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ATMOSPHERIC EXPOSURE TESTS ON NONFERROUS SCREEN WIRE CLOTH

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ABSTRACT

Atmospheric-exposure tests on seven compositions of nonferrous screen wire cloth were made by the National Bureau of Standards in cooperation with the American Society for Testing Materials over a period of about nine years. The specimens were exposed at Pittsburgh, Pa., a heavy-industrial atmosphere; at Portsmouth, Va., and Cristobal, C. Z., a temperate and a tropical seacoast atmosphere, respectively, with some industrial contamination; and at Washington, D. C., a normal inland atmosphere. At the termination of the tests at least one failure had occurred in each of the materials exposed at Pittsburgh; one of the materials had failed at both Portsmouth and Cristobal; while at Washington none of the materials had failed. The tensile strengths of the materials before and after exposure are compared.

There was no consistent relation between the results of laboratory accelerated-corrosion tests and the atmospheric-exposure tests at any of the locations.

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I. INTRODUCTION

In June 1924, a program of atmospheric-exposure tests on seven compositions of nonferrous screen wire cloth was formulated by Committee D–14 of the American Society for Testing Materials, the materials being furnished by members of the committee. Chemical analyses and certain laboratory tests were conducted at the direction of Subcommittee IV, under the chairmanship of the author, who represented the National Bureau of Standards on the committee. The exposure racks were placed on Government property as follows: (1) U. S. Bureau of Mines, Pittsburgh, Pa., (2) U. S. Lighthouse Depot, Portsmouth, Va., (3) Cristobal, C. Z., and (4) the National Bureau of Standards, Washington, D. C. The National Bureau of Standards arranged for the inspection and periodical reports of the condition of the exposed specimens.

During the summer of 1934 the necessity arose of removing the specimens at Portsmouth, Va., because the building on which they were located was to be razed. No other location was available in the immediate vicinity, and since failure had already occurred in most of the materials at Pittsburgh and several failures had been reported at Cristobal, although none had occurred at Washington, it was believed that more useful information would be obtained from an examination, at this time, of the remaining specimens than to prolong the tests until all materials had failed. Therefore it was decided to terminate the tests at the first three locations. As no failures had occurred at Washington, and extra materials which had been exposed for approximately the same length of time were available for examination, it was decided to continue the exposure of the framed materials at that location.

II. MATERIALS AND PREPARATION OF SPECIMENS

Seven nonferrous materials in the form of 16-mesh insect-screen cloth woven from wire .0113 in. in diameter were used. Their nominal compositions and the compositions determined by analysis of samples of the finished cloth are given in table 1.

TABLE 1.—*Composition of materials used in exposure tests of screen wire cloth*

Designation of alloy	Nominal composition	Composition, in percentage, determined by analysis [a]								
		Copper	Zinc	Nickel	Tin	Iron	Lead	Manganese	Silicon	Aluminum
1	90 copper, 10 zinc	90.7	[b] 9.05	[c] nd	0.23	<0.02	nd	-	-	-
2	80 copper, 20 zinc	80.1	19.88	nd	-	< .02	nd	-	-	-
3	75 copper, 20 nickel, 5 zinc	73.9	5.4	19.8	-	.3	-	0.5	0.06	
4	70 nickel, 30 copper (approx.)	26.5	-	68.3		2.4		2.7		
5	Unalloyed copper	99.94	nd	nd	<.01	-	nd	-	-	-
6	98 copper, 2 tin	98.3	nd	nd	1.8	< .01	nd	-	nd	-
7	95 copper, 5 aluminum	95.2	nd	nd	.08	-	nd	-	-	4.8

[a] Made by the Chemistry Division of the National Bureau of Standards.
[b] By difference.
[c] nd means not detected.

Of the seven compositions, unalloyed copper and the 90-copper, 10-zinc alloy were commercially available at the time the program was started and have continued to be since. The other alloys were not on the market at the time, but were included in the tests on the recommendation of various members of the committee.

Each material was mounted in three types of frames (1) 30- by 36-in. copper frames; (2) 30- by 36-in. wood frames; and (3) 12- by 12-in. (inside dimensions) wood frames. The cloth was mounted in the two larger frames by the Cincinnati Fly Screen Co. in the presence of the author. The cloth in the small frames was mounted, with very little tension in the screen, at the National Bureau of Standards. The frames were numbered for identification to correspond to the alloy numbers (see table 1). The 30- by 36-in. wood frames were numbered 1 to 7; the 30- by 36-in. copper frames were numbered 11 to 17; and the 12- by 12-in. wood frames, 21 to 27. The wood frames were painted several times during the exposure period with basic carbonate white-lead paint. The copper frames were not painted.

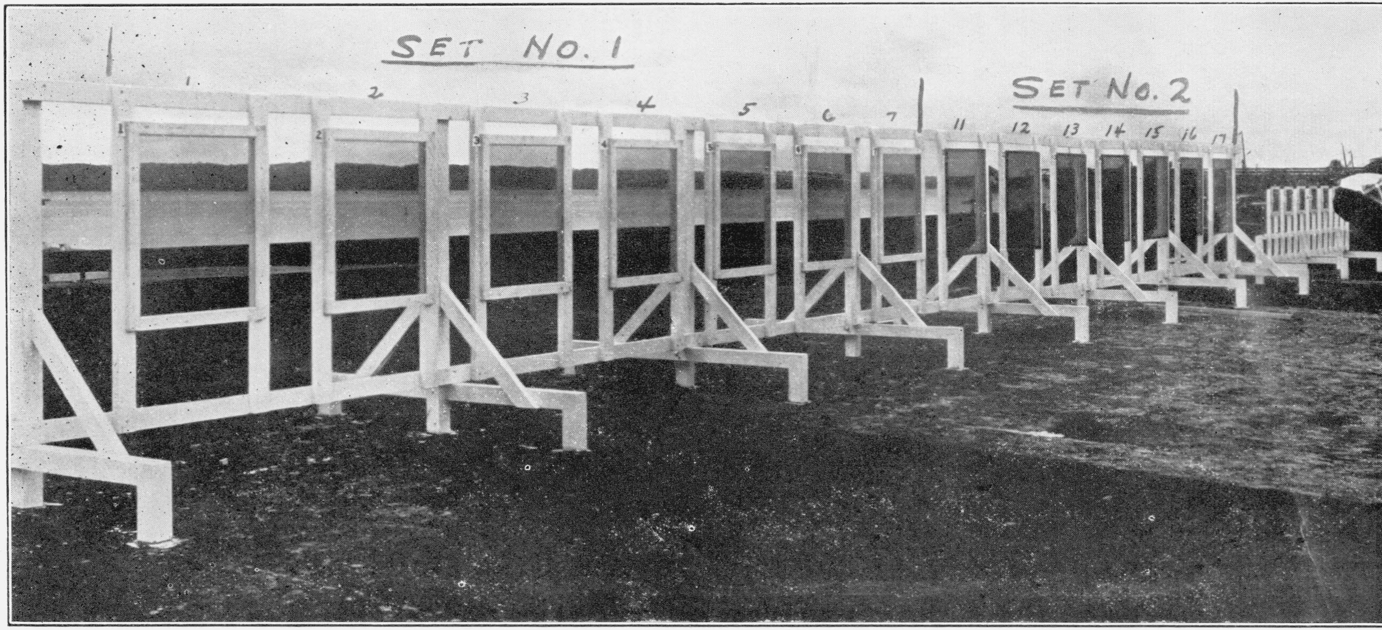

FIGURE 1.—*Appearance of the exposure specimens and racks on the roof of a warehouse at Cristobal, C. Z.*

This is typical of the arrangement at all four exposure locations.

The four test locations were selected to represent different atmospheric conditions, as follows: (1) The U. S. Bureau of Mines at Pittsburgh, a heavy-industrial atmosphere; (2) the Lighthouse Depot at Portsmouth, Va., a temperate seacoast atmosphere with some industrial contamination; (3) Cristobal, C. Z., a tropical seacoast atmosphere with some industrial contamination; and (4) the National Bureau of Standards, Washington, D. C., a normal inland atmosphere.

A photograph of the twenty-one framed specimens mounted on racks for exposure on the roof of a warehouse at Cristobal, C. Z., is shown in figure 1. This is typical of the arrangement at each of the four exposure locations. The test frames were fastened to vertical members, which were spiked to horizontal stringers so that the specimens were not directly under the longitudinal member.

Specimens of each material (unframed) were exposed in Washington, adjacent to the corresponding framed specimen, approximately one year after the start of the exposure tests. Tensile tests were made on specimens clipped from this material from time to time to demonstrate the changes in tensile strength on exposure.

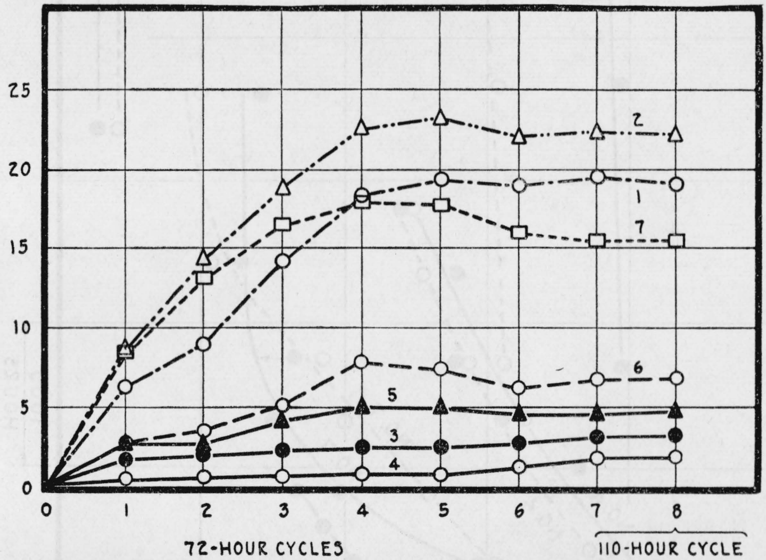

FIGURE 2.—*Loss of weight after exposure to salt spray, normal solution.*

III. LABORATORY TESTS

After the atmospheric-exposure tests had been started, accelerated corrosion tests were made to determine the relative corrodibility of the different materials, and whether such information would serve as a criterion to predict the expected life of the material in actual service. The sulphur-dioxide content of the atmosphere was also determined through the cooperation of several U. S. Government laboratories, over a period of one year at or near each of the exposure locations. The accelerated-corrosion tests consisted in exposure to (1) salt spray, and (2) intermittent immersion in a salt solution and in dilute sulphuric acid.

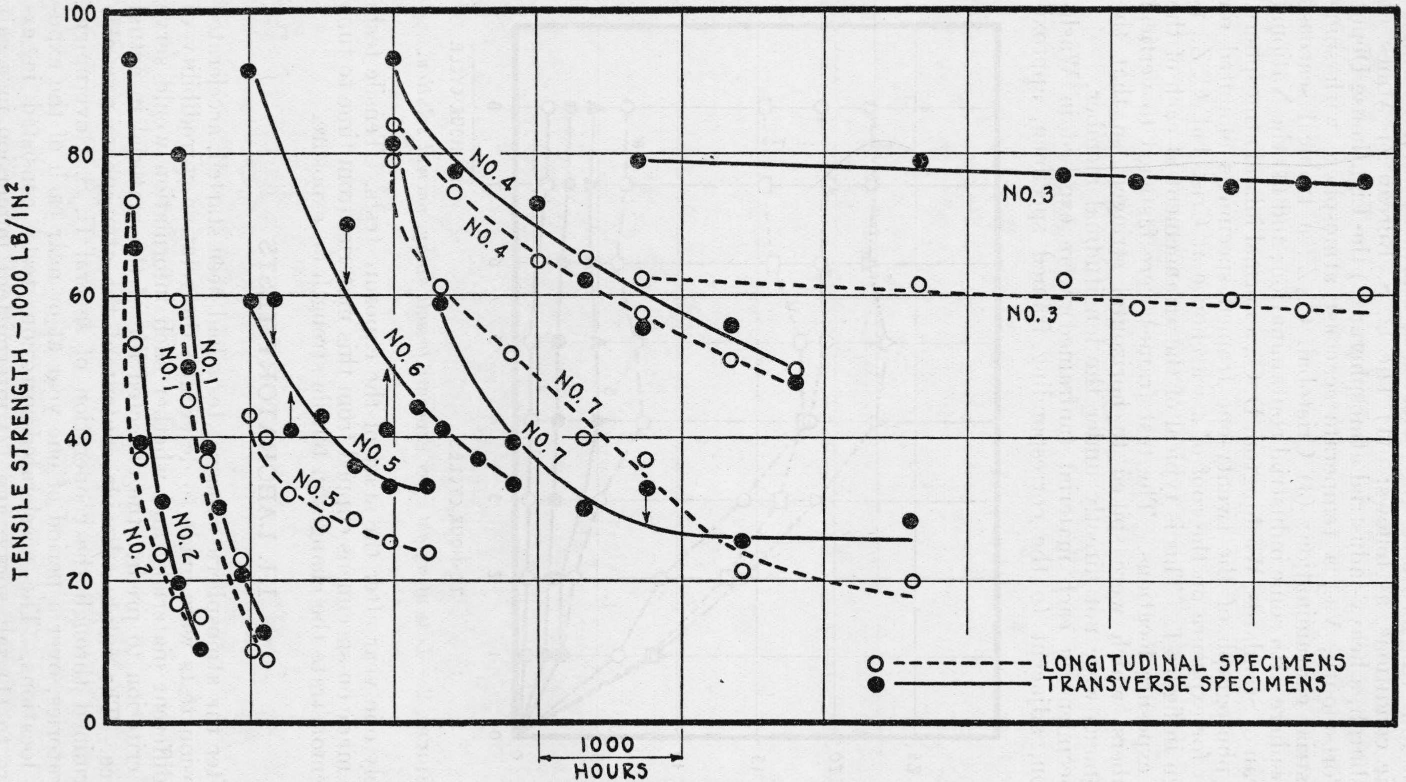

FIGURE 3.—*Decrease in tensile strength after exposure to salt spray, normal sodium-chloride solution.*

1. SALT SPRAY

In the salt-spray test the specimens were exposed to a spray or "mist" from a normal sodium-chloride solution (58.5 g of NaCl per liter). The effect of the exposure was measured by loss of weight in one series of specimens and by loss of tensile strength in another series. For each material a group of specimens 2 in. square was suspended from glass hooks in the spray box and, at intervals, duplicate specimens were withdrawn, scrubbed, and rinsed in alcohol, dried, and weighed. Specimens once withdrawn and weighed were not replaced in the salt-spray box. The average loss of weight of the pairs of specimens is shown in figure 2.

Specimens for the determination of loss of tensile strength after exposure to salt spray were taken both longitudinally and transversely to the direction of weaving, from each material. The tensile strengths after different periods of exposure are shown in figure 3.

The greatest loss of weight and of tensile strength occurred in the copper-zinc alloys, nos. 1 and 2; the alloys containing nickel, nos. 3 and 4, lost the least in weight and tensile strength; the remaining alloys fell between these extremes.

2. INTERMITTENT IMMERSION

These tests were made by dipping a specimen, 2 in. square, of each material into the corroding solution once each 15 minutes by use of an apparatus described by Rawdon, Krynitsky, and Finkeldey.[1] For approximately 13 minutes of each 15-minute period, the specimen was suspended in the air to dry. At intervals the specimen was removed from the apparatus, washed, dried, and weighed. The corroding solutions were:

(a) $N/10$ sulphuric acid (4.9 g of H_2SO_4 per liter).
(b) $N/50$ sulphuric acid (0.98 g of H_2SO_4 per liter).
(c) $N/2$ sodium-chloride solution (29.25 g of NaCl per liter).

The results of these tests are given in figures 4, 5, and 6. In the sulphuric-acid solutions, the loss of weight was greatest for the copper-zinc alloys, nos. 1 and 2, and least for the alloys containing nickel, nos. 3 and 4. These results were in agreement with those obtained in the salt-spray tests. Likewise, intermittent immersion in the $N/2$ sodium-chloride solution caused the greatest loss of weight in materials nos. 1 and 2, but the alloys containing nickel, nos. 3 and 4, lost more weight than the remaining alloys. However, the total amount lost by each alloy was much less in the salt-spray and salt solution than in the acid.

3. SULPHUR-DIOXIDE CONTENT OF THE ATMOSPHERE

It was thought that information regarding the sulphur-dioxide content of the atmosphere would aid the interpretation of the results of atmospheric-exposure tests on the screen-wire materials. The International Nickel Co. furnished the necessary equipment for making the determinations by use of the method of the Selby Smelter Commission in a somewhat modified form, as described by R. J. McKay and D. E. Ackerman.[2]

[1] Proc. Am. Soc. Testing Materials **24**, II, 717 (1924).
[2] Ind. Eng. Chem. **20**, 538–542 (1928).

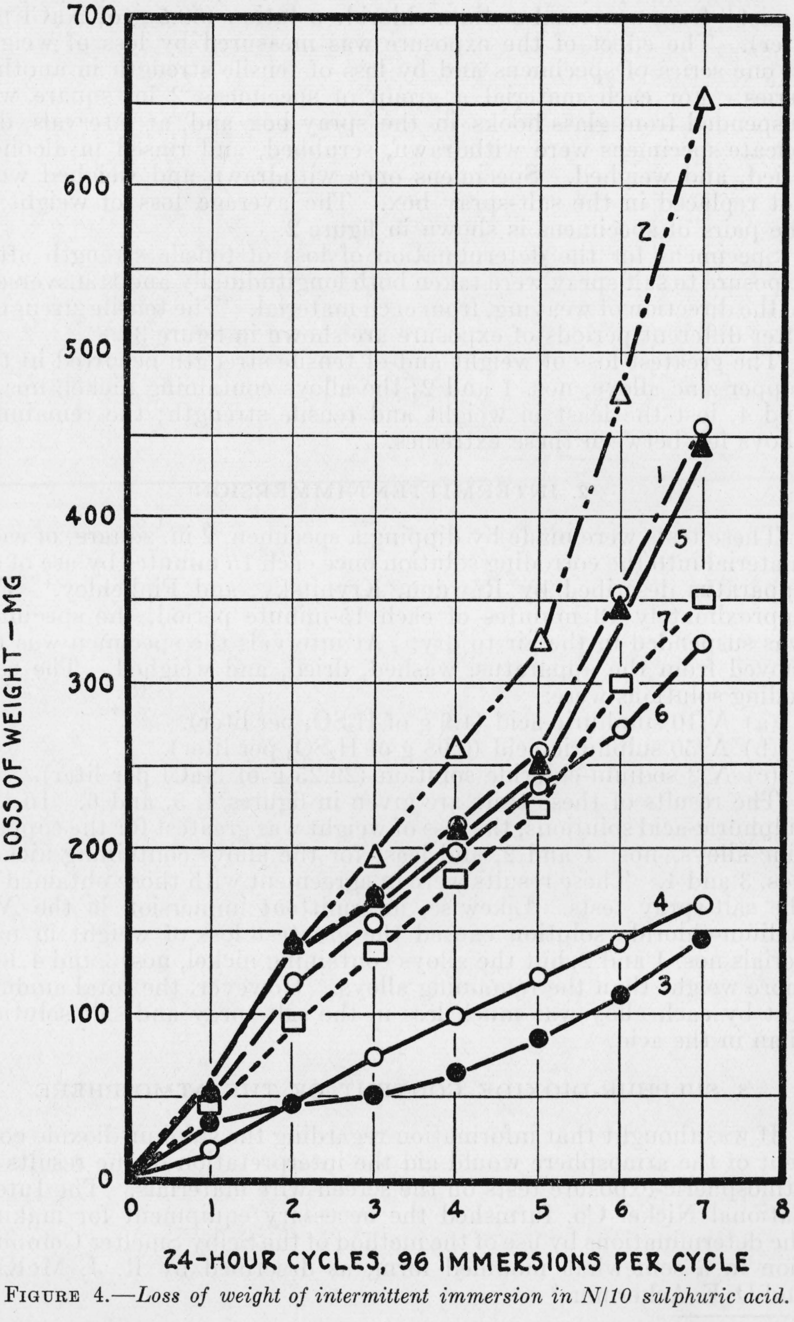

FIGURE 4.—*Loss of weight of intermittent immersion in N/10 sulphuric acid.*

Numerous determinations were made each month over a period of about a year, during 1927 and 1928, by the Bureau of Mines at Pittsburgh; by the Norfolk Navy Yard at Portsmouth; and by the Weather Bureau station at American University, Washington. Determinations at Cristobal were made only during the months May to October. The results are summarized in table 2.

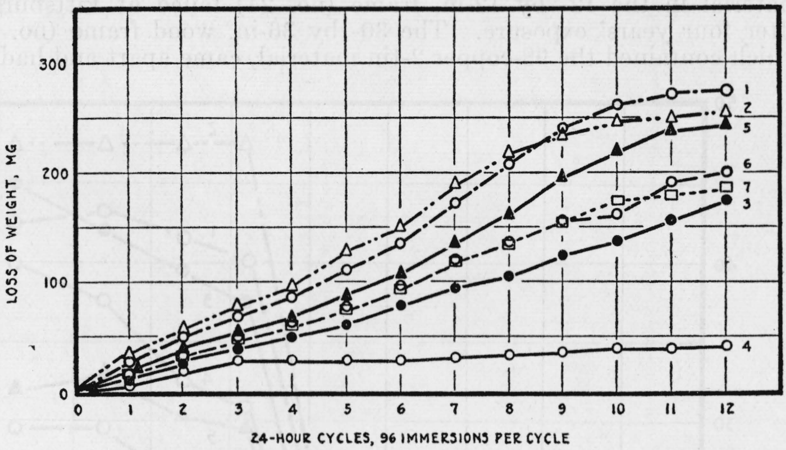

FIGURE 5.—*Loss of weight by intermittent immersion in N/50 sulphuric acid.*

TABLE 2.—*Sulphur-dioxide content of the atmosphere (parts per million by volume)*

Month (1927–28)	Pittsburgh, Pa.			Portsmouth, Va.			Cristobal, C. Z.			Washington, D. C.		
	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average
January	0.4	0.0	0.09	1.2	0.8	0.99	------	------	------	0.65	0	0.16
February	.4	.0	.15	1.1	.9	1.00	------	------	------	1.20	0	.27
March	.3	.0	.16	1.2	.6	1.00	------	------	------	1.30	0	.23
April	.3	.0	.04	1.0	.8	.95	------	------	------	.45	0	.09
May	.3	.0	.10	1.2	.9	1.05	0.92	0.37	0.64	.35	0	.08
June	.2	.0	.03	1.1	.7	.88	.58	.01	.18	.25	0	.07
July	.3	.0	.02	1.3	1.0	1.17	.39	.05	.18	1.20	0	.11
August	.3	.0	.08	1.2	.9	1.05	.35	.06	.16	.45	0	.11
September	.8	.0	.35	1.3	1.0	1.15	.42	.11	.21	.90	0	.22
October	1.1	.0	.67	------	------	------	.56	.06	.27	1.75	0	.53
November	.4	.0	.10	1.0	.2	.48	------	------	------	.45	0	.16
December	.4	.0	.09	------	------	------	------	------	------	1.10	0	.21

Apparently there is no correlation between these data and the results of the atmospheric exposure described in section IV of this paper.

The laboratory tests have been described in greater detail in reports of Committee D–14 of the American Society for Testing Materials.[3]

[3] Proc. Am. Soc. Testing Materials **26**, I, 492 (1926); and **30**, I, 864 (1930).

IV. RESULTS OF ATMOSPHERIC-EXPOSURE TESTS

Failure in the exposed screen cloth was considered to have occurred when there was a break in the wire in at least one place as a result of corrosion. The first failures occurred, at Portsmouth, in the 80-copper 20-zinc material (no. 2) in the 30- by 36-in. wood frame from dezincification after four years' exposure. The 70-nickel 30-copper material in the 12- by 12-in. frame (no. 24) failed at Pittsburgh, after four years' exposure. The 30- by 36-in. wood frame (no. 6), which contained the 98-copper 2-tin material, came apart and had to

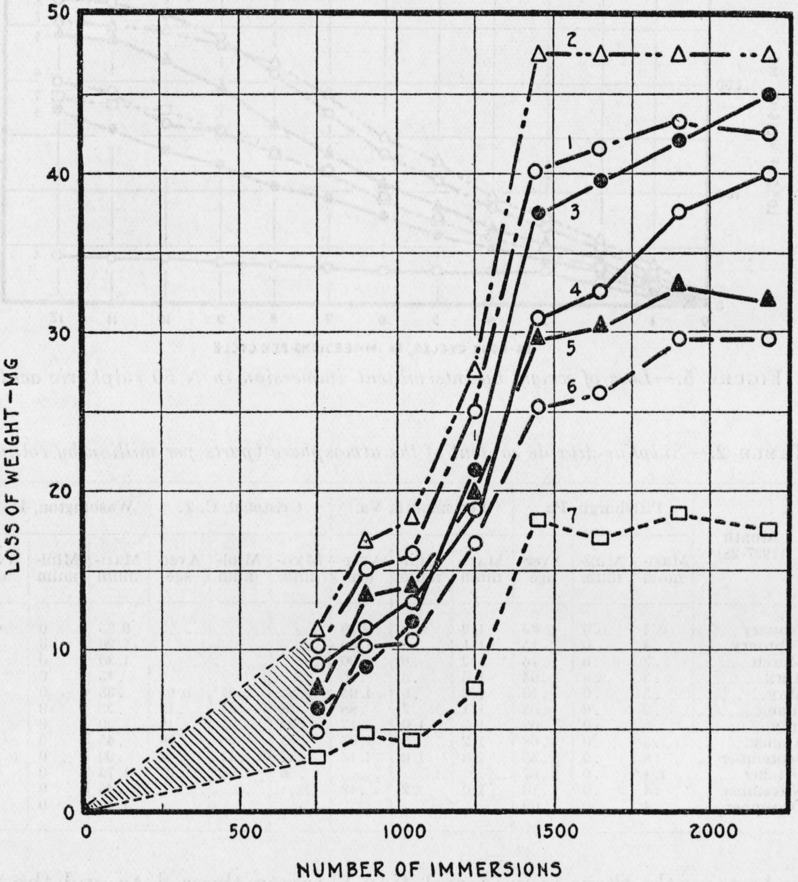

FIGURE 6.—*Loss of weight by intermittent immersion in N/2 sodium-chloride solution.*

be removed, although the wires were still in excellent condition. Since that time at least one failure has occurred in each of the materials exposed at Pittsburgh. At Cristobal, the 80-copper 20-zinc material (no. 2) failed in both the copper and wood 30- by 36-in. frames. The 12- by 12-in. wood frames at Cristobal were destroyed in some unknown manner after four years' exposure. The occurrence of failures and the condition of the materials at the termination of the exposure period at Pittsburgh, Portsmouth, and Cristobal are summarized in tables 3, 4, and 5. All the specimens exposed at Washington are in good condition.

TABLE 3.—*Condition of screen-wire materials after exposure at Pittsburgh, Pa., from Oct. 29, 1925 to July 10, 1934*

Screen material designation number and nominal composition	Type of frame and size (in inches)	Exposure time (up to first failure)		Appearance at end of test
		Years	Months	
No. 1:				
90 Cu, 10 Zn	30 by 36, wood	7	6	Uniform dark color. A few wires corroded through near the top. A few wires enlarged from corrosion products.
	30 by 36, Cu	7	6	Uniform dark color, holes at top and edge. Over half of cloth torn out by a slate in storm.
	12 by 12, wood	7	6	Uniform dark color; a few wires corroded through near the top.
No. 2:				
80 Cu, 20 Zn	30 by 36, wood	6	5	Very brittle; most of the cloth entirely gone. Dark color.
	30 by 36, Cu	6	4	Dark color; heavy corrosion products on some areas; other areas, the wires are thin, many holes; brittle.
	12 by 12, wood	6	10	Dark color; number of holes; brittle.
No. 3:				
75 Cu, 20 Ni, 5 Zn	30 by 36, wood	6	11	Dark color; badly corroded, several holes.
	30 by 36, Cu	7	3	Do.
	12 by 12, wood	8	2	Dark color; badly corroded, two holes near top.
No. 4:				
70 Ni, 30 Cu. (approx.)	30 by 36, wood	4	8	Dark color; badly corroded, most of the cloth gone.
	30 by 36, Cu	4	8	Do.
	12 by 12, wood	4	8	Dark color; badly corroded, considerable cloth gone near top.
No. 5:				
Cu (unalloyed)	30 by 36, wood			Dark color; considerable corrosion; wires thin near top.
	30 by 36, Cu	7	6	Dark color; considerable corrosion; wires thin with number of holes near the top.
	12 by 12, wood			Considerable corrosion; no holes.
No. 6:				
98 Cu, 2 Sn	30 by 36, wood	7	9	Dark color; a number of small holes near the top.
	30 by 36, Cu	7	10	Do.
	12 by 12, wood	7	6	Do.
No. 7:				
95 Cu, 5 Al	30 by 36, wood	5	7	Entirely failed; most of the cloth corroded away.
	30 by 36, Cu	5	7	Do.
	12 by 12, wood	4	10	Do.

TABLE 4.—*Condition of screen-wire materials after exposure at Portsmouth, Va., from Oct. 28, 1925 to May 1, 1934*

Screen material designation number and nominal composition	Type of frame and size (in inches)	Exposure time (up to first failure) Years	Months	Appearance at end of test
No. 1:				
90 Cu, 10 Zn	30 by 36, wood			Dark color; no holes.
	30 by 36, Cu			Do.
	12 by 12, wood			Do.
No. 2:				
80 Cu, 20 Zn	30 by 36, wood	4		Entirely failed; most of the cloth gone; very brittle.
	30 by 36, Cu	4	2	Failed from dezincification; dark color.
	12 by 12, wood	4	6	Do.
No. 3:				
75 Cu, 20 Ni, 5 Zn	30 by 36, wood			Material lost in storm.
	30 by 36, Cu			Dark color; no holes.
	12 by 12, wood			Do.
No. 4:				
70 Ni, 30 Cu. (approx.)	30 by 36, wood			Dark color; no holes.
	30 by 36, Cu			Do.
	12 by 12, wood			Partly lost in storm.
No. 5:				
Cu (unalloyed)	30 by 36, wood			Dark color; no holes.
	30 by 36, Cu			Do.
	12 by 12, wood			Material lost in storm.
No. 6:				
98 Cu, 2 Sn	30 by 36, wood			Frame failed after 4 years' exposure. Cloth in good condition.
	30 by 36, Cu			Dark color; no holes.
	12 by 12, wood			Do.
No. 7:				
95 Cu, 5 Al	30 by 36, wood			Dark color; no holes.
	30 by 36, Cu			Material lost in storm.
	12 by 12, wood			Dark color; no holes.

Figures 7 to 13 show the appearance of the seven materials after exposure at Pittsburgh. The 12- by 12-in. wood frames are used in these illustrations, except for material no. 5 which is in the 30- by 36-in. copper frame. This was the only frame in which the unalloyed copper had failed. To show more clearly the way corrosion had affected materials nos. 2 (80 copper, 20 zinc), 3 (75 copper, 20 nickel, 5 zinc), and 4 (70 nickel, 30 copper, approx.), two small pieces of each are shown in figures 14, 15, and 16. In each case one piece was rubbed and bent with the fingers to remove the corrosion products and show the brittleness and fineness of the wires. The products of corrosion are also shown in the photographs. A microscopic examination of the cross section of the wires of the several materials exposed at Pittsburgh showed that the corrosion penetrated the wires rather uniformly. The cores of the corroded wires appeared to be sound metal, except in material no. 2 (80 copper, 20 zinc), in which the zinc apparently had been removed from the copper, leaving the latter porous and brittle.

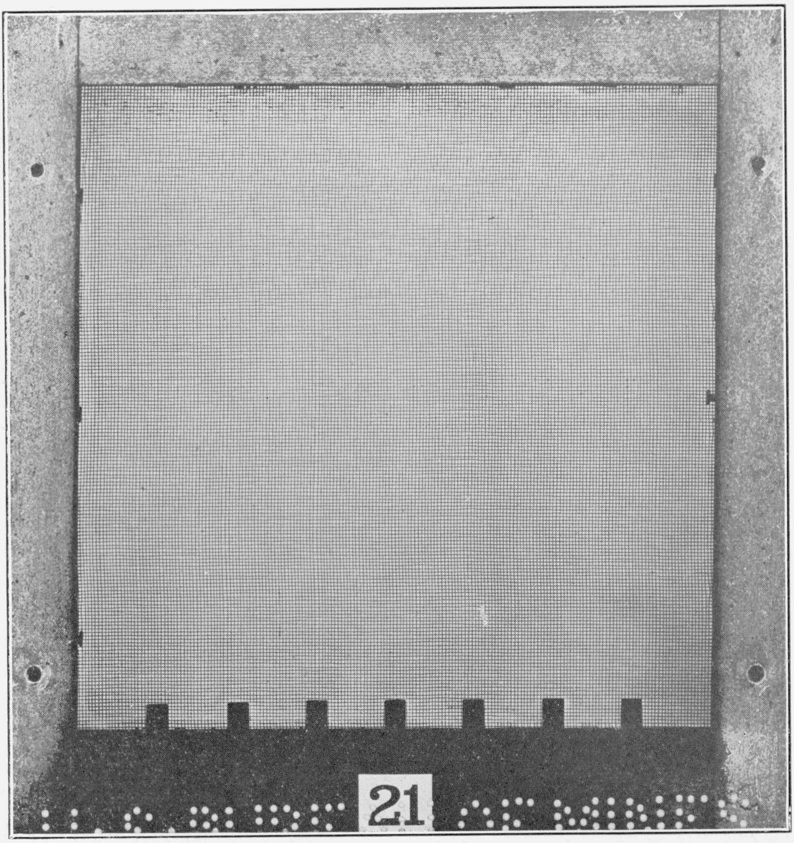

FIGURE 7.—*Appearance of material no. 1 (90 copper, 10 zinc) in the 12- by 12-inch wood frame after 9 years' continuous atmospheric exposure at Pittsburgh.*

A few of the wires near the top are corroded through. Photographs for figures 7 to 13 were furnished by the United States Bureau of Mines, Pittsburgh, Pa.

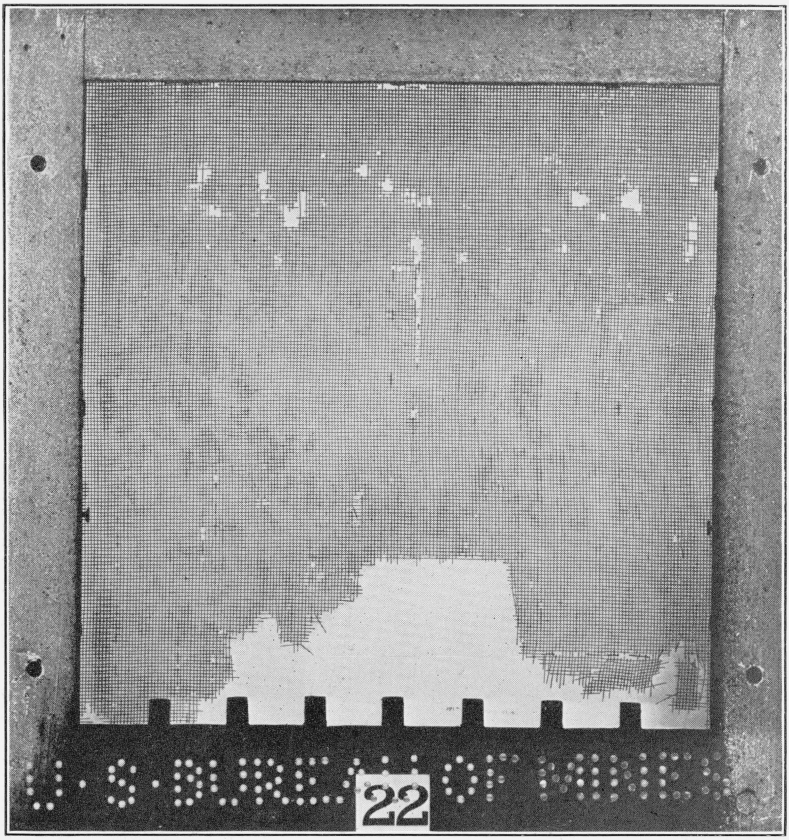

FIGURE 8.—*Appearance of material no. 2 (80 copper, 20 zinc) in the 12- by 12-inch wood frame after 9 years' continuous exposure at Pittsburgh.*

The material is badly corroded, very brittle, and has numerous holes.

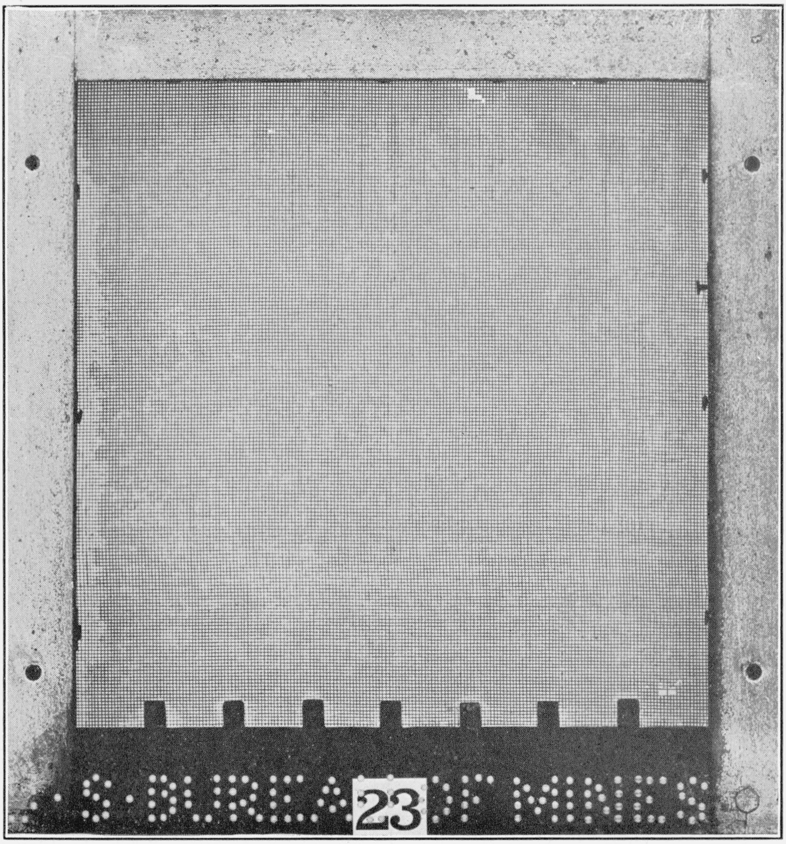

FIGURE 9.—*Appearance of material no. 3 (75 copper, 20 nickel, 5 zinc) in the 12- by 12-inch wood frame after 9 years' continuous exposure at Pittsburgh.*

The material is badly corroded and has a few holes near the top and bottom.

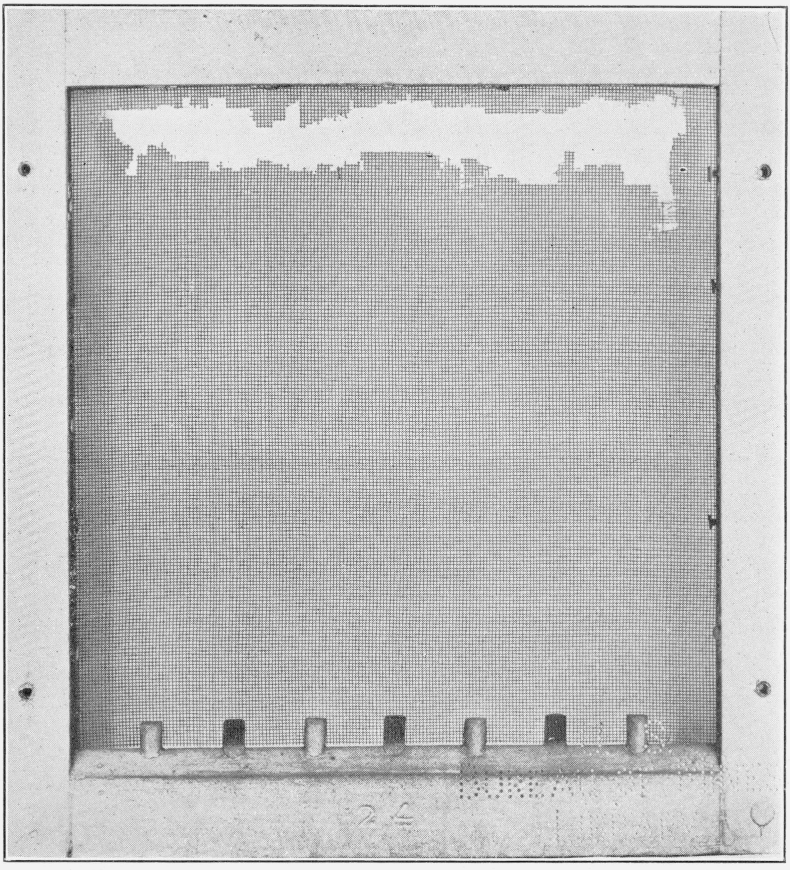

FIGURE 10.—*Appearance of material no. 4 (70 nickel, 30 copper, approximately) in the 12- by 12-inch wood frame after 4 years' continuous exposure at Pittsburgh.*

The material is badly corroded, with a considerable area near the top entirely gone.

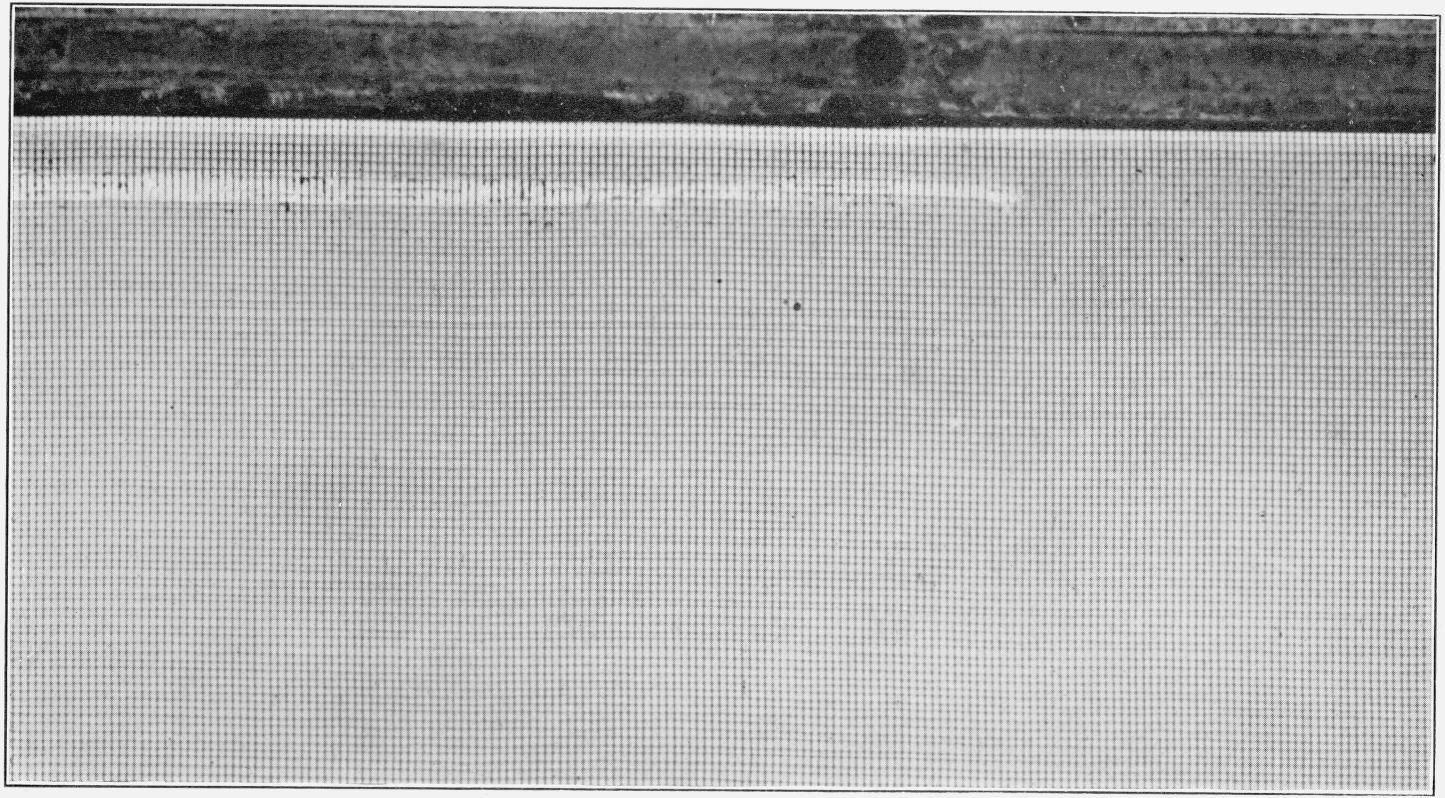

FIGURE 11.—*Appearance of material no. 5 (copper, unalloyed) from top of 30- by 36-inch copper frame after 9 years' continuous exposure at Pittsburgh,* × ⅔.

The wires near the top have corroded through in a number of places.

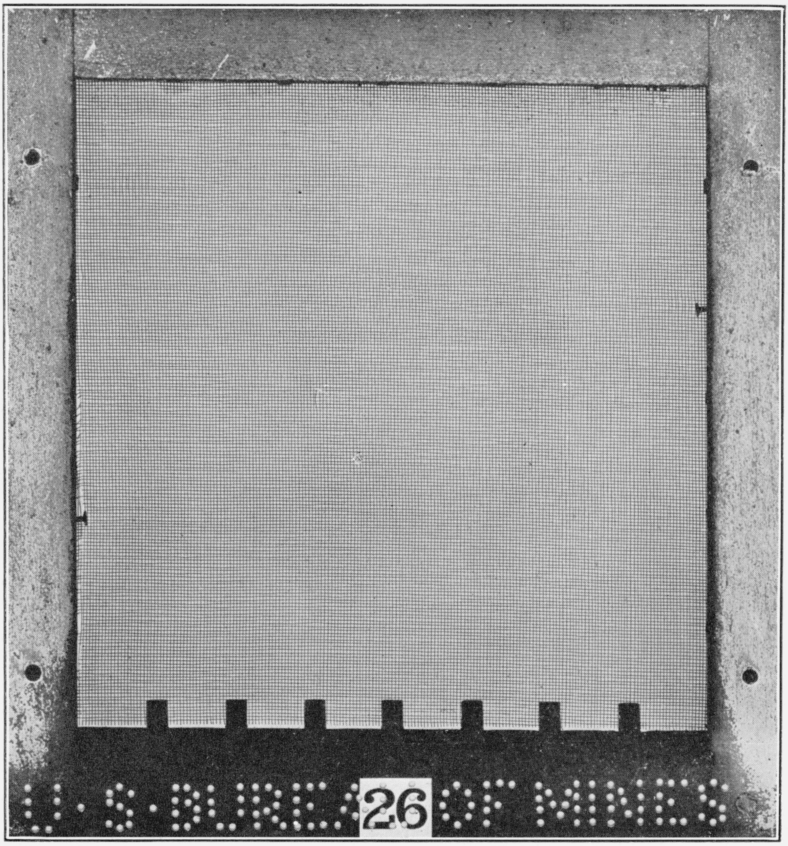

FIGURE 12.—*Appearance of material no. 6 (98 copper, 2 tin) in the 12- by 12-inch wood frame after 9 years' continuous exposure at Pittsburgh.*

A few of the wires at the top right corner are corroded through.

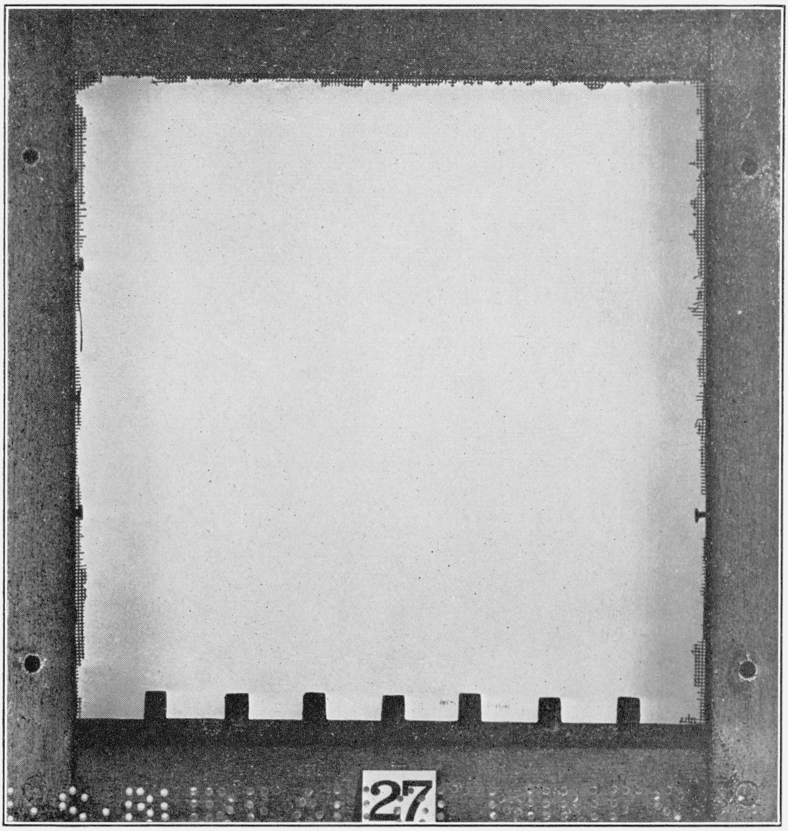

Figure 13.—*Appearance of material no. 7 (95 copper, 5 aluminum) in the 12- by 12-inch wood frame after 9 years' continuous exposure at Pittsburgh.*

The material was so badly corroded that the very little which remained was easily reduced to powder by rubbing between the fingers.

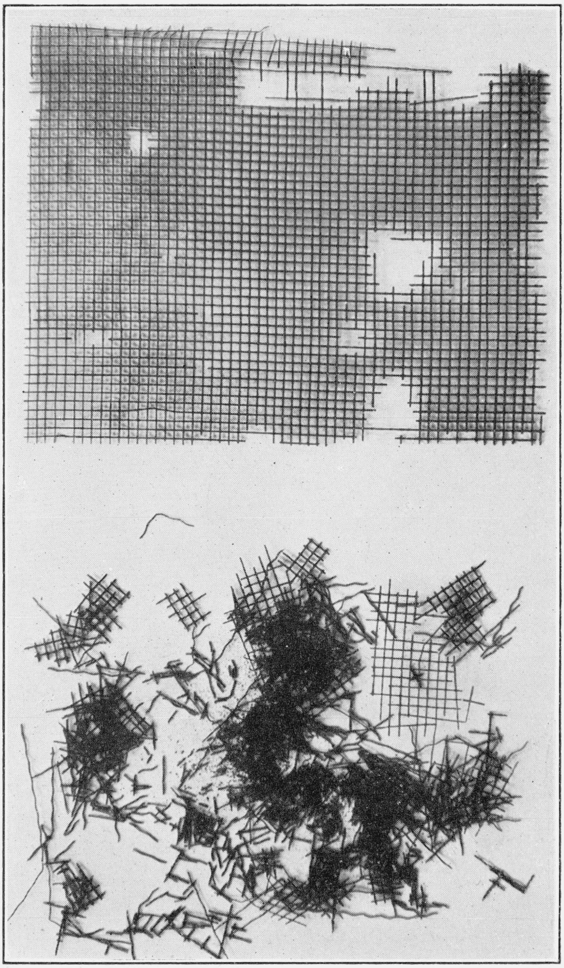

FIGURE 14.—*Two equal areas of material no. 2 (80 copper, 20 zinc) after 9 year's continuous atmospheric exposure at Pittsburgh.*

One of the pieces has been crushed in the hand to show the extreme brittleness of the material.

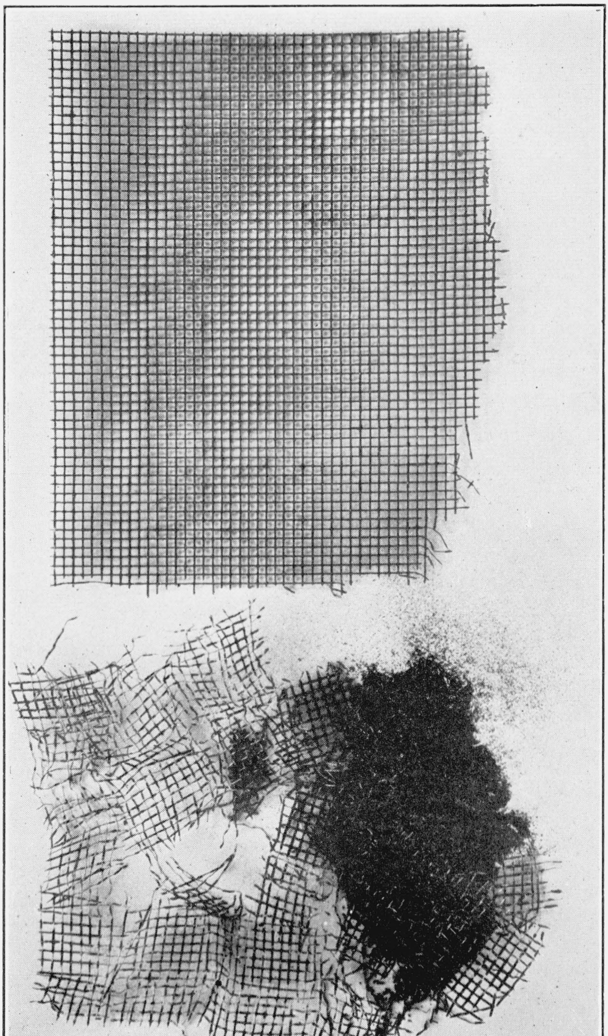

FIGURE 15.—*Two equal areas of material no. 3 (75 copper, 20 nickel, 5 zinc) after 9 years' continuous atmospheric exposure at Pittsburgh.*

One of the pieces has been crushed in the hand to show the extent of corrosion.

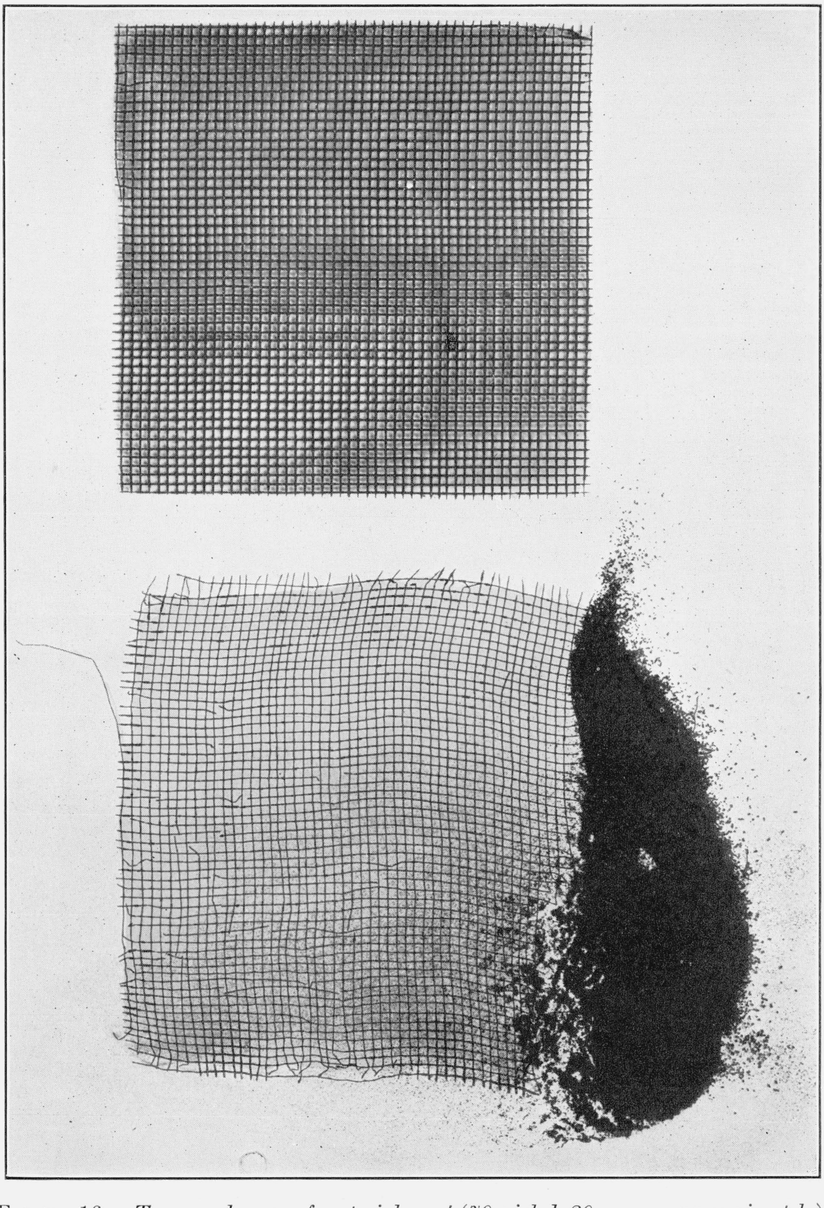

FIGURE 16.—*Two equal areas of material no. 4 (70 nickel, 30 copper, approximately) after 4 years' continuous exposure at Pittsburgh.*

One of the pieces has been rubbed between the fingers to show the extent of corrosion.

TABLE 5.—*Condition of materials after exposure at Cristobal, C. Z., from Nov. 16, 1925 to Jan. 19, 1935*

Screen material designation number and nominal composition	Type of frame and size (in inches) [a]	Exposure time up to first failure: Years	Exposure time up to first failure: Months	Appearance at end of test
No. 1: 90 Cu, 10 Zn	30 by 36, wood			Uniform dark color. Wires brittle; 1 bend to break.
	30 by 36, Cu			Do.
No. 2: 80 Cu, 20 Zn	30 by 36, wood	4	6	Considerable green patina on the fragments of cloth.
	30 by 36, Cu	About 5 years		Do.
No. 3: 75 Cu, 20 Ni, 5 Zn	30 by 36, wood			Dark color with greenish tinge, some wire enlarged with corrosion products. Two or three bends to break.
	30 by 36, Cu			Dark color with greenish tinge, some wire enlarged with corrosion products. Two or three bends to break. Damaged in handling.
No. 4: 70 Ni, 30 Cu (approx.).	30 by 36, wood			Dark color uniformly flecked with yellow. Tough; more than 12 bends to break wires.
	30 by 36, Cu			Do.
No. 5: Cu (unalloyed)	30 by 36, wood			Uniform dark color with scattered spots of brittle bluish-green vitreous-like material in a few of the openings.
	30 by 36, Cu			Uniform dark color with spots of copper salts deposited sparsely over this area. Some spots of salts segregated in several lines crossing each other at right angles. Very brittle at these points. Many wires would break when salts were picked off.
No. 6: 98 Cu, 2 Sn	30 by 36, wood			Uniform dark color with a few spots of salts scattered over the specimen, particularly along one vertical edge. Wires did not break when the salts were picked off. About 2 bends to break the wires. Greenish tinge.
	30 by 36, Cu			Uniform dark color with a few spots of salts scattered over the specimen, particularly along one vertical edge. Wires did not break when the salts were picked off. About 2 bends to break the wires. Greenish tinge. Torn along the bottom edge; probably caused in shipment.
No. 7: 95 Cu, 5 Al	30 by 36, wood			Uniform dark color with greenish tinge. Brittle; 1 bend to break wires.
	30 by 36, Cu			Uniform dark color with greenish tinge. Brittle; 1 bend to break wires. Torn along bottom edge; may have been caused in shipment.

[a] All the 12- by 12-in. specimens destroyed or lost after 4 years' exposure.

At Portsmouth, material no. 2 (80 copper, 20 zinc) failed in each of the three frames after 4- to 4½-years' exposure. The appearance was similar to that of the same material exposed at Pittsburgh (fig. 14). At Cristobal, this material also became brittle from dezincification and failed badly after 4½- to 5-years' exposure in the 30- by 36-in. wood and copper frames. A photograph of the material from the copper frame is shown in figure 17.

Material no. 5 (copper, unalloyed), exposed in the 30- by 36-in. copper frame at Cristobal for approximately nine years, showed two well-defined narrow bands of corrosion products extending across the screen at right angles to one another (fig. 18) and occasional spots of similar corrosion products distributed at random over the entire screen. Figure 19 shows a small area from one of the bands of corrosion products at higher magnification. When the deposits of corrosion products at these spots were picked off, the wires were found to be very thin, or corroded through as indicated by arrows 1 and 2 in figure 19. Arrow 3 indicates one of the larger deposits, under which the wire was found to be corroded through.

Material no. 6 (98 copper, 2 tin), exposed at Cristobal for approximately nine years, also was flecked with spots of corrosion products scattered more numerously over the upper than the lower half of the screen. The wires underneath the corrosion products were not greatly reduced in size and none was corroded through.

A distinct, uniformly greenish patina was formed on all the materials exposed at Cristobal, except material no. 4 (70 nickel, 30 copper, approx.), which was uniformly flecked with yellow. The patina was most pronounced on material no. 2 (80 copper, 20 zinc). No colored patina was noticeable on any of the materials exposed at Pittsburgh, Portsmouth, or Washington.

V. TENSILE STRENGTH OF MATERIAL BEFORE AND AFTER EXPOSURE

Specimens of the screen wire cloth for tensile tests were clipped from each of the frames containing sufficient material after the exposure period at Pittsburgh, Portsmouth, and Cristobal, and from the extra material exposed for this purpose at Washington. From each of the larger frames eight specimens were cut parallel to (longitudinal specimens) and six specimens perpendicular to (transverse specimens) the direction of weaving of the cloth. From the 12- by 12-in. frames four specimens were cut in each direction. Only two specimens in each direction were cut at this time from each of the materials exposed at Washington.

The specimens were 15 strands wide, with a central reduced section about 2½ in. long. The reduced section was made by clipping and removing two wires from each side at the midlength of the specimen. When tested, such specimens almost invariably broke in the midlength. The materials from some of the frames could not be tested because of loss during storms, failure of frames, or other reasons.

The averaged results of the tensile tests of specimens of the materials, before and after exposure for approximately nine years at Pittsburgh, Portsmouth, and Cristobal are shown in figures 20, 21, and 22. The value for the tensile strength of each of the uncorroded materials is the average for five specimens for each direction.

Materials nos. 2, 4, and 7 at Pittsburgh, and material no. 2 at Portsmouth and Cristobal, were either entirely gone, or so badly corroded at the end of the exposure period that the strength could not be measured.

At Washington, where no failures have occurred in any of the framed materials, tensile tests have been made at intervals through-

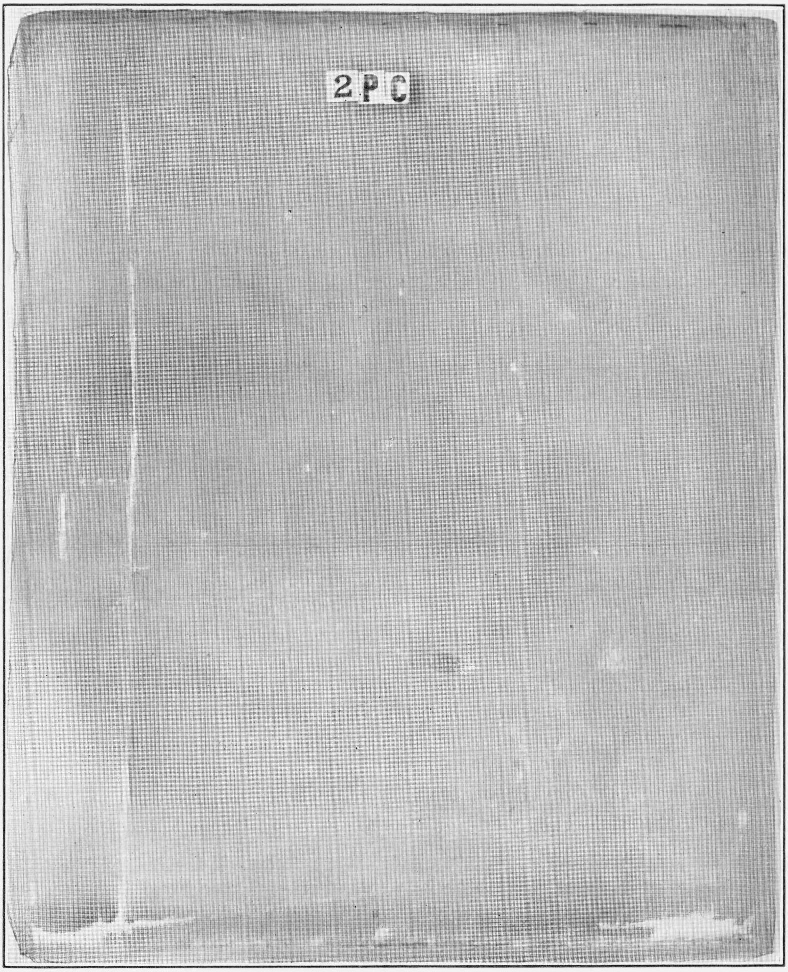

FIGURE 17.—*Appearance of material no. 2 (80 copper, 20 zinc) from the 30- by 36-inch copper frame after about 6 years' continuous exposure at Cristobal, C. Z.*

The material is extremely brittle and contains a great many holes.

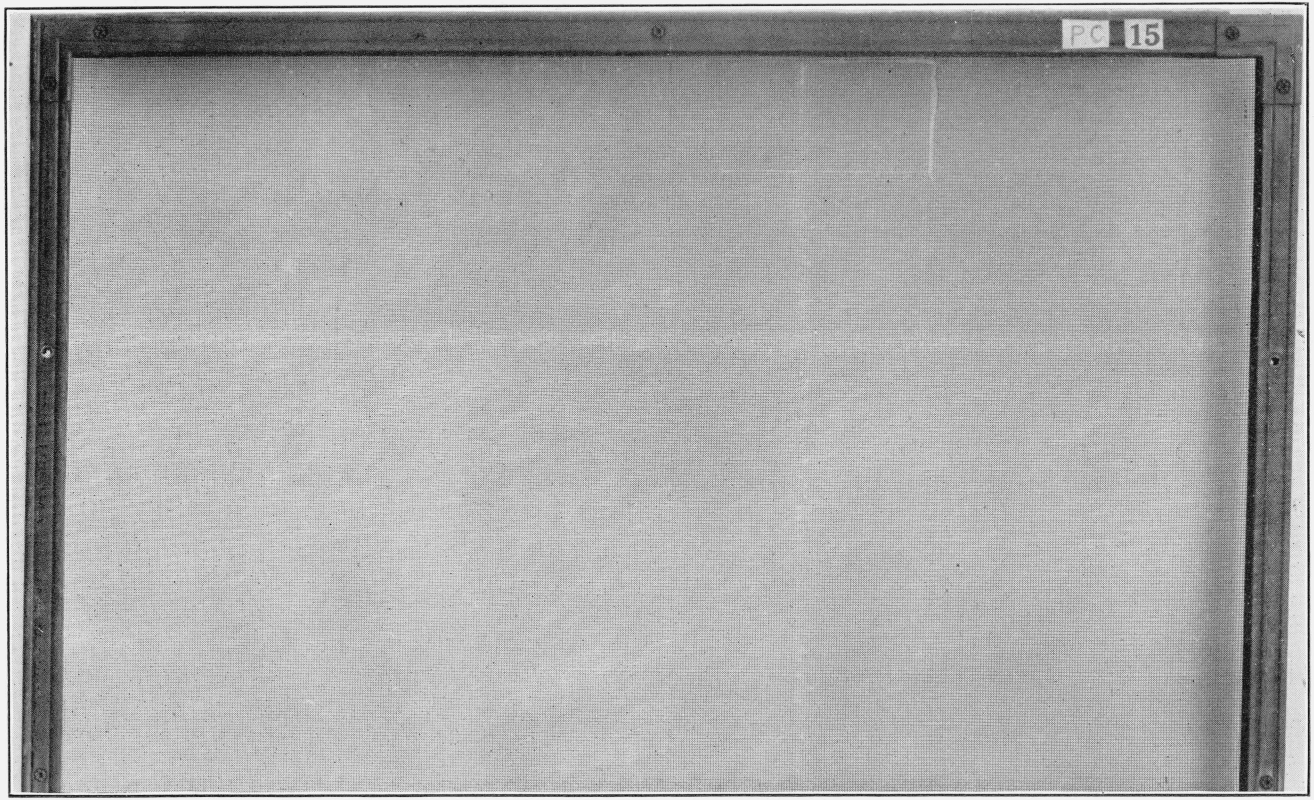

FIGURE 18.—*Appearance of the upper half of material no. 5 (copper, unalloyed) in the 30- by 36-inch copper frame after 9 years' continuous exposure at Cristobal.*

Note the two distinct bands of corrosion products extending across the screen at right angles to each other, and occasional spots of similar products which were distributed over the full specimen. The apparent tear near the top was made with shears.

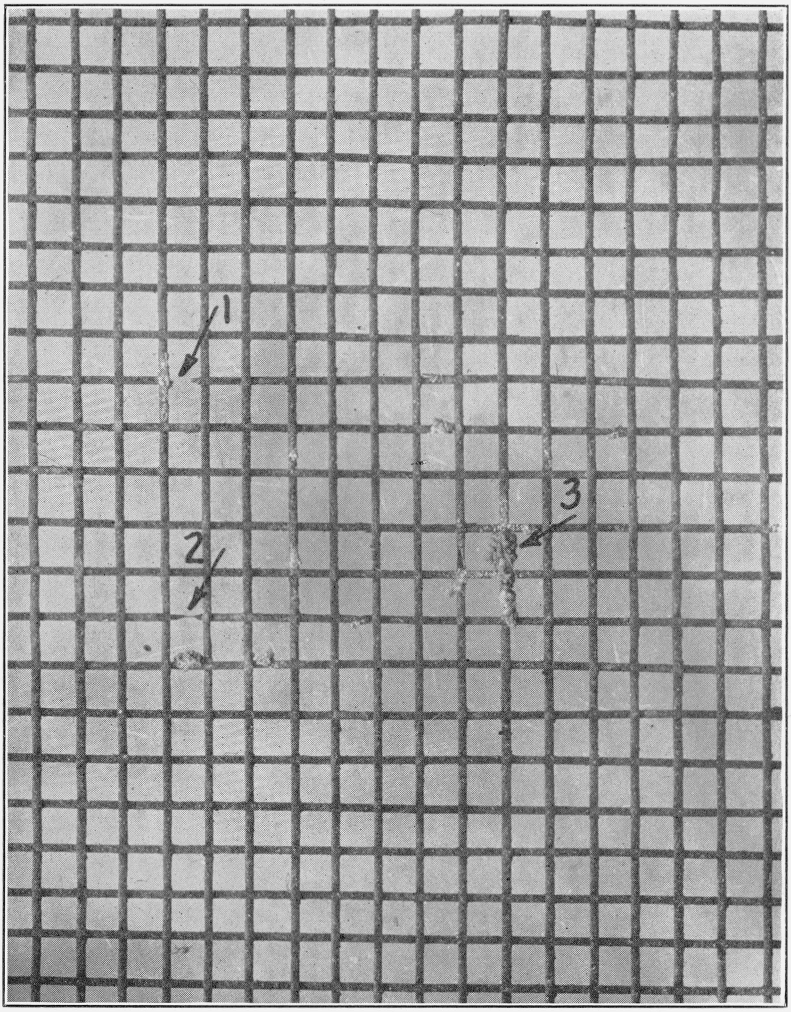

FIGURE 19.—*A small area from one of the bands of corrosion products shown in figure 18,* × *4.*

Arrows 1 and 2 show a broken and a thin wire, respectively, revealed by the removal of corrosion products. Arrow 3 indicates one of the larger deposits under which the wire was found to be corroded through.

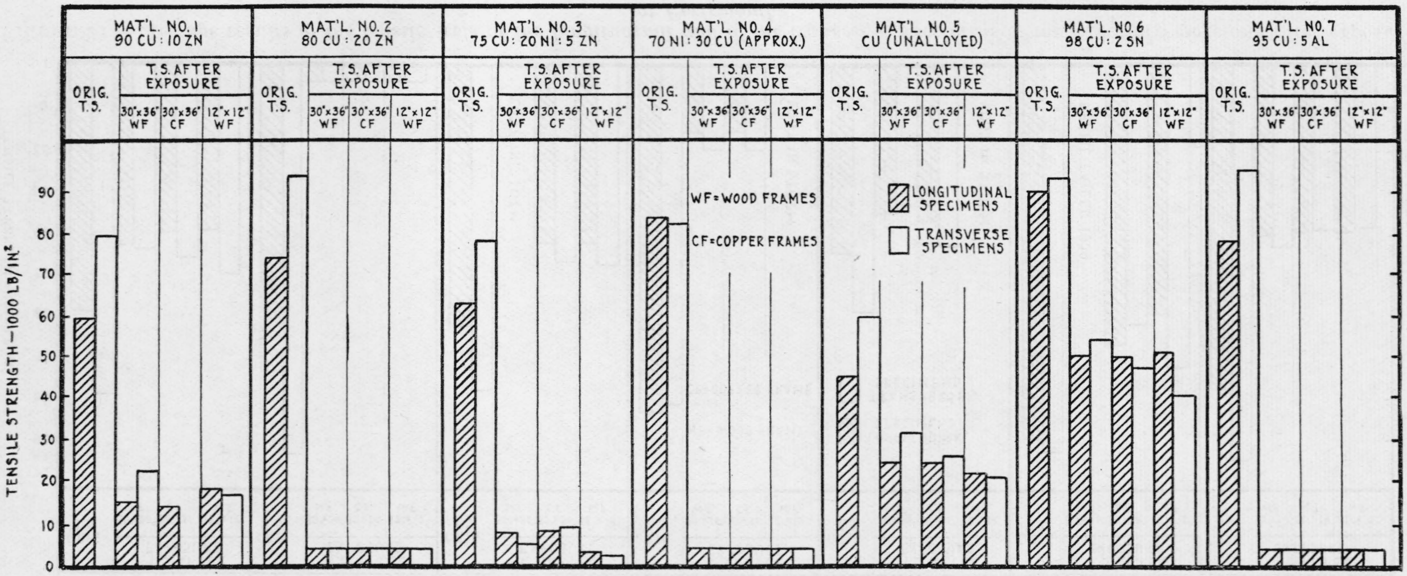

Figure 20.—*Average results of the tensile tests of the longitudinal and of the transverse specimens of the material before and after exposure at Pittsburgh.*

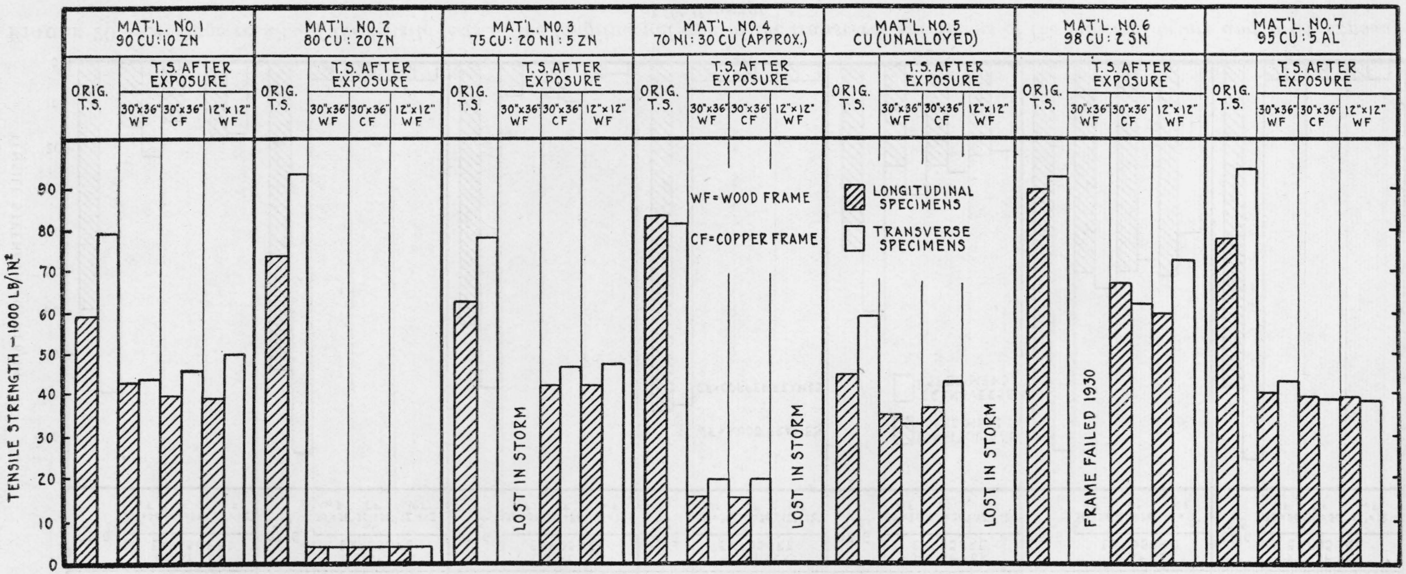

FIGURE 21.—*Average results of the tensile tests of the longitudinal and of the transverse specimens of the material before and after exposure at Portsmouth.*

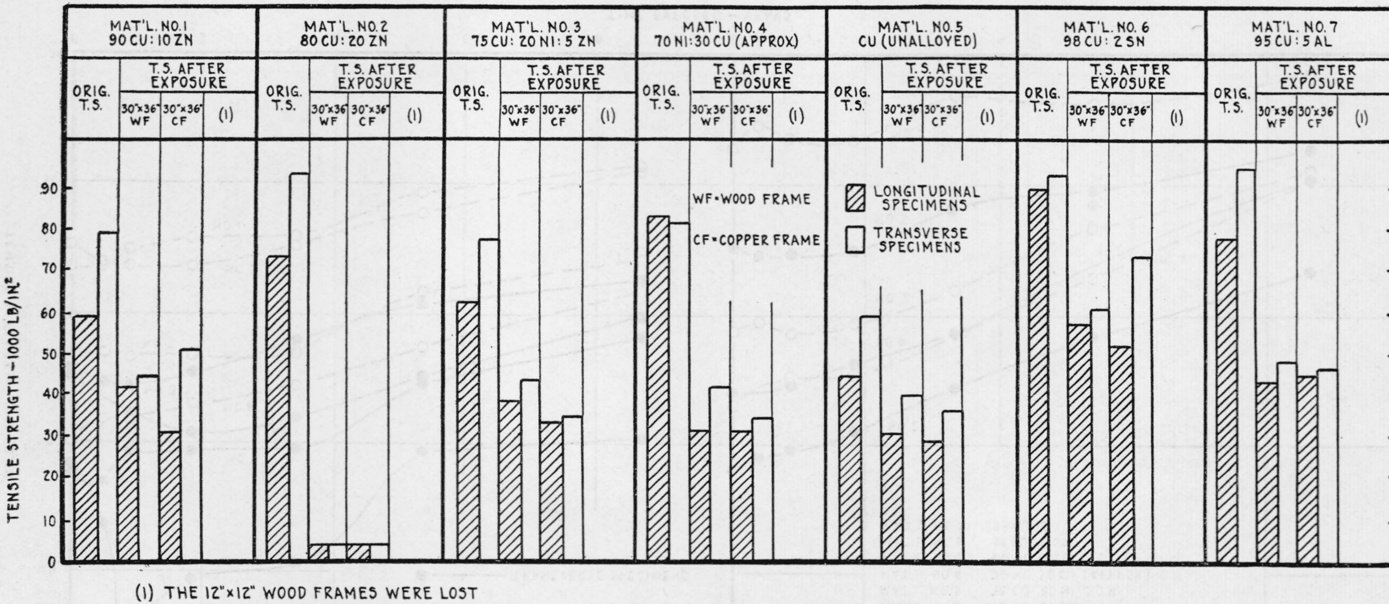

FIGURE 22.—*Average results of the tensile tests of the longitudinal and of the transverse specimens of the material before and after exposure at Cristobal.*

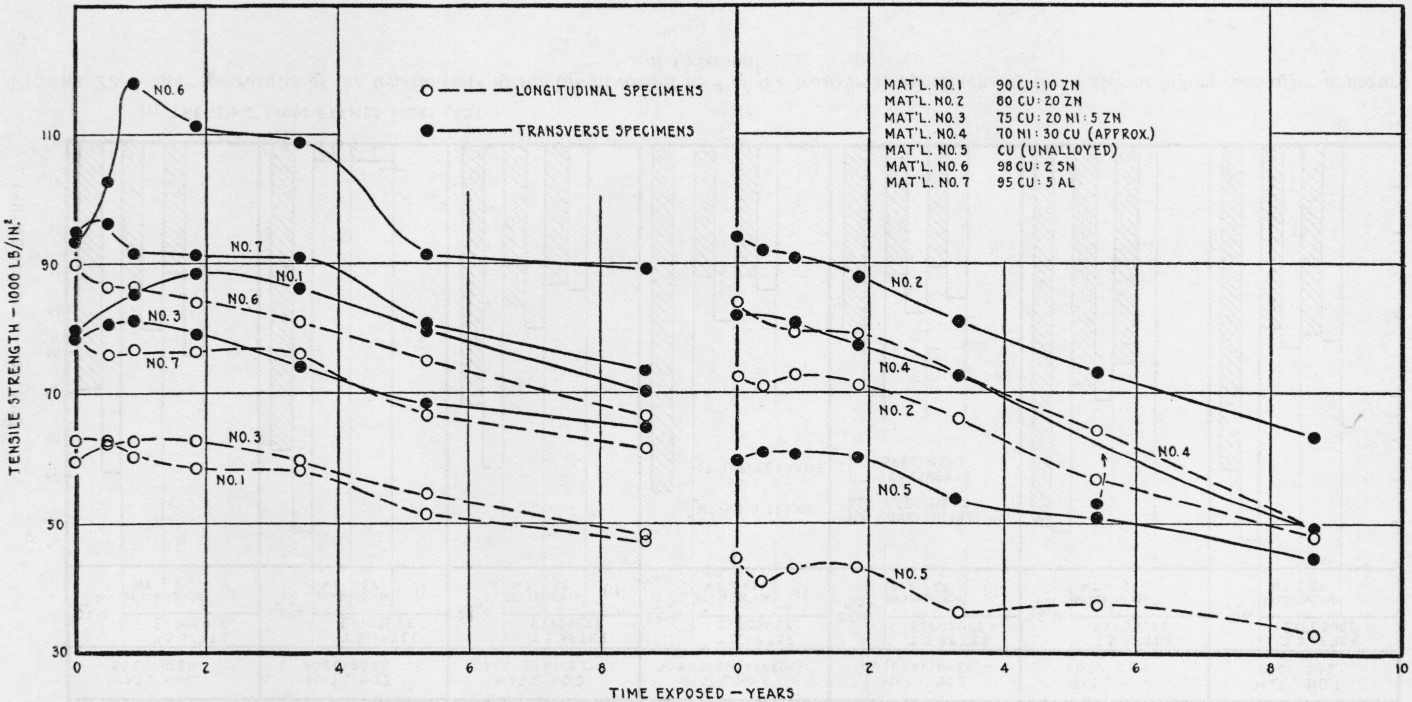

FIGURE 23.—*Results of tensile tests, at intervals throughout the exposure period, on longitudinal and transverse specimens of extra material exposed at Washington.*

out the nine-year exposure period on longitudinal and transverse specimens of the extra materials. The results are shown in figure 23. No explanation is suggested for the increased strength of the transverse specimens of materials nos. 1 and 6, during the early part of the exposure period.

The average tensile strength of each material, in its original condition and at the end of the exposure period, at each of the four stations, is shown in figure 24, the values given being the averages of the tensile strengths of the longitudinal and the transverse specimens.

The results of the laboratory accelerated-corrosion tests that had previously been made showed no consistent correlation with the results of the atmospheric-exposure tests at any of the locations.

The percentage loss of tensile strength after 500 hours' exposure to salt spray, and corresponding changes after approximately nine years' exposure at each of the four locations are given, for each material, in table 6. In table 7, the materials are listed, by designation numbers, in the order of increasing percentage loss of tensile strength after exposure at the four locations and in salt spray.

It is evident, from these tables, that the salt-spray test cannot be used as a basis on which to predict the behavior of the materials at the exposure stations. The same was true for the other laboratory tests. Likewise, the behavior of the materials could not be correlated with the results of the determinations of the sulphur-dioxide content of the atmosphere at the four locations.

TABLE 6.—*Percentage loss of tensile strength after approximately 9 years' exposure at the 4 locations; and after 500 hours in the salt spray* ([a])

Designation of material	Nominal composition	Percentage loss in tensile strength after exposure at—				
		Pittsburgh, Pa.	Portsmouth, Va.	Cristobal, C. Z.	Washington, D. C.	500 hours in salt spray
1	90 Cu, 10 Zn	75	37	39	16	74
2	80 Cu, 20 Zn	100	100	100	33	87
3	75 Cu, 20 Ni, 5 Zn	92	36	47	20	([b])
4	70 Ni, 30 Cu, (approx.)	100	90	59	43	10
5	Cu (unalloyed)	51	29	34	21	33
6	98 Cu, 2 Sn	47	28	32	13	23
7	95 Cu, 5 Al	100	54	48	22	41

[a] The data in this table were taken, for the four exposure stations, from figure 24; for the salt spray from figure 3.
[b] Negligible after 5,000 hours.

TABLE 7.—*Materials listed by designation numbers in the order of increasing percentage loss of tensile strength after exposure at the four locations and in the salt spray*

Locations				Salt spray
Pittsburgh, Pa.	Portsmouth, Va.	Cristobal, C. Z.	Washington, D. C.	
6	6	6	6	3
5	5	5	1	4
1	3	1	3	6
3	1	3	5	5
[a] 7	7	7	7	7
[a] 2	4	4	2	1
[a] 4	2	2	4	2

[a] Materials nos. 4, 2, and 7 failed completely in the following order: No. 4, first; no. 2, next; and no. 7 failed last.

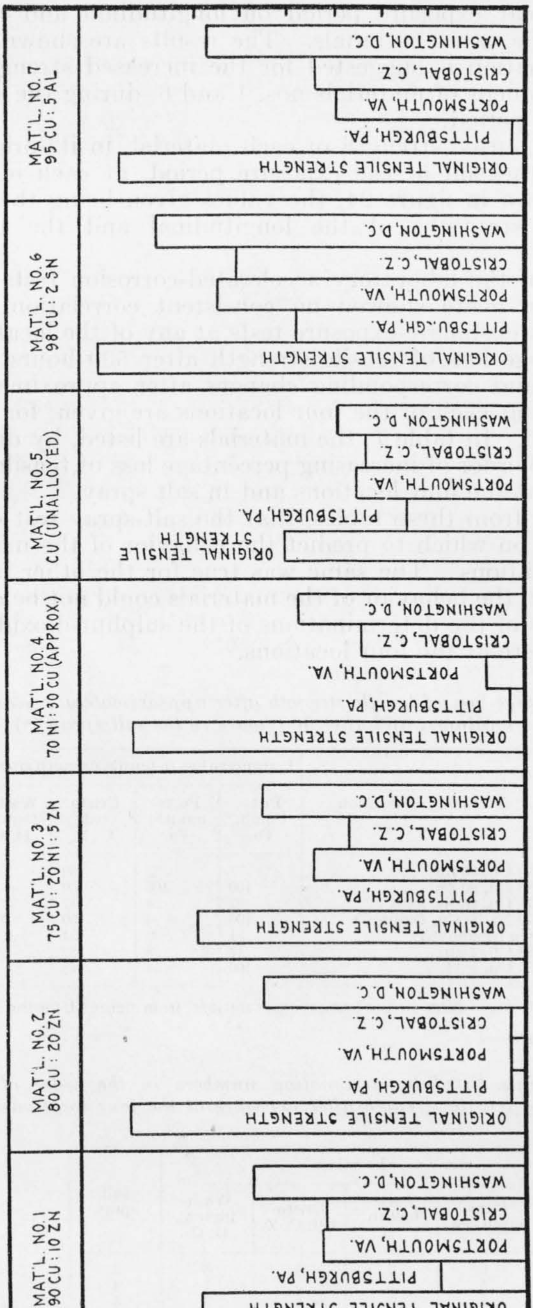

FIGURE 24.—*Average results of tensile tests on all specimens (both longitudinal and transverse) of each material before and after exposure at each of the four exposure locations.*

VI. SUMMARY

The National Bureau of Standards, in cooperation with the American Society for Testing Materials, has conducted atmospheric-exposure tests at Pittsburgh, Pa., Portsmouth, Va., Cristobal, C. Z., and Washington, D. C., on seven nonferrous screen wire materials of the following compositions: No. 1, 90 copper, 10 zinc; no. 2, 80 copper, 20 zinc; no. 3, 75 copper, 20 nickel, 5 zinc; no. 4, 70 nickel, 30 copper (approx.); no. 5, copper (unalloyed); no. 6, 98 copper, 2 tin; and no. 7, 95 copper, 5 aluminum.

When the test was terminated after approximately nine years' exposure, each material had failed at Pittsburgh in the following order: (1) no. 4, after four years; (2) no. 7, after four years ten months; (3) no. 2, after six years four months; (4) no. 3, after six years eleven months; and (5) nos. 1, 6, and 5 after seven years six months; the exposure being typical of a heavy-industrial atmosphere. Composition no. 2 had failed at Portsmouth, a temperate seacoast atmosphere with some industrial contamination, after four years, and at Cristobal, a tropical seacoast atmosphere with some industrial contamination, after four years, six months, while at Washington, typical of a mildly corrosive atmosphere, no failures had occurred.

The tensile strengths of the materials before and after exposure at the four stations were determined. Tables give the percentage loss in tensile strength after exposure and a list of the alloys by number in the order of increasing percentage loss in tensile strength. Alloys nos. 6 and 5 maintained their strength best at Pittsburgh, Portsmouth, and Cristobal; and nos. 6 and 1, at Washington.

The results of laboratory accelerated-corrosion tests previously made on the materials, which consisted in salt spray, and intermittent-immersion tests in salt solutions and dilute acids, were not consistent with the results of the exposure tests at any of the locations and could not have been used to predict the behavior of the material in service.

WASHINGTON, April 24, 1935.