35	Hot and cold water and kauri.
6	184	26	55	O. K.
10	184	24	55	Do.
22	184	19	50	Do.
36	184	20	50	Do.
27	184	22	50	Do.
9	191	26	60	Hot and cold water and draft.
19	191	19	50	O. K.
30	191	20	50	Do.
15	198	26	55	Do.
25	198	21	65	Do.
38	198	28	50	Do.
44	198	25	60	Do.
8	205	28	75	Do.
29	205	26	50	Do.
35	205	28	65	Do.
41	205	22	45	Viscosity and kauri.
48	205	32	70	Draft.
14	212	27	65	Draft and viscosity.
4	219	25	80	Draft.
11	219	[1] 10	70	O. K.
21	219	21	60	Do.
27	219	30	105	Draft and viscosity.
28	219	28	105	O. K.
46	219	30	75	Hot and cold water and draft.
32	Over 226	[1] 27	130	O. K.
39	Over 216	[1] 19	110	Do.

[1] Failed abnormally.

Table 3 and Figure 1 show the relation between the accelerated weathering test and the outdoor exposure test. Figure 1 and Table 5 also show the relation between the kauri reduction test [3] and the two exposure tests. Table 3 also shows for each varnish the number of days on the roof equivalent to one day's exposure in the accelerated weathering apparatus. For the set of varnishes placed outdoors on January 10 the average ratio found is that one day in the

[3] See footnote 4, p. 256.

accelerated weathering apparatus is equivalent to approximately eight days outdoors, and for the set of varnishes placed outdoors April 1 one day of accelerated exposure is equivalent to about five and one-half days outdoors.

3. RELATION BETWEEN KAURI REDUCTION VALUES AND OUTDOOR EXPOSURE TESTS

Table 5 shows best the relation between outdoor exposure and the kauri reduction test. In general, there is fairly good agreement. For example, of the 26 varnishes found to be the best on exposure, only 1, varnish No. 41, had a kauri reduction value of less than 50. This varnish also showed the largest discrepancy of any varnish between the two outdoor exposure sets as is shown in Table 3; that is, a difference of 74 days between end points of the January 10 set and the April 1 set. Of the 24 poorer varnishes in the exposure test only 4, Nos. 49, 50, 12, and 26, had a kauri reduction value of 50 or more. This relationship indicates that the 50 per cent kauri reduction requirement of Federal specification No. 18b for spar varnish will generally keep out the material of poorer quality. Of the poorest 15 varnishes as shown by the outdoor exposure, none passed a kauri reduction test of over 40 per cent, and of the 15 best varnishes as shown by the outdoor exposure, test all but 2 passed a kauri reduction of 60 per cent or better.

4. RELATION BETWEEN ACCELERATED WEATHERING TEST AND OUTDOOR EXPOSURE TESTS

Table 5 also shows best the relation between outdoor exposure and the accelerated weathering. In general, there is fairly good agreement between the two. For example, of the 26 varnishes found best on outdoor exposure, only 2 show failure in the accelerated test in less than 20 days, and these 2, varnishes Nos. 19 and 22, lasted 19 days in the accelerated test before failure. Of the 24 varnishes classified as poor on roof exposure only 8 lasted 20 days or more in the accelerated test, and of the poorest 13 varnishes of this group none lasted 20 days. The kauri reduction value appears to be in somewhat better agreement with the outdoor exposure test than does the accelerated test.

5. RELATION BETWEEN OUTDOOR EXPOSURE TESTS AND RESULTS OF TESTS FOR CONFORMITY TO FEDERAL SPECIFICATION No. 18b

Table 5 also shows the relation between outdoor exposure and the results of tests for conformity to Federal specification No. 18b for spar varnish. Of the 26 varnishes showing up as the best of the 50 varnishes exposed outdoors 19 passed the specifications in every respect and only 1 failed on the kauri reduction test. This was No. 41, which was mentioned before as the particular varnish showing the greatest discrepancy between two outdoor exposure tests. Of the remaining 6 of these 26 varnishes, 2 failed to pass the draft test and hot and cold water tests, 2 failed to pass the draft test only, and 2 failed to pass the draft test and viscosity test.

88500°—30——6

Of the 24 varnishes classified as poor on the outdoor exposure test only 4 passed the specification in all respects, and of the poorest 15 none passed.[4]

In a previous outdoor exposure test of 75 commercial spar varnishes completed in the fall of 1928, 30 varnishes of the 56 found to have good durability passed the requirements of Federal specification No. 18b in every respect, and of the 26 which did not pass only 7 failed on the kauri reduction test. Of the remaining 19 of the 26 which failed to pass the specification 3 failed on the cold and hot water tests; 1 failed on the draft test and was slightly cloudy; 1 was slightly cloudy and had a slightly high viscosity; 2 failed because of cloudiness only; 1 failed on the viscosity, nonvolatile, and cold and hot water tests; 3 failed on the hot water test only; 1 failed on the viscosity and hot water tests; 1 failed on the nonvolatile and cold and hot water tests; 2 failed on the viscosity tests only; 1 failed because of cloudiness and in the cold and hot water tests; and 3 failed on the nonvolatile test only.

Of the 19 varnishes classified as poor 12 failed to pass the kauri reduction test and only 1 passed Federal specification No. 18b in all respects.

III. DURABILITY OF A SERIES OF 30-GALLON[5] VARNISHES MADE IN THE LABORATORY

The following 30-gallon varnishes were prepared in the laboratory: Rosin and linseed oil, ester gum and linseed oil, kauri gum and linseed oil, amberol B. S. 1 and linseed oil, amberol F. 7 and linseed oil, rosin and china-wood oil, ester gum and china-wood oil, amberol B. S. 1 and china-wood oil, amberol F. 7 and china-wood oil.

Mineral spirits passing Federal specification No. 16 was used as the thinner for all the varnishes. Lead acetate and cobalt acetate were used as driers. In each varnish the weight of lead in the drier, added, was 1.0 per cent and the weight of cobalt 0.05 per cent of the weight of oil used. The percentage of nonvolatile matter was approximately 50 and the viscosities of all the varnishes were about F to G on the Gardner-Holdt scale. Several attempts at heat treating several of the varnishes had to be made before the proper viscosity was obtained.

The varnishes were exposed on American Russia iron panels 3 by 6 inches in size. Two brushed coats were applied. A good grade of a commercial spar varnish and a high-grade clear lacquer were also

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[4] Brief description of requirements of Federal specification No. 18b.

1. Appearance, clear and transparent.
2. Color, not darker than a solution of 3 g of potassium dichromate in 100 cc of pure sulphuric acid, specific gravity 1.84.
3. Nonvolatile matter at 105 to 110° C., not less than 45 per cent by weight.
4. Set to touch in not more than 5 hours.
5. Dry hard in not more than 24 hours.
6. Viscosity, not less than 1.40 nor more than 2.25 poises.
7. Must have good brushing, flowing, covering, and leveling properties. Dried film shall have the characteristic gloss of spar varnish.
8. Shall pass the draft test; that is, shall show no dulling, crow's footing, or frosting when allowed to dry about 2 feet in front of an electric fan.
9. Dried film shall withstand cold water for 18 hours and boiling water for 15 minutes without whitening or dulling.
10. Shall pass a 50 per cent kauri reduction test. Briefly, this test is carried out by adding to the varnish an amount of kauri solution (a 33⅓ per cent solution of "run kauri" gum in turpentine) equivalent to 50 per cent by weight of the nonvolatile matter in the varnish, flowing a film of this mixture on metal, baking in an oven for 5 hours at 95 to 100° C., cooling and bending over a 3 mm (⅛ inch) rod. The film must show no cracks on bending.

[5] The expression "30-gallon" refers to the proportions of oil and resin in the varnish; that is, 30 gallons of oil per 100 pounds on resin.

exposed at the same time. The results of the accelerated weathering tests and outdoor exposures are to be found in Table 6. The kauri reduction values are also shown in this table. The amberol-linseed oil varnishes appear to be much more durable on outdoor exposure than the varnishes made from linseed oil, using either rosin or kauri, and varnish containing linseed oil and the amberol F. 7 is somewhat more durable than those with either the ester gum or amberol B. S. 1. The china-wood oil varnishes, as was expected, showed greater durability than the linseed-oil varnishes, except that the one containing ester gum and linseed oil had a slightly longer life than that made from rosin and china-wood oil. With both linseed and china-wood oils the amberol F. 7 varnishes apparently were somewhat more durable than the varnishes made from any of the other resins. The varnish made from china-wood oil and amberol B. S. 1, however, seems to have no more durability than the varnish made from ester gum and china-wood oil. The commercial brand of varnish which was exposed with these varnishes is believed to be approximately a 30-gallon varnish. It is very interesting to note the extreme durability in both the accelerated weathering cycle and the outdoor exposure of the clear lacquer coating. This lacquer is a commercial product. The vinyl coatings were two brushed coats of vinyl resins dissolved in toluol.

TABLE 6.—*Exposure of series of 30-gallon varnishes, a commercial clear lacquer, and some vinyl resin coatings*

Type of material	Kauri reduction value	Accelerated		Outdoors	
		Days to first checks	Days to end-point of failure	Days to first checks	Days to end-point of failure
Rosin, linseed	80	6	11	28	119
Ester gum, linseed	85	6	11	76	178
Kauri, linseed	60	6	7	34	119
Amberol B. S. 1, linseed	70	6	12	76	184
Amberol F. 7, linseed	80	11	12	106	212
Commercial spar varnish	70	14	17	90	205
Rosin, C. W. O	10	10	12	41	168
Ester gum, C. W. O	65	14	15	97	212
Amberol B. S. 1, C. W. O	65	14	15	106	212
Amberol F. 7, C. W. O	80	14	20	119	240
Commercial clear lacquer		O. K. after 106 days.		O. K. after 331 days.	
Vinyl resin (A) (low viscosity)		O. K. after 111 days.		O. K. after 111 days.	
Vinyl resin (B) (high viscosity)		O. K. after 111 days.		O. K. after 111 days.	
Vinyl acetate (A) (high viscosity)		O. K. after 111 days.		O. K. after 111 days.	
Vinyl acetate (B)		O. K. after 300 days.		O. K. after 387 days.	

In Table 6 it is also very interesting to observe how low the kauri reduction value is for the rosin and china-wood oil varnish as compared with the other varnishes, particularly the ester gum and china-wood oil varnish. The two varnishes both contain the same percentage of oil and yet the kauri reduction values differ by 55 per cent.

IV. CONCLUSION

1. A continuous, 24-hour per day cycle, in which 50 commercial spar varnishes received light from the carbon arc all of the time and a spray of water for approximately 40 seconds every 20 minutes, was found to cause the most rapid failure of varnish coatings. The nature

of the breakdown of the varnish coating is similar to the breakdown on outdoor weathering. The agreement is fairly good between the relative order of failure in the accelerated weathering test and outdoor exposure.

2. The relative order of failure is almost identical for a given set of varnishes exposed outdoors at two different seasons of the year.

3. Kauri reduction values are a somewhat better indicator than the accelerated weathering test of the durability of spar varnishes when exposed outdoors.

4. There is no apparent difference in the relative order of failure of a given set of varnishes, whether the coatings are applied by brushing or by whirling, or whether the panels are sand blasted or not sand blasted before application of the varnish.

5. Results of exposure tests show that the commercial spar varnishes which pass the requirements of Federal specification No. 18b are above the average in quality.

6. The varnishes made from the F. 7 amberol resin were somewhat more durable than varnishes made from rosin, ester-gum kauri, or B. S. 1 amberol. Varnishes made from B. S. 1 amberol had about the same durability as ester-gum varnishes, and were considerably more durable than the rosin or kauri varnishes. The commercial clear lacquer and the clear vinyl resin coatings were far more durable than any of the experimental varnishes, in both the accelerated weathering and outdoor exposure tests.

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WASHINGTON, September 9, 1929.