NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL NOTE

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EFFECT OF SIMULATED SERVICE CONDITIONS ON PLASTICS DURING ACCELERATED AND 2-YEAR WEATHERING TESTS

By W. A. Crouse, D. C. Caudill, and F. W. Reinhart

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SUMMARY

The effects of outdoor weathering for 2 years and of an accelerated weathering test on the weight, dimensional stability, and flexural properties of selected reinforced plastics were investigated. The results of all tests, both in this report and the previous report (NACA TN No. 1240), indicate that none of the laboratory aging tests correlated with outdoor weathering with respect to all properties and all materials.

INTRODUCTION

This report supplements information given in a previous report on this same subject (reference 1). The results of a 2-year outdoor weathering test and an accelerated weathering test (Method 6023, reference 2) on the weight, dimensional stability, and flexural properties of selected reinforced plastics are presented.

This investigation, conducted at the National Bureau of Standards, was sponsored by and conducted with the financial assistance of the National Advisory Committee for Aeronautics.

MATERIALS AND TEST PROCEDURES

The materials tested were the same as those used in the tests previously reported in reference 1. A description of the materials is given in table I, which has been reproduced from reference 1 for convenience. The dimensions of the specimens were also the same as those described in reference 1.

The 2-year outdoor weathering test was a continuation of the 1-year test previously reported (reference 1).

The accelerated weathering test was made in accordance with Method No. 6023 of Federal Specification L-P-406a (reference 2). This test involves exposure to cycles of soaking, freezing, drying, and radiation rich in ultraviolet light. The conditions used in this test are as follows:

(a) 24 hours at 100° F (38° C) over water
(b) 4 hours at -70° F (-57° C)
(c) 16 hours at 160° F (71° C)
(d) 4 hours of exposure to ultraviolet radiation

In (a) the condition was obtained by suspending the specimens individually over water in 8-ounce bottles. In (b) and (c) the low and high temperatures were attained by placing the specimens in a low-temperature test cabinet and in a circulating-air oven, respectively. In (d) the source of ultraviolet radiation was an S-1 bulb in a sunlamp, as specified in Method No. 6021 of reference 2. During this part of the cycle the specimens were turned end for end every 2 hours to obtain more uniform exposure to the radiation over the entire length. The bolts and nuts above the disk were arranged so as to be suitable for holding the 1- by 3-inch specimens.

The weight and dimensions of one set of specimens were measured within 10 minutes after the conclusion of 1, 3, 5, and 10 cycles. The flexural properties were determined on other sets at the end of 5 and 10 cycles, respectively, after conditioning at 77° F and 50-percent relative humidity for 48 hours.

RESULTS AND DISCUSSION

Weight and Dimensional Changes

The percentage changes in weight, length and width, and thickness of the materials on exposure to the 2-year outdoor weathering and accelerated weathering tests are shown in table II. In most instances the percentage changes in weight, length, width, and thickness decreased. Of those showing increases, most were observed in thickness.

Comparing the accelerated service tests generally, test IV caused the greatest changes followed by accelerated weathering test 6023; it is to be noted, however, that the effects of accelerated tests are different from the outdoor weathering test as shown by the differences in the rankings (table III) for the outdoor and for the accelerated service tests.

The relative weight and dimensional stability of the various materials are shown in table III. The results of aging tests shown in table V of reference 1 are incorporated into this table for comparison. The rating method is the same as used in reference 1.

Changes in Flexural Properties

The percentage changes in flexural strength, flexural modulus of elasticity, and maximum deflection in flexure of the materials on exposure to the 2-year outdoor weathering and accelerated weathering tests are shown in table IV.

Considering the tests shown in table IV of reference 1 and table IV of the present report, the 10-cycle accelerated service test IV gives percentage changes in flexural strength of approximately the same order of magnitude as the 2-year outdoor weathering and is the most severe of the aging procedures with respect to changes in flexural strength. However, the rankings of different materials for the outdoor weathering and accelerated weathering test IV are not in concordance.

The relative retention of flexural strength by the various materials is shown in table III. The aging tests shown in table V of reference 1 are incorporated into this table for comparison. The rating method is the same as used in reference 1.

Correlation of Laboratory Aging Tests

with Outdoor Weathering

Correlation coefficients of rank were obtained by comparing the rankings of the plastics for the accelerated weathering tests with the rankings for the outdoor weathering tests. No accelerated weathering tests correlated with the outdoor weathering tests sufficiently well to be regarded in any way as a useful substitute. It is worth noting that the five accelerated service tests show concordance among themselves to a statistically significant extent, though they do not reproduce the ranking of the outdoor weathering tests.

CONCLUSION

A comparison of the degree of correlation of the results obtained in the various laboratory aging procedures with those observed in the 1- and 2-year exposure tests out of doors, confirms the previous conclusion that none of the laboratory tests give results with all the materials and for all the properties which correlate with the results of outdoor weathering.

National Bureau of Standards
Washington, D. C., April 16, 1947

REFERENCES

1. Crouse, W. A., Caudill, D. C., and Reinhart F. W.: Effect of Simulated Service Conditions on Plastics. NACA TN No. 1240, 1947.

2. Federal Specification L-P-406a: Plastics Organic; General Specifications, Test Methods; Jan. 24, 1944. Government Printing Office, Washington 25, D. C.

TABLE I.- DESCRIPTION OF MATERIALS

[From reference 1]

NBS material designation	Type of laminate[1]	Manufacturer	Average thickness (in.)	Density (g/cu cm)	Resin		Reinforcement					Molding conditions			Time	
					Type	Content by weight (percent)	Type	Thread count		Ply arrangement	No. of plies	Pressure (lb/sq in.)	Curing temperature		Curing (min)	Cooling (min)
								Warp	Filling				Initial (°F)	Maximum (°F)		
A1	Macerated-cotton-fabric phenolic molding compound	Bakelite Corp.	0.121	1.37	Bakelite BM-199		Macerated cotton fabric	--	--	--------		2100	250	320	15	5
B1	High-strength paper, phenolic	Consolidated Water Power and Paper Co.	.121	1.43			Paper	--	--	Parallel		250				
C1	High-strength paper, phenolic	Consolidated Water Power and Paper Co.	.124	1.43			Paper	--	--	Crossed		250				
D1	Lignin paper	Formica Insulation Co.	.128	1.38	Lignin		Lignin paper	--	--							
E1	Glass-fabric, unsaturated polyester	Swedlow Aeroplastics Corp.	.116	1.70	Marco MR-1A		Glass fabric, plain weave ECC-11-162	29	17	Crossed	7					
F1	Muslin-cotton-fabric, unsaturated polyester	Swedlow Aeroplastics Corp.	.131	1.27	Marco MR-1A		Cotton fabric (muslin), twill weave	70	48		7					
H1	Enameled-duck cotton-fabric, unsaturated polyester	Pittsburgh Plate Glass Co., Columbia Chemical Division	.145	1.37	Allymer CR39	62-65	Cotton fabric (enameled duck), plain weave	36	32	Crossed	6	1-5	158	239	2 hours at 158° F 10 hours at 158-239° F	Gradual
I1	Grade C phenolic	Synthane Corp.	.122	1.36	Bakelite No. 1112	48	Cotton fabric, plain weave, 10 oz/sq yd	50	40	Crossed	7	1800		340	50	20
J1	Grade L phenolic	Synthane Corp.	.125	1.34	Bakelite BV-1112	48-52	Cotton fabric, plain weave, 3.7 oz/sq yd	80	80	Parallel	19	1620		320	45	25
K1	Grade AA phenolic	Synthane Corp.	.149	1.50	Bakelite No. 2427	47	Asbestos fabric, plain weave, 18 oz/sq yd	18	16	Parallel	5	1800		340	50	20

[1]Material A1 was obtained in the form of sheets prepared from a molding compound; all of the other materials were laminated sheet products.

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TABLE II.- CHANGES IN WEIGHT AND DIMENSIONS OF PLASTICS DURING OUTDOOR AND ACCELERATED WEATHERING TESTS

Material designation	Change during outdoor weathering test, 2 years (percent) (a)	Changes during accelerated weathering test (b)			
		1 cycle (percent)	3 cycles (percent)	5 cycles (percent)	10 cycles (percent)
Weight					
A1	-1.05	-2.26	-3.10	-3.44	-3.98
B1[c]	1.63	-.73	-.62	-.65	-.76
B1[d]	1.68	-.79	-.76	-.81	-.98
C1	1.52	-.85	-.87	-.97	-1.13
D1	.30	-1.34	-1.70	-1.88	-2.10
E1	-.49	-.34	-.43	-.47	-.56
F1	-.22	-1.50	-1.85	-2.00	-2.26
H1	-.20	-1.27	-1.58	-1.69	-1.93
I1	-.79	-1.70	-2.25	-2.47	-2.74
J1	-.92	-1.42	-1.88	-2.12	-2.42
K1	-.84	-1.22	-1.36	-1.38	-1.36
Length and width					
A1	-0.18	-0.26	-0.38	-0.44	-0.54
B1[c]	-.16	-.14	-.16	-.16	-.18
B1[d]	-.20	-.14	-.14	-.14	-.20
C1	-.16	-.08	-.10	-.10	-.08
D1	-.12	-.16	-.20	-.23	-.30
E1	.02	.00	.00	.00	.00
F1	-.22	-.20	-.24	-.28	-.36
H1	-.18	-.19	-.26	-.29	-.38
I1	-.12	-.16	-.22	-.26	-.15
J1	-.11	-.14	-.20	-.22	-.30
K1	-.10	-.07	-.08	-.07	-.13
Thickness					
A1	0.46	-0.04	-0.04	0.08	-0.35
B1[c]	4.33	.22	.55	.63	.44
B1[d]	4.85	.27	.43	.71	.41
C1	4.06	.03	.14	.27	-.02
D1	1.10	-.18	-.11	-.13	-.41
E1	.39	.28	.10	.10	-.19
F1	1.17	-.19	-.08	-.14	-2.18
H1	.96	.11	.02	.12	-.09
I1	-.05	-.13	-.24	-.13	-.24
J1	-.03	-.08	-.05	-.19	-.43
K1	-.51	-.05	-.13	-.15	-.36

[a]Washington, D. C.; specimens facing south on racks inclined at 45°.
[b]Method No. 6023, Federal Specification L-P-406a (reference 2).
[c]Specimens cut lengthwise.
[d]Specimens cut crosswise.

TABLE III.- STABILITY RATINGS OF THE PLASTIC MATERIALS IN OUTDOOR WEATHERING, ACCELERATED WEATHERING, AND ACCELERATED SERVICE TESTS[a]

Material designation	Weathering						Accelerated service test -									
	Outdoor		Accelerated 6021 (c)		Accelerated 6023 (d)		I		II		III		IV		V	
	1 yr	2 yr	120 hr	240 hr	5 cy	10 cy	5 cy	10 cy	5 cy	10 cy	5 cy	10 cy	5 cy	10 cy	5 cy	10 cy
							Weight[b]									
A1	8	8	11	11	11	11	11	11	11	11	11	11	11	11	11	11
B1[e]	9	10	2	3	2	2	1	1	5	6	1	1.5	3	2	2	3
B1[f]	11	11	4	4.5	3	3	3	3	6	7	3	3	2	1	4	4
C1	10	9	3	4.5	4	4	4	4	8	8	4	4	1	3	5	5
D1	1	3	9	10	7	7	5	6	9	9	7	7	8	8	7	7
E1	2	4	1	1	1	1	2	2	1	1	2	1.5	4	4	1	1
F1	5.5	2	6	6	8	8	8	7.5	3	3	6	6	10	10	6	6
H1	3	1	7	7	6	6	7	7.5	4	4	8	9	7	7	9	9
I1	7	5	10	9	10	10	10	10	10	10	10	10	9	9	10	10
J1	4	7	8	8	9	9	9	9	7	5	9	8	6	6	8	8
K1	5.5	6	5	2	5	5	6	5	2	2	5	5	5	5	3	2
							Length and width[b]									
A1	2.5	8.5	9.5	10	11	11	11	11	11	11	11	11	9	8	11	11
B1[e]	7.5	6.5	3.5	3.5	5	5	2	2	5	5	2.5	3	4.5	4	2.5	3.5
B1[f]	10	10	2	2	4	6	6.5	5	4	4	4	4	3	3	4	3.5
C1	7.5	6.5	3.5	3.5	3	2	3	3	2.5	3	2.5	2	2	2	2.5	2
D1	6	4.5	8	8.5	7	7.5	8	8	9	9.5	7	7	11	11	7	7
E1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
F1	9	11	7	7	9	9	4.5	5	6	6	8	8	10	10	8	8.5
H1	11	8.5	9.5	8.5	10	10	10	10	8	8	10	9.5	8	9	10	10
I1	5	4.5	11	11	8	4	9	9	10	9.5	9	9.5	7	7	9	8.5
J1	2.5	3	6	6	6	7.5	6.5	7	7	7	6	6	6	6	6	6
K1	4	2	5	5	2	3	4.5	5	2.5	2	5	5	4.5	5	5	5
							Thickness[b]									
A1	3	4	7	7	1	5	2.5	6.5	6	7	11	11	11	11	11	11
B1[e]	10	10	4	8	10	10	10	10	10	10	2	1.5	9	8	9.5	10
B1[f]	11	11	2	4	11	7.5	11	11	9	9	5	3	10	9	5	4
C1	9	9	8.5	10	9	1	9	9	11	11	4	10	7	7	9.5	6
D1	7	7	10	11	4.5	7.5	6	5	8	8	9	8	8	10	8	8
E1	4	3	1	1	2	3	2.5	3	1	1	2	6.5	4.5	3	1	7
F1	8	8	8.5	9	6	11	7	8	7	6	6.5	5	6	6	6	1
H1	6	6	6	2	3	2	8	6.5	3	4	10	1.5	2	1	2	9
I1	2	2	5	6	4.5	4	5	2	4	3	6.5	4	4.5	5	7	3
J1	1	1	3	5	8	9	1	1	5	5	2	6.5	3	4	4	2
K1	5	5	11	3	7	6	4	4	2	2	8	9	1	2	3	5
							Flexural strength[b]									
A1	2	3	11	10	8	11	11	11	6	8	11	8	11	11	11	10
B1[e]	11	10	9	7	10	10	10	9	4	4	6	9	7	7	6	5
B1[f]	10	11	4	5	9	9	9	10	5	5	8.5	11	10	6	3	4
C1	9	9	2	3	5.5	5	6	8	3	3	3	3	6	5	2	2
D1	7	6.5	6	6	5.5	3	7	6	8	6	10	7	9	10	9	7
E1	3	2	5	4	11	7	8	7	11	11	4	2	2	3	5	3
F1	8	5	3	2	1	8	3	3	7	7	5	5	8	8	4	8
H1	4	6.5	7	11	4	4	5	5	10	10	8.5	10	5	9	10	11
I1	5	8	8	9	7	6	4	4	9	9	7	6	4	4	8	6
J1	6	4	10	8	3	2	2	2	1	1	2	4	3	2	7	9
K1	1	1	1	1	2	1	1	1	2	2	1	1	1	1	1	1
							Modulus of elasticity in flexure[b]									
A1	8	11	11	11	11	11	11	11	10	11	11	11	11	11	11	11
B1[e]	10	10	9	8	7	8	8	8	7	7	3	6	4	5	6	6
B1[f]	11	8	7	4	9	9	9	9	6	4	9	10	9	7	8	7
C1	7	9	3	5	5	6	3	7	3	3	6	7	3	3	4	3
D1	3	4.5	4	6	3.5	3	4	3	5	6	5	4	8	9	5	5
E1	2	3	5	2	6	4	2	2	11	10	1	2	2	2	1	2
F1	4	1	2	1	2	2	6	5	4	2	4	3	7	8	3	8
H1	5	7	8	9	8	7	5	6	9	9	7	8	5	4	9	9
I1	6	4.5	6	7	3.5	5	7	4	8	8	8	5	6	6	7	4
J1	9	6	10	10	10	10	10	10	1	1	10	9	10	10	10	10
K1	1	2	1	3	1	1	1	1	2	5	2	1	1	1	2	1
							Maximum deflection in flexure[b]									
A1	11	11	11	11	10.5	11	11	11	10	10	11	11	11	11	11	11
B1[e]	6	6	5	4	6	5	7	6	8	9	7	2	7	7	9	8
B1[f]	10	7.5	9.5	9	8	10	10	10	5.5	6	9	10	10	9	10	10
C1	8	7.5	8	6	9	9	8	5	7	7	8	9	5	8	8	9
D1	4	5	7	10	5	6	4	4	9	8	4	7	9	5	7	6
E1	5	9	9.5	8	10.5	8	3	9	11	11	10	4	8	10	3	7
F1	1	2	2	2	4	1	9	8	1	1	3	5	3	3	2	4
H1	2	1	1	1	2	4	2	1	2	4	1	1	1	1	1	1
I1	7	3	3	3	1	3	5	3	3	2	2	6	2	4	4	3
J1	3	4	4	5	7	7	6	7	4	3	6	8	6	6	6	2
K1	9	10	6	7	3	2	1	2	5.5	5	5	3	4	2	5	5

[a]Data for tests other than the 2-year outdoor weathering and accelerated weathering by Method No. 6023 were taken from reference 1.

[b]For changes in weight and dimensions the materials are rated according to the degree of change, the least change being denoted by a rating of 1. For the flexural strength and the flexural modulus of elasticity the materials are rated according to the retention of strength, the material with the greatest increase being rated 1 and that with the greatest decrease being rated 11. For the maximum deflection in flexure the material with the greatest negative change is rated as 1 and that with the greatest positive change as 11.

[c]Method No. 6021, Federal Specification L-P-406a (reference 2).

[d]Method No. 6023, Federal Specification L-P-406a (reference 2).

[e]Specimens cut lengthwise.

[f]Specimens cut crosswise.

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TABLE IV.- CHANGES IN FLEXURAL STRENGTH, MODULUS OF ELASTICITY, AND MAXIMUM DEFLECTION IN FLEXURE OF PLASTICS DURING OUTDOOR AND ACCELERATED WEATHERING TESTS

Material designation	Initial strength (lb/sq in.), modulus (lb/sq in.), or deflection (mils)	Change during outdoor weathering test, 2 years (percent) (a)	Changes during accelerated weathering test (b)	
			5 cycles (percent)	10 cycles (percent)
Flexural strength				
A1	12,700	-13.4	-8.7	-25.9
B1[c]	42,600	-37.6	-14.3	-18.5
B1[d]	29,000	-39.3	-13.1	-15.9
C1	25,100	-35.3	-4.6	-7.7
D1	23,500	-24.3	-4.7	-4.3
E1	34,100	-2.6	-17.9	-11.1
F1	16,100	-20.5	1.9	-15.5
H1	13,100	-24.4	-3.0	-6.9
I1	22,900	-24.9	-6.6	-8.3
J1	17,400	-18.4	.6	-1.2
K1	9,000	8.6	1.1	3.3
Modulus of elasticity in flexure				
A1	1,170,000	-40.2	-41.7	-47.2
B1[c]	3,363,000	-34.8	-16.3	-18.9
B1[d]	1,845,000	-27.8	-20.0	-23.9
C1	2,567,000	-29.4	-13.5	-16.0
D1	1,920,000	-18.1	-10.6	-10.9
E1	1,810,000	-7.1	-14.4	-13.6
F1	706,000	2.0	-4.2	-8.8
H1	652,000	-25.3	-17.5	-17.9
I1	1,238,000	-18.2	-10.5	-14.7
J1	1,121,000	-22.1	-22.0	-25.3
K1	986,000	-1.9	11.6	13.8
Maximum deflection in flexure				
A1	24.0	41.7	43.3	45.8
B1[c]	26.4	-2.6	11.4	8.8
B1[d]	31.0	.0	21.9	38.7
C1	27.4	.0	24.1	23.4
D1	21.5	-10.2	8.8	10.7
E1	45.7	5.0	43.5	18.8
F1	72.7	-39.9	7.2	-8.2
H1	68.2	-40.2	-8.6	3.7
I1	65.2	-18.4	-8.9	-1.5
J1	41.2	-13.8	14.8	16.5
K1	21.0	6.2	-3.8	-4.8

[a]Washington, D. C.; specimens facing south on racks inclined at 45°.
[b]Method No. 6023, Federal Specification L-P-406a (reference 2).
[c]Specimens cut lengthwise.
[d]Specimens cut crosswise.