Atmospheric Corrosion Investigation of Aluminum-Coated, Zinc-Coated, and Copper-Bearing Steel Wire and Wire Products

A Twenty-Year Report

Occasione/Britton/Collins

ASTM STP 585A

ATMOSPHERIC CORROSION INVESTIGATION OF ALUMINUM-COATED, ZINC-COATED, AND COPPER-BEARING STEEL WIRE AND WIRE PRODUCTS: A TWENTY-YEAR REPORT

Sponsored by
ASTM Committee A-5 on
Metallic-Coated Iron
and Steel Products

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NOTE

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Foreword

Committee A-5 on Metallic-Coated Iron and Steel Products[1] was organized in 1907, to investigate the corrosion of iron and steel. In 1908, the Committee sponsored its first atmospheric exposure of metallic-coated wires to evaluate their corrosion resistance. Since this date, there have been a considerable number of test programs involving wire, sheet, and hardware. Of particular interest is the program initiated in 1936 and reported on in ASTM Special Technical Publication 290 entitled "Twenty-Year Atmospheric Corrosion Investigation of Zinc-Coated and Uncoated Wire and Wire Products" by Fred M. Reinhart.

In June 1959, the Advisory Committee on Corrosion authorized Committee A-5 to conduct atmospheric corrosion tests of aluminum coated wire and wire products at seven ASTM sites in the United States (see map on next page) and an eighth site in Warrington, England. The responsibility for the latter site was assumed by Rylands Whitecross Limited.

Exposure of the wire and wire products specimens was initiated in 1961. For comparative purposes bare copper-bearing steel wire and zinc-coated steel wire and fabricated products were included in the testing program.

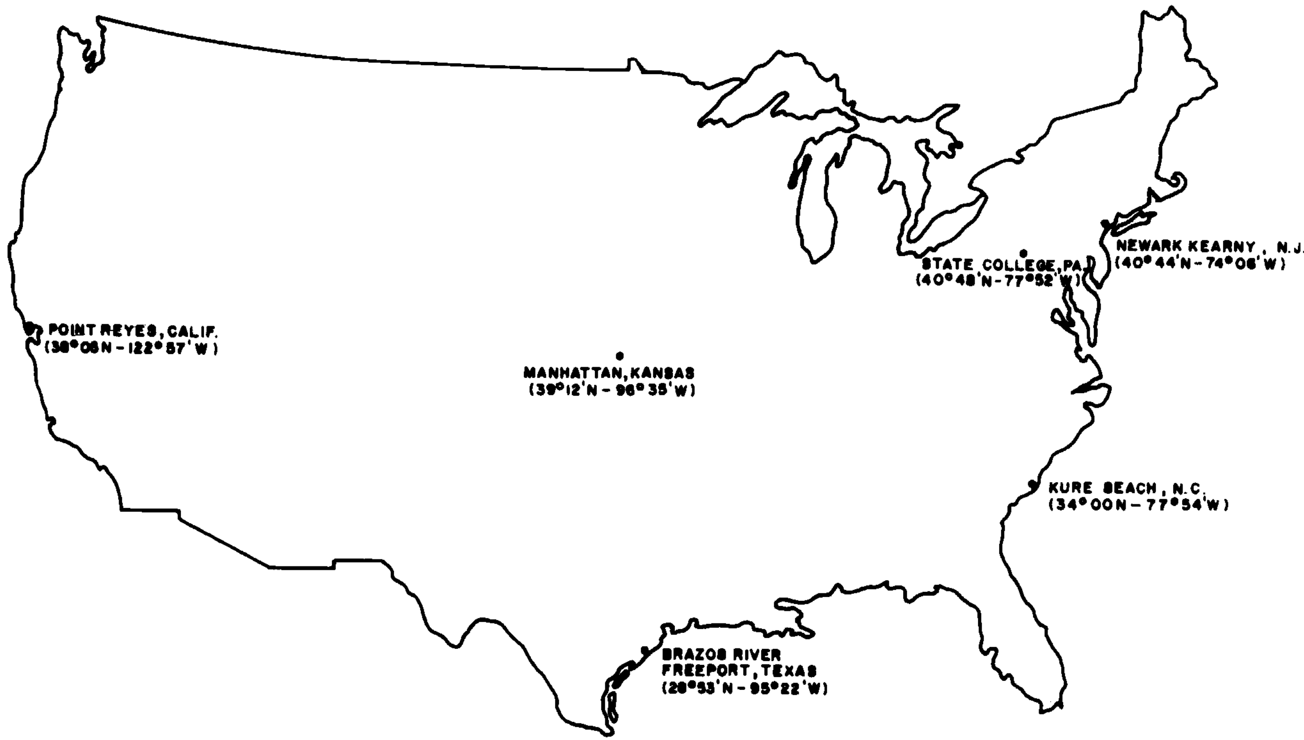
A twelve year report on the 1961 exposure program entitled ASTM STP 585 "Atmospheric Corrosion Investigation of Aluminum-Coated, Zinc-Coated, and Copper-Bearing Steel Wire and Wire Products" by V. I. Kelley was published in 1975.

This report presents the results of 20 years of exposure for the 1961 exposure program, and was prepared by John F. Occasione,[2] Thomas C. Britton, Jr.,[3] and Roy C. Collins.[3]

[1]Committee A-5 was originally titled "Corrosion of Iron and Steel."

[2]Retired in 1975 after 41 years with American Steel and Wire, Cleveland, Ohio and the U.S. Steel Corp., Pittsburgh, Pa., in various metallurgical positions.

[3]Duke Power Company, Charlotte, N.C. 28242.



MAP - LOCATION OF TEST SITES IN THE UNITED STATES

A Note of Appreciation to Reviewers

The quality of this publication reflects not only the obvious efforts of the authors but also the unheralded, though essential, work of the reviewers. On behalf of ASTM we acknowledge with appreciation their dedication to high professional standards and their sacrifice of time and effort.

ASTM Committee on Publications

Related ASTM Publications

Corrosion of Metals in Association with Concrete, STP 818 (1983), 04-818000-27

Atmospheric Corrosion of Metals, STP 767 (1982), 04-767000-27

Corrosion of Reinforcing Steel in Concrete, STP 713 (1980), 04-713000-27

Corrosion Fatigue Technology, STP 642 (1978), 04-642000-27

Brief Summary of Results

The wire and wire product specimens were exposed at the seven U.S. sites in the spring and summer of 1961 and at Warrington, England on 1 March, 1964. There were 340 unfabricated tension test specimens exposed at each of four sites. To date, 276 have been removed and tested. Wire product specimens (field fence, barbed wire, chain-link fence, and 7-wire strand) were exposed at all eight sites.

The hot dipped aluminum-coated specimens ranged from 0.08 to 0.19 kg/m^2 (0.27 to 0.63 oz/ft^2) of surface, and the aluminum powder metallurgy clad specimen ranged from 0.54 to 1.39 kg/m^2 (1.76 to 4.54 oz/ft^2) of surface. The hot dipped zinc coatings ranged from 0.11 to 0.86 kg/m^2 (0.36 to 2.81 oz/ft^2) of surface, and the electroplated zinc coatings ranged from 0.27 to 0.91 kg/m^2 (0.87 to 2.98 oz/ft^2) of surface.

The corrosion rate of the coatings to initial rust on aluminum-coated unfabricated wires ranged from 0.01 kg/m^2 (0.03 oz/ft^2) per year at the Newark, New Jersey, site to 0.02 kg/m^2 (0.07 oz/ft^2) per year at the Warrington, England, site. In general the corrosion rates of the coatings to initial rust on aluminum-coated fabricated product specimens was within this range at all locations. The corrosion rate of the coatings to initial rust on the zinc-coated unfabricated wire ranged from 0.02 kg/m^2 (0.06 oz/ft^2) per year at State College, Pennsylvania, to 0.06 kg/m^2 (0.20 oz/ft^2) per year at Warrington, England. The corrosion rates of the coatings to initial rust on zinc-coated fabricated products varied considerably from a low of 0.01 kg/m^2 (0.03 oz/ft^2) per year at the Manhattan, Kansas, site to a high of 0.12 kg/m^2 (0.38 oz/ft^2) per year at the Kure Beach, North Carolina, 80 ft site.

The loss in breaking strength over the 20-year period varied considerably from a high in excess of 60% for uncoated and lightly zinc-coated wires exposed at Warrington to some slight gain in strength for some of the heavier aluminum-coated specimens. In general, the aluminum-coated wires sustained less loss in strength than the zinc-coated wires.

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Contents

FIGURES

Scope of A-5 and Authorization

The scope of Committee A-5 on Metallic-Coated Iron and Steel Products is quoted as "The collection of engineering information relating to the serviceability of both bare and metallic-coated iron and steel products when subject to corrosion and the formulation of methods of tests and specifications, and work on related subjects." Subcommittee A05.15 is responsible for tests on the atmospheric corrosion of wire and wire products, be they bare or metallic-coated.

With the June 1959 authorization from the Advisory Committee on Corrosion, Subcommittee A05.15, Wire Tests, organized a task group composed of the following:

E. G. Baker, Steel Co. of Canada
B. A. Beery, Page Steel and Wire Division, American Chain and Cable Co., Inc.
W. W. Bradley, Bell Telephone Labs, Inc.
R. S. Dalrymple, Reynolds Metals Co.
O. B. Ellis, Armco Steel Corp.
E. T. Englehart, Aluminum Co. of America
P. M. Emmons, R. E. A.
H. H. Hormann, Consolidated Edison of New York
J. B. Horton, Bethlehem Steel Co.
R. B. Koontz, National Standard Co.
J. B. Kopec, Keystone Steel and Wire Co.
T. A. Lowe, Kaiser Aluminum and Chemical Corp.
J. F. Murphy, Olin Mathieson Chemical Corp.
F. M. Reinhart, U. S. Naval Engineering Lab
Jane H. Rigo, U. S. Steel Corp.
T. A. Schneider, J. A. Roebling's Sons Division
C. W. Straitor, Detroit Edison Co.
C. E. Topping, Consumers Power Co.
L. C. Whitney, Copperweld Steel Co.

Seven producers contributed the aluminum-coated steel wire test samples for the exposure program. These producers were: Bethlehem Steel Co., Copperweld Steel Co., Keystone Steel and Wire Co., National Standard Co., Page Steel and Wire Division, J. A. Roebling's Sons Division, and U.S. Steel Corp. Copper-bearing steel and zinc-coated steel wires were also provided for comparative purposes. Southern Electrical Co., Division of Olin Mathieson Chemical Corp., contributed to the program in the stranding of the steel-reinforced aluminum conductors. Preformed Line Products Co. supplied the dead-end fittings used in the test installations of high-strength strand and steel-reinforced aluminum conductors.

Fabricated items were exposed at eight exposure sites. At four of the sites, unfabricated wires were also exposed. Five types of fabricated wire products are under test. These are barbed wire, chain-link fencing, field fence, high-strength steel wire strand, and steel-reinforced aluminum conductor. The latter two products are referred to as "7-wire strand" in this document. The relative corrosion resistance of the various test items in the several atmospheres will be established by visual inspection of the unfabricated and fabricated wire items and by periodic determination of percentile loss in breaking strength of the 3.760 and 2.515 mm (0.148 and 0.099-in.) unfabricated wires.

Test Plan

The test plan involved the exposure of specimens representing the following:

1. *Unfabricated Wires*—Evaluation by visual observation and by loss in breaking strength
   Number of replicates: 20
   Test length: 990.6 mm (39 in.)
   Materials
   (*a*) Bare copper-bearing steel wire 3.760 mm (0.148 in.) diameter
   (*b*) Zinc-coated steel wire 3.760 mm (0.148 in.) diameter
      Hot dipped
      Electroplated
   (*c*) Aluminum-coated steel wire 3.760 mm (0.148 in.) diameter
      Hot dipped
      Powder metallurgical technique
   (*d*) Aluminum-coated steel wire 2.515 mm (0.099 in.) diameter
      Hot dipped
      Powder metallurgical technique
2. *Fabricated Wire Products*—Evaluation by visual observation
   Number of replicates: 1
   Test length: 3.05 m (10 ft)
   Materials
   (*a*) Field fence—two sizes: 939-6-11 and 939-6-9
      Zinc-coated steel wire—Hot dipped-two coating weight classes
      Aluminum-coated steel wire—Hot dipped
   (*b*) Barbed wire—12½ gage: Lyman 4-point
      Zinc-coated steel wire—Hot dipped-two coating weights
      Aluminum-coated steel wire—Hot dipped-three coating weights-two wires have aluminum barbs
   (*c*) Chain-link fence—1219.2 mm (48 in.), 9 gage, 50.8 mm (2 in.) mesh, barbed top, knuckled bottom
      Zinc-coated steel wire
         Hot dipped-two coating weights
         Electroplated-two coating weights
      Aluminum-coated steel wire
         Hot dipped-two coating weights

(*d*) High-strength strand

Zinc-coated steel wire—Electroplated 9.525 mm (3/8 in.) diameter, 7 wire 3.048 mm (0.120 in.)-two coating weights

Aluminum-coated steel wire—Various processes, 9.525 mm (3/8 in.) diameter, 7-wire 3.048 mm (0.120 in.), and 7.9375 mm (5/16 in.) diameter, 7-wire, 2.642 mm (0.104 in.)

Range of coating weights

(*e*) Steel reinforced aluminum conductors

Zinc-coated, electroplated steel core wire and aluminum coated steel wire—Various processes. Seven aluminum coated wire strands [1.9609 mm (0.0772 in.)] one zinc-coated steel strand [2.6137 mm (0.1029 in.)] Conventional stranding and compacted strand.

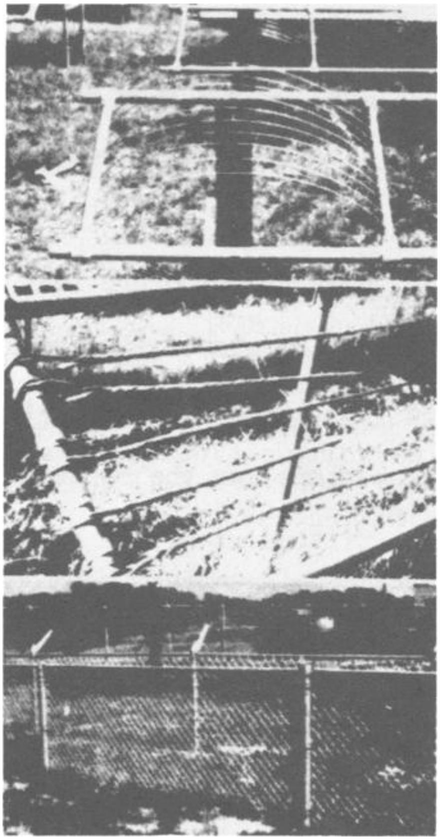
3. *Placement of Specimens*—Figure 1 (*top, center,* and *bottom*) depicts the manner in which the unfabricated wire and fabricated wire products are exposed at the several atmospheric test sites. In all instances precautions are taken to eliminate dissimilar metal contact.

In Fig. 1 (*top*) the unfabricated test wires are racked in groups of 10 on the standard ASTM pipestand by insertion into predrilled 38.1 mm (1½ in.) diameter aluminum rounds. Prior to insertion into the aluminum rounds both ends of the wire were dipped in an adhesive, EC 1099 (product of Minnesota Mining and Manufacturing Co.). The aluminum rounds are installed at center-to-center distance of approximately 1016 mm (40 in.) to accommodate the coil set of the test wires. Each round was predrilled with holes of prescribed diameters to a 6.35 (¼ in.) depth at 51 mm (2 in.) centers.

Figure 1 (*center*) shows the exposure test setup for the high-strength steel strands and the steel reinforced aluminum conductors. Braces of 31.75 mm (1¼ in.) galvanized pipe are drilled at 76 mm (3 in.) centers for the strand and at 95.25 mm (3¾ in.) centers for the conductors. The test strands and conductors are outfitted at either end of the test lengths with galvanized or aluminum dead ends, depending upon the contact metal involved.

Field fence and chain-link fencing are erected on suitably finished fence posts as shown in Fig. 1 (*bottom*). The barbed wire specimens are also shown mounted on appropriately finished cross arms, the aluminum in contact with aluminum-coated steel and the zinc-coated fittings in contact with zinc-coated steel. Since these samples were installed by professional erectors, they are tensioned to the degree normally encountered in service.

4. *Test Locations and Exposure Sites*—Table 1 lists the exposure sites, the assigned site numbers, for future reference, the exposure dates, and the type of product, that is, fabricated or unfabricated. The type of atmosphere at each location is classified in accordance with that set forth in the 1958 Report of the Advisory Committee on Corrosion. The three major types are industrial, marine, and rural. A brief description of each site follows.



(*top*)	Unfabricated wire
(*center*)	Strand (7 wire)
(*bottom*)	Chain-link and farm-field fence

FIG. 1—*Aluminum-coated steel wire, strand, and chain-link and field fence erected at the test sites.*

State College, Pennsylvania

This rural site was established in 1925 and is located one mile north of State College, Pennsylvania [elevation 358 m (1175 ft)]. The specimens are mounted 30 deg from the horizontal and face southeast at an azimuth of 147 deg.

Newark, New Jersey—Newark-Kearny, New Jersey

This severe industrial test site was established in 1956 to replace the Port Authority test site. The specimens are mounted at an angle of 30 deg from the

TABLE 1—*Exposure sites.*[a]

Exposure Site, Number, and Location	Type of Atmosphere	Exposure Date	Products Exposed
1. Brazos River, Tex.	marine	17 July 1961	fabricated
2. Kure Beach, N.C. (80 ft)	marine beach exposure	22 May 1961	fabricated
3. Kure Beach, N.C. (800 ft)	marine east coast	23 May 1961	fabricated and unfabricated
4. Manhattan, Kans.	rural	19 July 1961	fabricated
5. Newark, Kearny, N.J.[b]	industrial	12 June 1961	fabricated and unfabricated
6. Point Reyes, Calif.	marine west coast	21 July 1961	fabricated
7. State College, Pa.	rural	19 June 1961	fabricated and unfabricated
8. Warrington, England[c]	industrial	1 March 1964	fabricated and unfabricated

[a] Information concerning these exposure sites follows.
[b] Specimens moved to Kearny, N.J., on 2 July 1970.
[c] Warrington, England, site closed April 1977.

horizontal and face the south southwest at an azimuth of 193 deg [elevation 3 m (11 ft)]. On 2 July, 1970, the wire specimens were taken to a new test site known as Newark-Kearny, New Jersey, on the grounds of Kearny Generation Station at Public Service Electric and Gas Company.

Point Reyes, California

Point Reyes test site was established in 1950 and is located 588 m (1930 ft) from the Pacific Ocean behind low hills covered with salt grass and bushes. The specimens are mounted at an angle of 30 deg from the horizontal and face due west, toward the Pacific Ocean. The atmosphere here is characterized by salt spray and condensation exposure due to westerly winds, dense fogs, and heavy rains which keep the specimens moist during most of the winter. In summer the area is very dry by day with frequent heavy fogs at night.

Kure Beach, North Carolina

The two exposure sites at Kure Beach are under the direction of the International Nickel Co. and are located on the Cape Fear Peninsula 17 miles southeast of Wilmington, North Carolina. One test site is approximately 243 m (800 ft) and the other approximately 24 m (80 ft) from the Atlantic Ocean. The specimens are mounted 30 deg from the horizontal and face south at an azimuth of 177 deg at the 800 ft site. At the 24 m (80 ft) site, the specimens parallel the beach at an azimuth of 110 deg. The 24 m (80 ft) site is characterized by seawater spray falling directly on the test specimens.

Freeport, Texas (Brazos River)

In 1952, a test site was established on the Brazos River 1188 m (3900 ft) northwest of the Gulf of Mexico. The specimens are mounted at 30 deg from the horizontal and face southeast (azimuth of 144 deg). The climate in this area is noted for its consistently high humidity. The daytime relative humidity varies between 85 and 93% in the summer and averages 80% in the winter. The night-time humidity is also 100% all year with frequent heavy dews.

Manhattan, Kansas

This rural site is located in an agricultural area with very little industrial contamination. It is a continental climate with relatively large diurnal and annual temperature ranges. There is abundant sunshine as compared to the eastern United States. The elevation is approximately 335 m (1100 ft) above sea level. The annual average rain fall is 851 mm (33.52 in.).

Warrington, England

This industrial site is located on the recreation grounds at Rylands-Whitecross Ltd. at an elevation of 8.5 m (28 ft) above sea level. The location is at 53 deg-24.2′N latitude and 2 deg-34.5′ W longitude. The prevailing wind is south westerly blowing from the town over the site. The exposure racks run from east to west and face south. The town has a diversified industry which includes wire production, light and heavy engineering, hot-rolled steel products, board and paper mills, chemical processing, and extensive brewing. The average (annual) sulfur dioxide (SO_2) contamination for the years 1964 through 1973 was 0.065 ppm. The more recent years indicate a 50% reduction of SO_2 from the earlier annual figures.

Description of the Test Specimens

The following information was provided by each manufacturer for the unfabricated and fabricated wire products which each supplied:

(*a*) General description of the coating process.
(*b*) Chemical analysis of the base metal and metallic coating.
(*c*) Weight of metallic coating.
(*d*) Mechanical properties of the unfabricated wires.
(*e*) Minimum and maximum coating thicknesses as measured microscopically.
(*f*) Cross-sectional photomicrograph to illustrate structure of coating only.

Most of the descriptive information which was supplied by the several manufacturers was accepted without rechecking by disinterested parties. Only the coating weights and mechanical properties were rechecked, and any discrepancies were resolved.

General descriptions of the coating processes for the test wires are summarized in Table 2. According to these descriptions the zinc-coated steel wires were processed by conventional hot dip or electrolytic methods. Aluminum-coated steel wires prepared by processes 1, 2, 4, and 5 were coated by passage through a molten bath of aluminum or an aluminum-silicon alloy. Except for two processes, 1 and 6, the steel wires were chemically fluxed prior to passage through the molten bath of coating metal. Process 3 utilizes a powder metallurgical technique.

TABLE 2—*Process description-preparation of test wires.*

Specimen	Description	Coating Process
	BARE STEEL	
	copper bearing, steel hard drawn	
	ZINC-COATED STEEL	
2,24,25,27,28,32,33	hot dipped	cleaned steel wire coated in a molten bath of zinc
3,4,34,35,39,40,46,52	electrolytic	cleaned steel wire electroplated in a zinc sulfate bath using insoluble anodes
	ALUMINUM-COATED STEEL	
9,11,17,26,29,37,42,49,55	process 1	fluxless molten aluminum-coated method employing vibratory technique on precleaned wire
5,6,41,48,54	process 2	cleaned steel wire immersed in aqueous flux solution, dried, dipped in silicon-bearing aluminum bath
8,21,45,47,53	process 3	powdered aluminum is applied to a steel core to produce a composite rod which is subsequently cold drawn to size
7,19,51,57,58	process 4[a]	straight-line, hot-dip method
10,12,18,20,30,31,38,43,50, 56,59	process 5	prefluxed in aqueous solution of fluoride salt and dipped in molten aluminum bath
13,36	process 6	continuous fluxless hot-dip process
22,44	process 7	heavy coating applied by patented process

[a]Specimens manufactured by process 4 were dropped from the program after 5 years because the manufacturer informed that the wire was no longer commercially available from process 4.

Table 3 reports the chemical analyses of the base metal for all test specimens, unfabricated and fabricated. A review of these steel analyses shows the carbon content of the base metal for aluminum coating in a molten bath to be significantly higher than for comparable zinc-coated wire. Starting with a higher carbon content for the aluminum-coated steel wire compensates for the greater reduction in tensile strength which is caused by a higher operating temperature for an aluminum bath as compared to a molten zinc bath. The operating temperature for an aluminum bath ranges from 649 to 704°C (1200 to 1300°F) whereas the operating temperature of a zinc bath varies from 427 to 482°C (800 to 900°F).

Low, medium, and high-carbon steel analyses are represented among the unfabricated wires. Aluminum Conductor Steel Reinforced (ACSR) core wires and high-strength steel strand are high-carbon products, while barbed wire and field fence are essentially low-carbon products. Base metal analyses classifies the zinc-coated chain-link fencing as a steel product of lower carbon content than the aluminum-coated steel chain-link fencing. The latter utilized steels of medium carbon content.

The reported coating weights are tabulated next and indicate the range of coating weights observed for the electrolytic and hot dip zinc coatings, and for the two types of aluminum coatings.

	Zinc,[a] oz/ft^2		Aluminum, oz/ft^2	
Specimen	Hot Dipped	Electroplated	Hot Dipped	Powder Metallurgy
Unfabricated, 9 gage	0.50	0.99, 2.84	(light weight) 0.27 (heavy weight) 0.48 to 0.63	2.44
12½ gage			0.21, 0.29, 0.37, 0.43	1.76, 3.36
ACSR core		0.87	0.30, 0.34, 0.43, 0.45	1.92
Barbed wire	0.43, 0.97	...	0.25, 0.39	...
Chain link	1.77, 2.81	1.53, 2.23	0.44, 0.54, 0.57	...
Field fence	0.36, 0.42, 0.49, 0.99	...	0.27, 0.38, 0.43	...
High-strength strand	...	0.99, 2.98	0.32, 0.33, 0.43, 0.49	2.26, 4.54

[a] 1 oz/ft^2 = 0.30 kg/m^2.

The heavier zinc coatings were deposited by the electrolytic method as opposed to the hot dip method. The aluminum coatings deposited by passage

TABLE 3—*Base metal analysis of unfabricated and fabricated wires.*

Specimen	Coating	Carbon, %	Manganese, %	Phosphorus, %	Sulfur, %	Silicon, %	Copper, %
9 GAGE 3.76 MM (0.148 IN.) UNFABRICATED TEST WIRE							
No. 1	...	0.09	0.34	0.010	0.026	0.01	0.23
No. 2	Zn	0.08	0.50	0.010	0.021	0.16	0.03
No. 3	Zn	0.04	0.44	0.013	0.032	0.01	0.14
No. 4	Zn	0.05	0.34	0.012	0.033	0.01	0.09
No. 5	Al	0.07	0.45	0.014	0.03	0.01	0.10
No. 6	Al	0.72	0.75	0.015	0.033	0.22	0.14
No. 7[a]	Al	0.06	0.41	0.006	0.035	0.103	0.28
No. 8	Al	0.44	0.81	0.020	0.013	0.21	0.02
No. 9	Al	0.29	0.82	0.011	0.026	0.23	0.03
No. 10	Al	0.23	0.48	0.013	0.042	0.007	...
No. 11	Al	0.22	0.91	0.012	0.019	0.01	...
No. 12	Al	0.26	0.51	0.014	0.046	0.023	...
No. 13	Al	0.25	0.44	0.010	0.027	0.19	0.07
12-1/2 GAGE 2.515 MM (0.099 IN.) UNFABRICATED TEST WIRE							
No. 17	Al	0.18	0.41	0.010	0.027	0.01	0.03
No. 18	Al	0.08	0.49	0.012	0.25	0.005	...
No. 19[a]	Al	0.07	0.41	0.006	0.032	0.103	0.32
No. 20	Al	0.12	0.58	0.012	0.031	0.005	...
No. 21	Al	0.06	0.27	0.034	0.010	0.010	0.03
No. 22	Al	0.72	0.90	0.013	0.024	0.22	...
ACSR CORE WIRE							
No. 46,52	Zn	0.66	1.04	0.012	0.032	0.14	0.14
No. 47,53	Al	0.56	0.86	0.021	0.018	0.19	0.02
No. 48,54	Al	0.84	0.74	0.015	0.028	0.15	0.11
No. 49,55	Al	0.82	0.92	0.010	0.032	0.28	trace
No. 50,56	Al	0.80	0.70	0.013	0.034	0.132	...
No. 51,57[b]	Al	0.85	0.73	0.011	0.023	0.19	0.10
LYMAN 4 POINT BARBED WIRE, 12-1/2 GAGE LINE WIRE							
No. 27	Zn	0.10	0.38	0.012	0.021	0.16	0.03
No. 28	Zn	0.08	0.40	0.010	0.025	0.16	0.03
No. 29	Al	0.17	0.40	0.010	0.026	0.01	0.03
No. 30	Al	0.08	0.49	0.012	0.025	0.005	...
No. 31	Al	0.12	0.58	0.012	0.031	0.005	...
9 GAGE 50.8 MM (2 IN.) CHAIN-LINK FABRIC							
No. 32	Zn	0.10	0.59	0.015	0.037	0.13	0.08
No. 33	Zn	0.08	0.38	0.013	0.028	0.18	0.03
No. 34	Zn	0.14	0.38	0.013	0.026	0.01	0.06
No. 35	Zn	0.17	0.41	0.013	0.027	0.02	0.03
No. 36	Al	0.23	0.53	0.008	0.025	0.18	0.08
No. 37	Al	0.29	0.81	0.011	0.030	0.22	0.03
No. 38	Al	0.23	0.48	0.013	0.042	0.007	...

(continued)

TABLE 3 (*Continued*)

Specimen	Coating	Carbon, %	Manganese, %	Phosphorus, %	Sulfur, %	Silicon, %	Copper, %
			FARM-FIELD FENCE				
No. 24 line (9 gage)	Zn	0.11	0.43	0.011	0.032	0.19	0.03
No. 24 line (11 gage)	Zn	0.09	0.44	0.010	0.024	0.16	0.03
No. 24 stay (11 gage)	Zn	0.08	0.39	0.015	0.015	0.20	0.07
No. 25 line (9 gage)	Zn	0.11	0.34	0.015	0.026	0.20	0.07
No. 25 stay (9 gage)	Zn	0.11	0.37	0.014	0.027	0.21	0.10
No. 26 line (9 gage)	Al	0.21	0.86	0.013	0.022	0.01	0.10
No. 26 line (11 gage)	Al	0.21	0.83	0.012	0.022	0.01	0.08
No. 26 stay (11 gage)	Al	0.07	0.45	0.010	0.020	0.01	0.03
			9.53 MM (3/8 IN.) 7-WIRE STRAND				
No. 39	Zn	0.55	0.91	0.013	0.026	0.17	0.07
No. 40	Zn	0.54	0.95	0.003	0.023	0.14	0.07
No. 41	Al	0.60	0.61	0.020	0.028	0.14	0.06
No. 43	Al	0.79	0.84	0.010	0.024	0.11	...
No. 44	Al	0.65	0.89	0.010	0.017	0.09	...
No. 45	Al	0.45	0.81	0.02	0.013	0.21	0.03
No. 58[b]	Al	0.77	0.66	0.010	0.026	0.15	0.12
			7.935 MM (5/16 IN.) 7-WIRE STRAND				
No. 42	Al	0.82	0.80	0.024	0.034	0.22	0.07
No. 59	Al drawn[b]	0.75	0.88	0.013	0.026	0.15	...

[a] Specimens dropped after 5 years (See footnote *a* under Table 2).
[b] Drawn after coating.

through a molten bath were substantially lighter than those deposited by the powder metallurgical technique. The range for the hot-dip aluminum coatings was 0.06 to 0.19 kg/m^2 (0.21 to 0.63 oz/ft^2) as compared to 0.54 to 1.39 kg/m^2 (1.76 to 4.54 oz/ft^2) for the other type aluminum coating.

Coating Data

The weights and analyses of the coating metals as well as minimum and maximum coating thicknesses are recorded in Figs. 2 through 7. The coating thicknesses were determined microscopically. Photomicrographs of the wire's cross-sectional area are also given to illustrate the structure of the metallic coating.

In Figs. 2 through 7 coating analyses of the zinc coatings for iron range from a trace of iron for the electrolytically deposited coatings to a maximum of 15% iron for the hot dip coatings. Steel wires which were coated with essentially pure aluminum by a hot dip or a powder metallurgical technique showed an iron content of less than 1% in the outer portion of the coating. Wires which were aluminum-coated in siliconized-aluminum baths had iron contents in the outer portion of the coatings in excess of 1%. In these instances, the overall range in iron content was 1 to 5%. Aluminum-coated steel specimen Nos. 7, 19, 51, 57, and 58, where the entire coating weight of aluminum was analyzed for iron instead of the outer portion, had iron contents ranging from approximately 8.75% iron for a 3 to 4% siliconized-aluminum coating to an excess of 20% for a siliconized-aluminum coating of approximately 1% silicon. However, as previously noted (see footnote *a* under Table 2) these specimens were dropped from the program after 5 years.

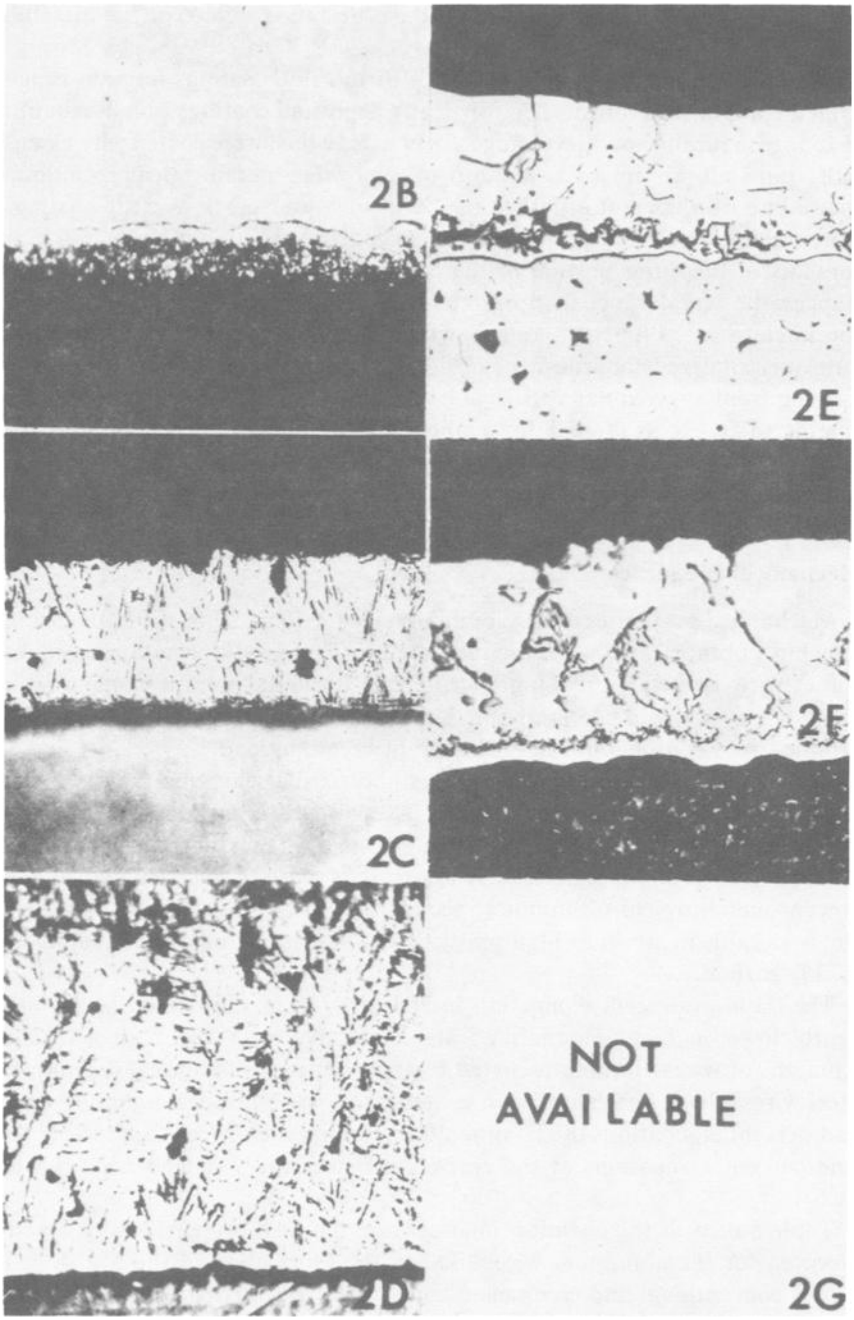
Mechanical Properties

Mechanical properties of the nominally sized 3.76 and 2.51 mm (0.148 and 0.099 in.) unfabricated wires are tabulated in Table 4. Information listed includes wire diameter, breaking load, tensile strength, percent elongation in 254 mm (10 in.), and percent reduction in area. Determinations on corroded samples were confined to establishment of breaking load.

The zinc-coated steel wire specimens had tensile strengths ranging from 399 895 to 599 844 kPa (58 000 to 87 000 psi). All aluminum-coated wires which were coated by passage through a molten bath except for Specimen No. 6 had tensile strength significantly lower than those of wires coated by the powder metallurgical technique (Specimens Nos. 8, 21, and 22). Specimen No. 6 was able to attain its high-tensile strength by utilizing a steel analysis of 0.72% carbon.

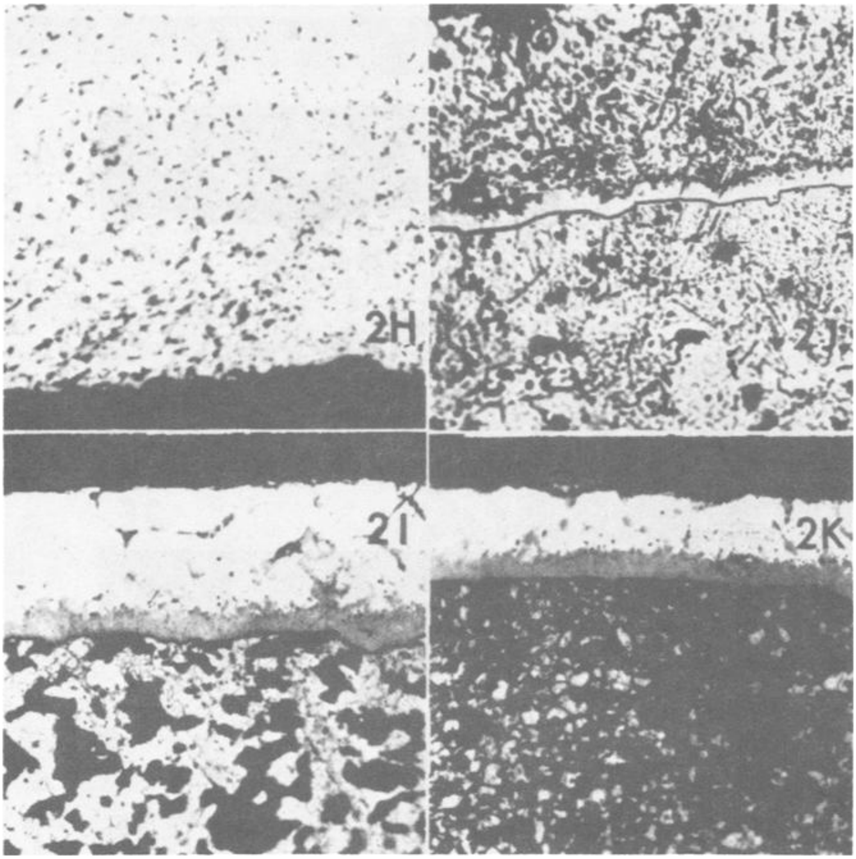
The data on percent elongation in 254 mm (10 in.) indicate that significantly lower percent elongations are associated with the higher tensile strengths of wires aluminum-coated by the powder metallurgical technique. Steel wires which were aluminum coated by passage through a molten bath had percent elongations in 254 mm (10 in.) which varied from 5.8 to 15.7%. The percent elongations of the zinc-coated steel wires ranged from 5.8 to 11.6%.

Table 5 records the chemical analyses and physical properties which were reported for the aluminum wires used in the fabrication of the No. 4, 7/1 ACSR conventional and compacted conductors. Also listed for comparative purposes are the specified values which aluminum wire must meet for this application.



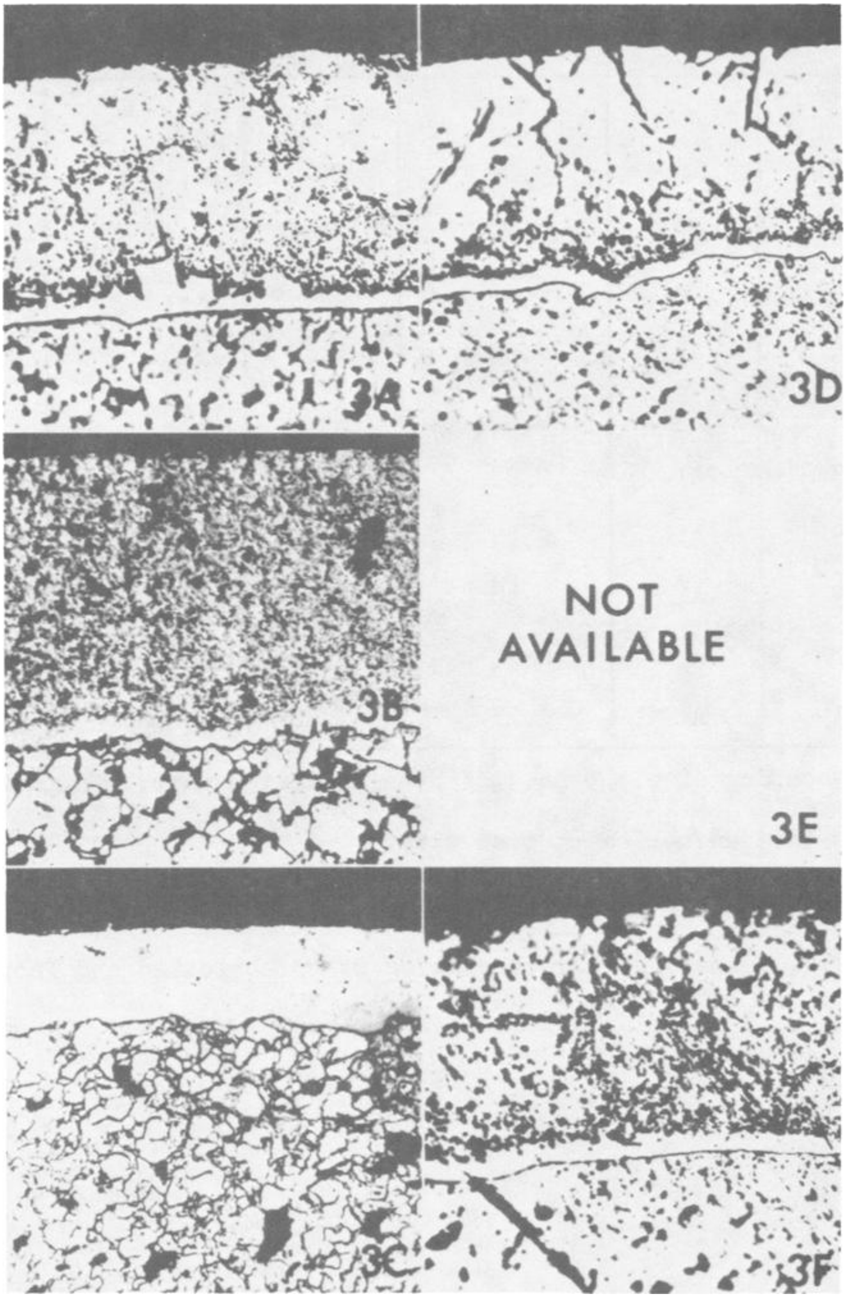
(All photomicrographs magnified ×500 except as noted)

FIG. 2—*Coating characteristics of unfabricated and fabricated wire.*



			Coating				
				Analysis, %		Thickness, mil	
Figure	Code	Metal	Weight,[c] oz/ft^2	Iron	Silicon	min	max
2A[a]	1						
2B[b]	2	Zn	0.50	10	...	0.54	0.84
2C[b]	3	Zn	0.99	trace	...	1.58	1.76
2D[b]	4	Zn	2.84	trace	...	4.42	4.62
2E[b]	5	Al	0.52	4.10	1.70	0.65	4.07
2F[b]	6	Al	0.54	2.80	1.90	0.96	2.94
2G[b]	7	Al	0.27	22.31	1.10	0.80	2.30
2H[b]	8	Al	2.44	0.084	0.005	8.80	11.5
2I[b]	9	Al	0.48	2.52	2.82	0.97	3.06
2J[b]	10	Al	0.51	1.50	2.81	0.78	2.59
2K[b]	11	Al	0.27	1.30	2.96	0.60	2.36

[a] Plain copper-bearing steel; 9 gage 3.76 mm (0.148 in.) unfabricated wire. No photomicrograph.
[b] 9 gage 3.76 mm (0.148 in.) unfabricated test wire.
[c] 1 $oz/ft^2 = 0.30 kg/m^2$.



(All photomicrographs magnified ×500 except as noted)

FIG. 3—*Coating characteristics of unfabricated and fabricated wire.*

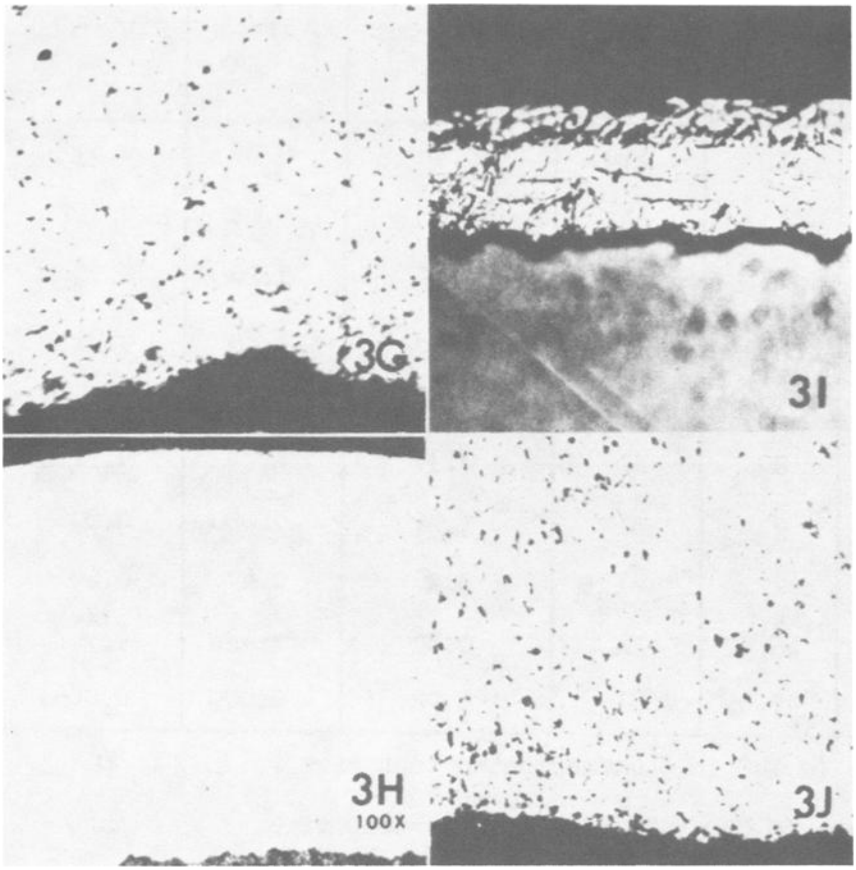
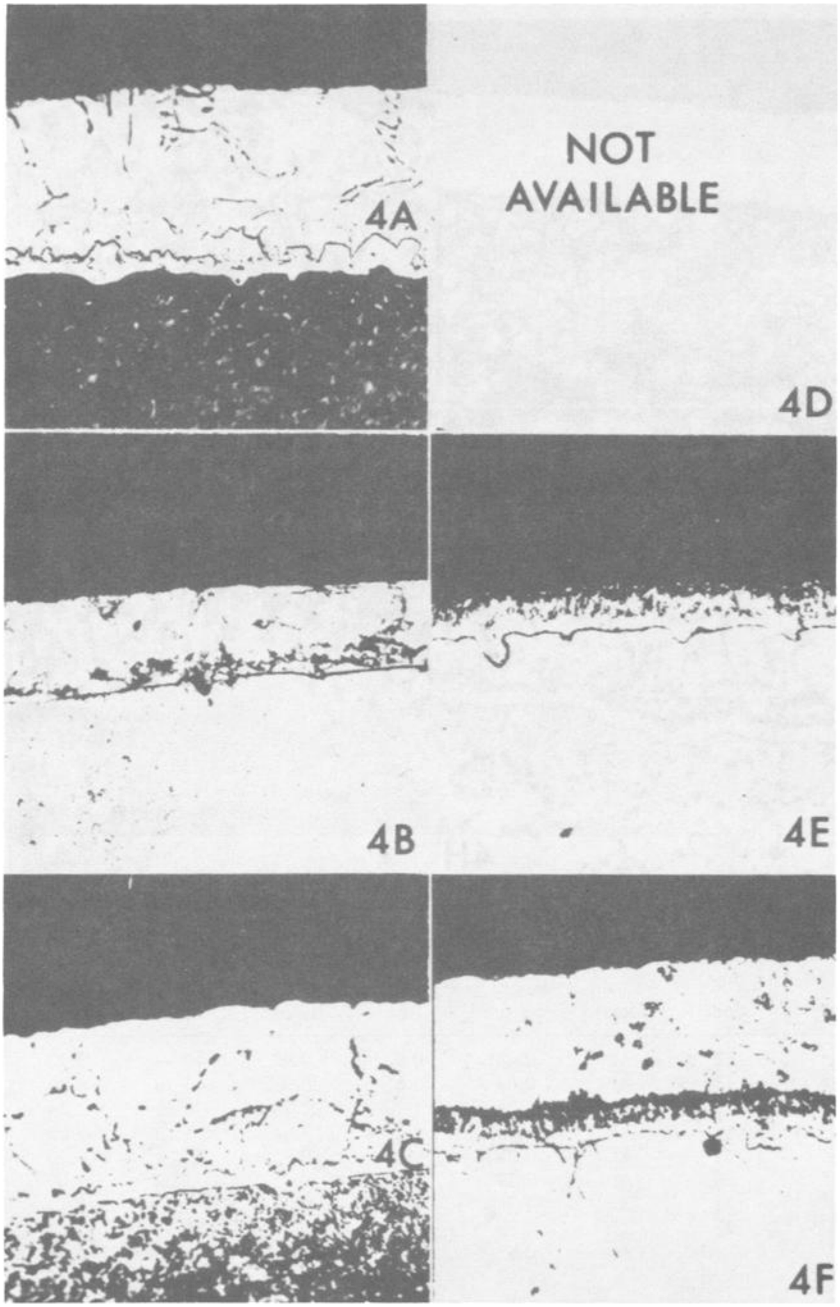


Figure	Code	Metal	Weight,[d] oz/ft²	Coating Analysis, % Iron	Silicon	Thickness, mil min	max
3A[a]	12	Al	0.48	0.98	4.43	0.945	3.70
3B[a]	13	Al	0.63	0.61	0.057	1.70	4.80
3C[b]	17	Al	0.29	1.20	2.70	0.66	2.24
3D[b]	18	Al	0.43	1.24	2.91	1.73	2.60
3E[b]	19	Al	0.21	20.25	0.93	0.70	2.70
3F[b]	20	Al	0.37	1.29	4.71	1.02	2.60
3G[b]	21	Al	1.76	0.080	0.006	5.1	8.7
3H[b]	22	Al	3.36	0.47	0.69	11.9	15.3
3I[c]	46,52	Zn	0.87	trace	...	1.46	1.58
3J[c]	47,53	Al	1.92	0.080	0.006	6.2	10.3

[a] 9 gage 3.76 mm (0.148 in.) unfabricated test wire.
[b] 12½ gage 2.515 mm (0.099 in.) unfabricated test wire.
[c] ACSR core wire.
[d] 1 oz/ft² = 0.30 kg/m².



(All photomicrographs magnified ×500 except as noted)

FIG. 4—*Coating characteristics of unfabricated and fabricated wire.*

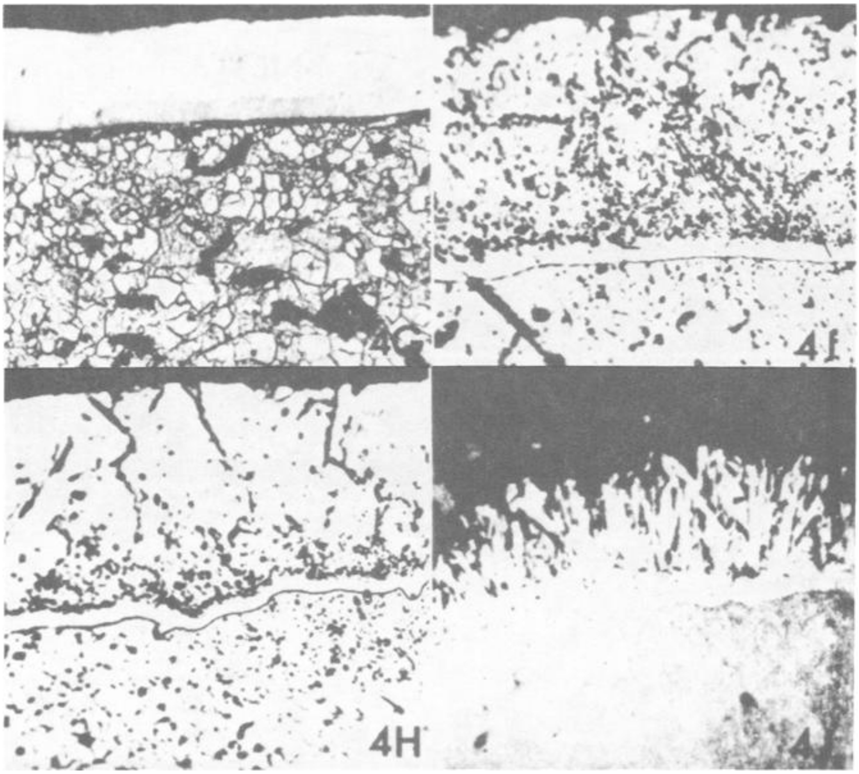


Figure	Code	Metal	Weight,[e] oz/ft²	Coating: Analysis, %: Iron	Coating: Analysis, %: Silicon	Coating: Thickness, mil: min	Coating: Thickness, mil: max
4A[a]	48,54	Al	0.45	4.20	0.70	0.91	2.84
4B[a]	49,55	Al	0.34	1.0	4.0	0.28	2.16
4C[a]	50,56	Al	0.43	0.49	4.93	1.0	3.9
4D[a]	51,57	Al	0.30	8.59	3.91	0.50	2.60
4E[b]	27	Zn	0.43	15	...	0.30	0.81
4F[b]	28	Zn	0.97	9.2	...	1.01	2.95
4G[b]	29	Al	0.25	1.34	2.92	0.60	2.41
4H[b]	30	Al	0.42	1.24	2.91	1.73	2.60
4I[b]	31	Al	0.39	1.29	4.71	1.02	2.60
4J[c]	32[d]	Zn	1.77	4.25	...	0.63	1.96

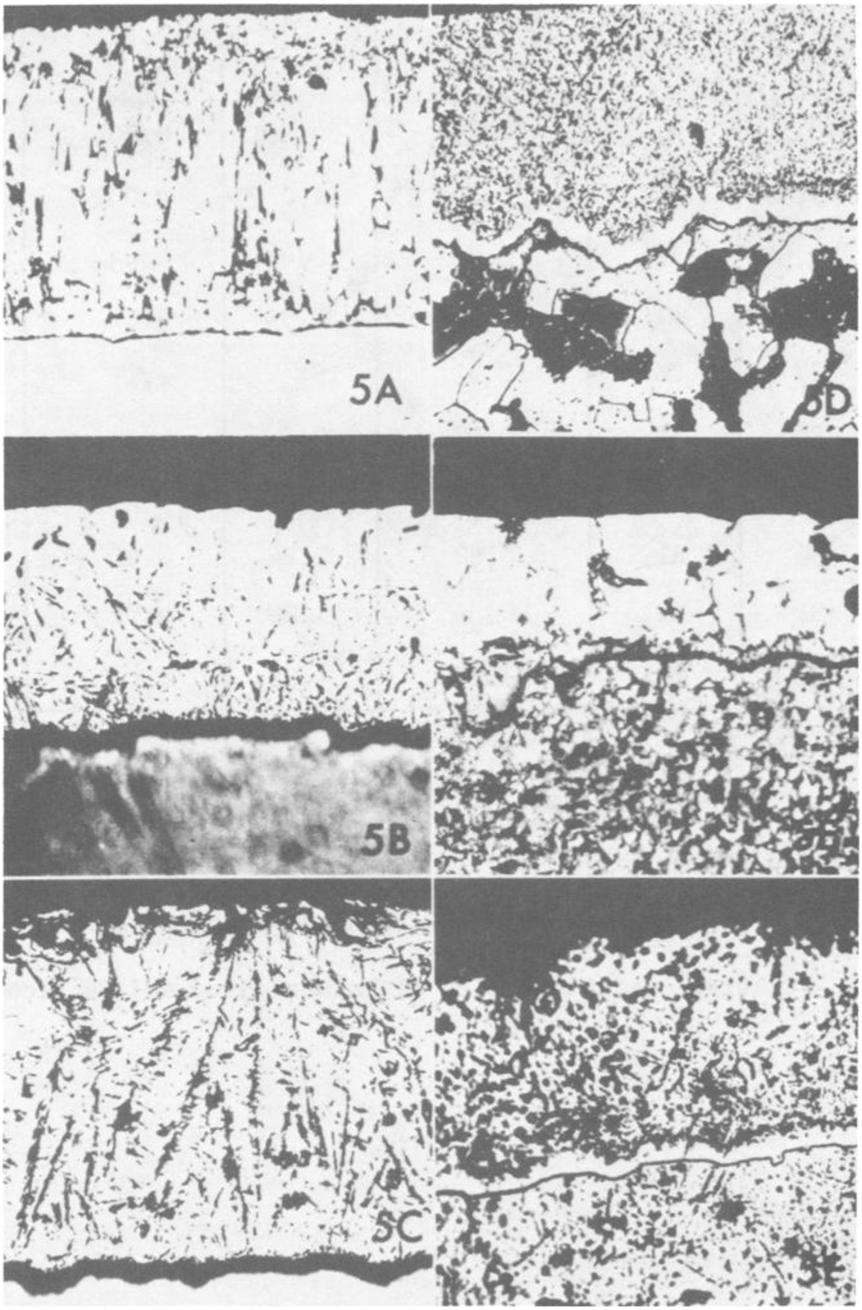
[a] ACSR core wire.

[b] Lyman 4-point barb, 12½ gage line wire.

[c] 9 gage 50.8 mm (2 in.) chain-link fence.

[d] An apparent inconsistency between the reported coating weight and the min/max coating thickness was investigated. Based chiefly on samples taken in 1983 of the fence at Manhattan, Kansas, we believe the weight of 1.77 oz/ft² and the minimum thickness of 0.63 mil to be accurate and the maximum thickness of 1.96 mils to be understated by a factor of at least 2.5. This does not affect the printed results.

[e] 1 oz/ft² = 0.30 kg/m².



(All photomicrographs magnified ×500 except as noted)

FIG. 5—*Coating characteristics of unfabricated and fabricated wire.*

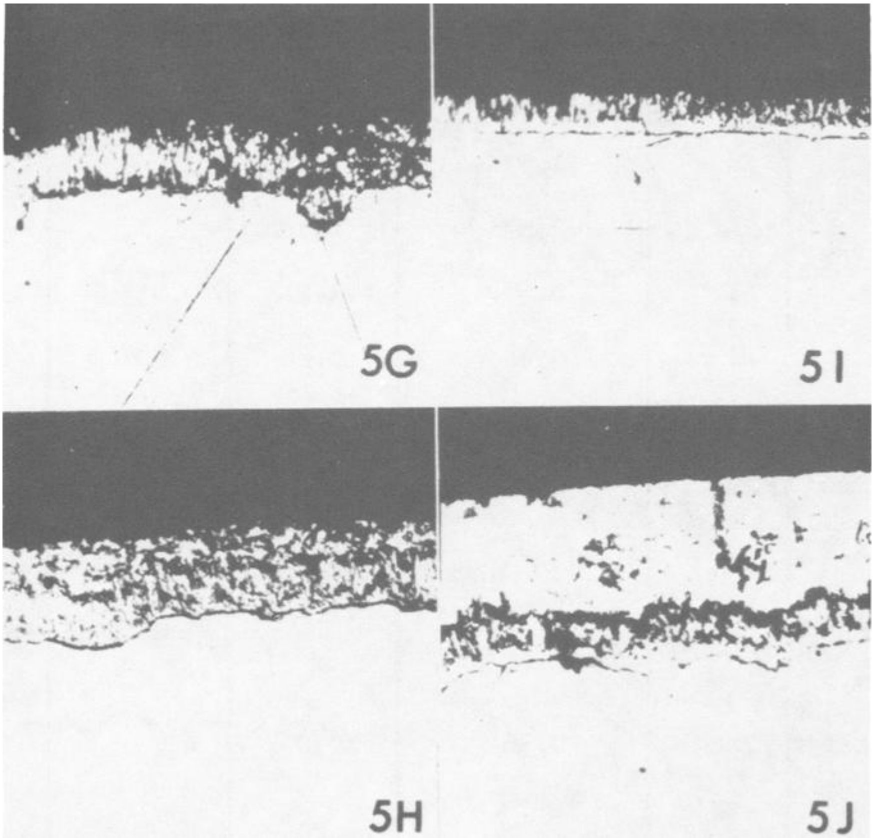
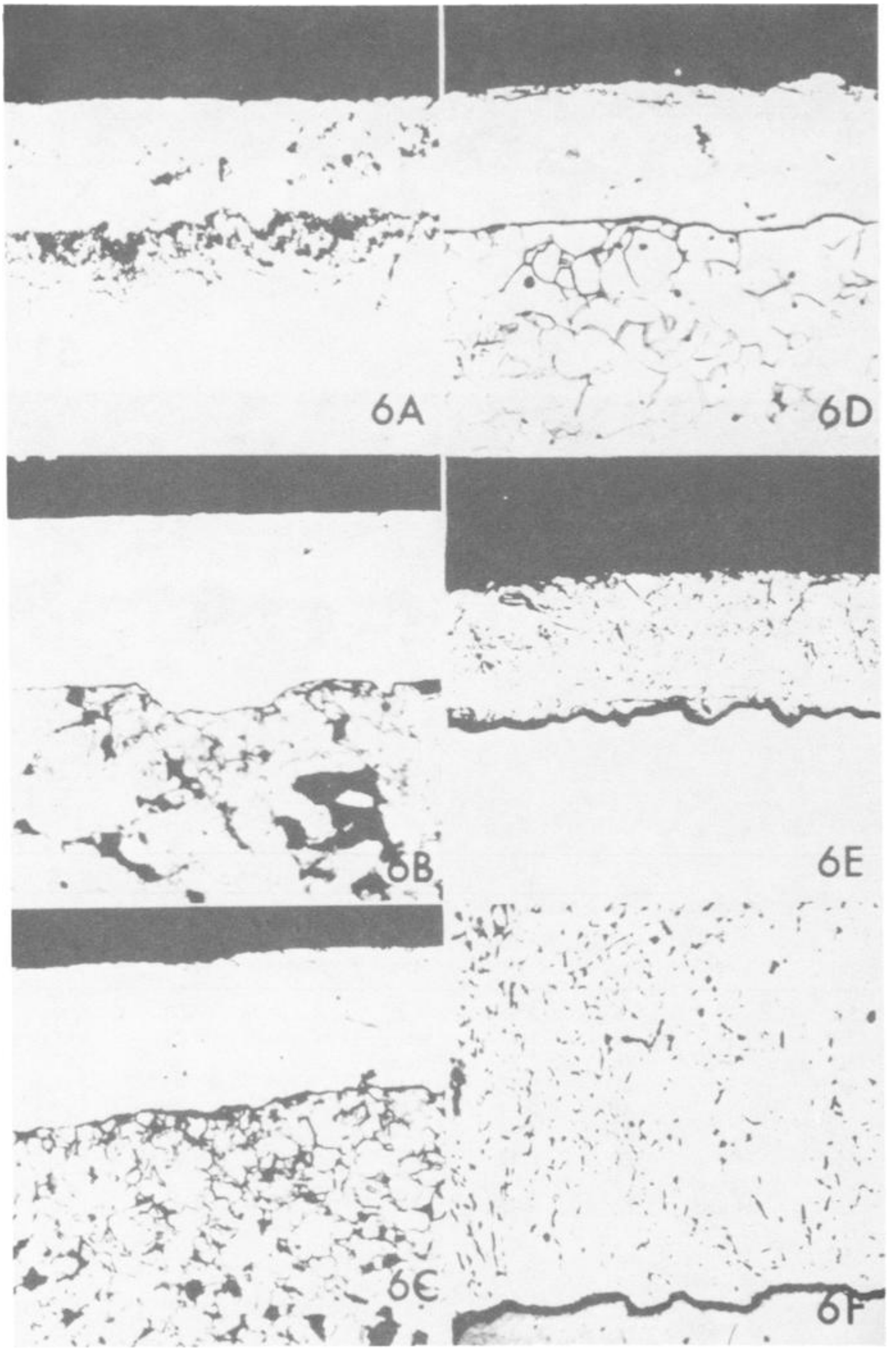


Figure	Code	Metal	Weight,[c] oz/ft²	Coating Analysis, % Iron	Silicon	Thickness, mil min	max
5A[a]	33	Zn	2.81	5.07	...	3.00	4.90
5B[a]	34	Zn	1.53	trace	...	2.29	2.61
5C[a]	35	Zn	2.23	trace	...	3.45	3.87
5D[a]	36	Al	0.57	1.21	0.035	1.0	4.4
5E[a]	37	Al	0.44	1.60	2.80	0.79	3.18
5F[a]	38	Al	0.54	1.50	2.81	0.945	3.700
5G[b]	24 line (9 gage)	Zn	0.49	8.7	...	0.64	1.31
5H[b]	24 line (11 gage)	Zn	0.42	11.4	...	0.42	1.21
5I[b]	24 stay (11 gage)	Zn	0.36	10.0	...	0.42	0.80
5J[b]	25 line (9 gage)	Zn	1.00	3.5	...	1.10	1.83

[a]9 gage 50.8 mm (2 in.) chain-link fence.
[b]Field fence.
[c]1 oz/ft^2 = 0.30 kg/m^2.



(All photomicrographs magnified ×500 except as noted)

FIG. 6—*Coating characteristics of unfabricated and fabricated wire.*

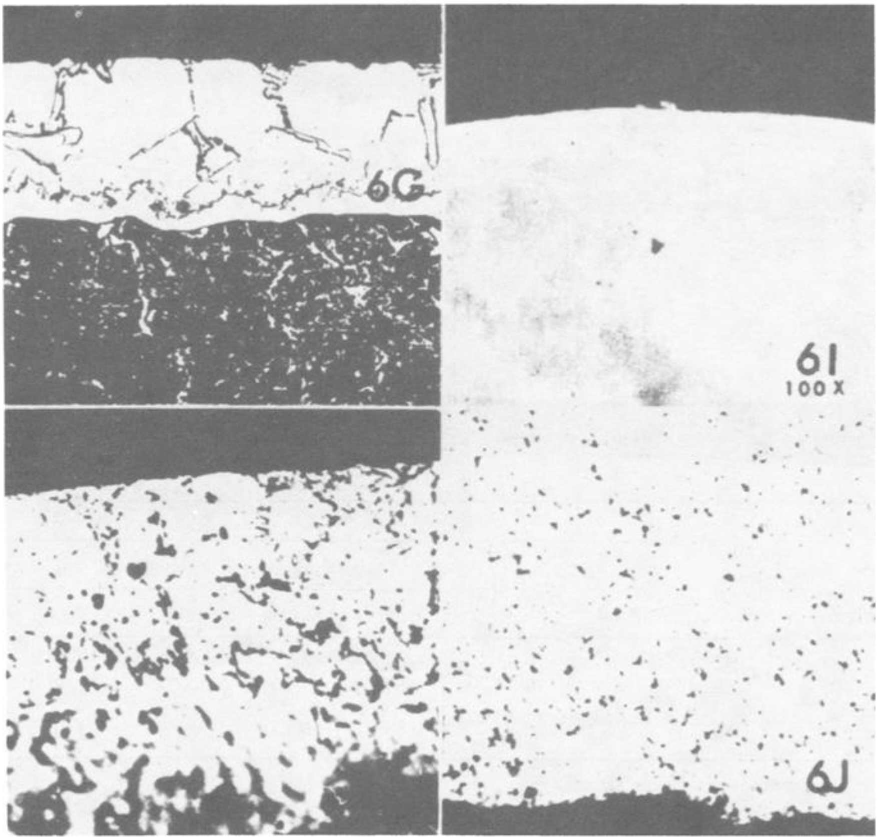
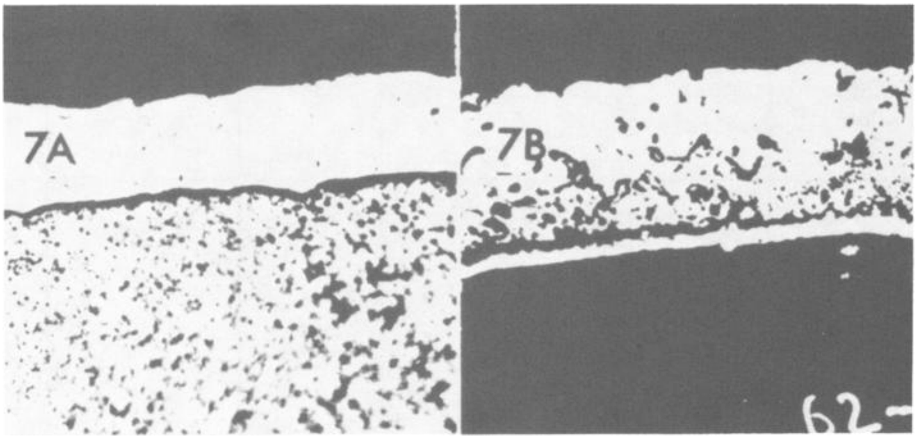


Figure	Code	Metal	Weight,[c] oz/ft^2	Coating Analysis, % Iron	Coating Analysis, % Silicon	Thickness, mil min	Thickness, mil max
6A[a]	25 stay (9 gage)	Zn	0.99	4.3	...	0.92	2.16
6B[a]	26 line (9 gage)	Al	0.43	1.72	2.98	0.81	4.20
6C[a]	26 line (11 gage)	Al	0.38	1.57	6.08	0.66	3.52
6D[a]	26 stay (11 gage)	Al	0.27	2.05	3.91	0.68	1.45
6E[b]	39	Zn	0.99	trace	...	1.37	1.48
6F[b]	40	Zn	2.98	trace	...	4.50	4.71
6G[b]	41	Al	0.43	5.1	3.1	0.40	2.76
6H[b]	43	Al	0.49	0.97	4.47	1.65	2.52
6I[b]	44	Al	4.54	0.17	0.047	12.0	18.0
6J[b]	45	Al	2.26	0.090	0.007	7.4	9.6

[a]Field fence.
[b]9.53 mm (3/8 in.) 7-wire strand.
[c]1 oz/ft^2 = 0.30 kg/ft^2.



			Coating				
				Analysis, %		Thickness, mil	
Figure	Code	Metal	Weight,[d] oz/ft^2	Iron	Silicon	min	max
7A[a]	42	Al	0.33	0.86	3.24	0.47	2.72
7B[b]	59	Al	0.32	1.57	3.30	0.70	2.60
7C[c]	58	drawn Al	0.30	9.24	3.14	0.70	2.10

[a]9.53 mm (3/8 in.) 7-wire strand.
[b]7.94 mm (5/16 in.) 7-wire strand.
[c]No photomicrograph.
[d]1 oz/ft^2 = 0.30 kg/ft^2.

(All photomicrographs magnified ×500 except as noted)

FIG. 7—*Coating characteristics of unfabricated and fabricated wire.*

Materials and ASTM Specifications

The materials exposed in this program have wide variations in coating weight due to the many different coating processes employed. Some of these items do not meet the ASTM specifications which eventually evolved in the aluminum-coated product line. The following ASTM specifications pertain to the products exposed in this program. The date of original issue is given in parentheses.

1. A 116 Specification for Zinc-Coated (Galvanized) Iron or Steel Farm-Field and Railroad Right-of-way Wire Fencing (1927).
2. A 121 Specification for Zinc-Coated (Galvanized) Steel Barbed Wire (1928).

TABLE 4—*Mechanical properties of unfabricated wires.*

Specimen	Coating Metal	Coating Weight, oz/ft^2	Diameter, in.	Breaking Load, lb	Tensile Strength, psi	Elongation in 10 in., %	Reduction of Area, %
No. 1	...	...	0.148	1723	100 166	0.9	53.7
No. 2	Zn	0.50	0.148	1487	86 533	5.8	55.2
No. 3	Zn	0.99	0.146	1058	62 967	11.4	48.2
No. 4	Zn	2.84	0.150	1030	58 290	11.6	55.6
No. 5	Al	0.52	0.150	1040	58 633	13.2	51.4
No. 6	Al	0.54	0.149	2885	165 067	9.6	53.8
No. 7	Al	0.27	0.148	1245	72 400	11.5	50.3
No. 8	Al	2.44	0.149	3077	176 533	2.2	56.3
No. 9	Al	0.48	0.144	1617	99 100	9.8	51.7
No. 10	Al	0.51	0.149	1438	82 933	9.5	54.4
No. 11	Al	0.27	0.148	1488	85 500	9.7	57.4
No. 12	Al	0.48	0.148	1407	82 667	11.3	48.4
No. 13	Al	0.63	0.150	1423	80 250	10.8	55.4
No. 17	Al	0.29	0.098	487	63 700	12.2	60.1
No. 18	Al	0.43	0.103	490	58 600	15.7	75.4
No. 19	Al	0.21	0.102	558	68 433	10.9	64.3
No. 20	Al	0.37	0.102	565	74 633	5.8	59.5
No. 21	Al	1.76	0.0985	768	101 200	1.9	42.5
No. 22	Al	3.36	0.0980	1012	134 667	1.5	51.8

NOTE—Procedure utilized three 18-in. replicates for the Method of Tension Testing of Steel Wire (A 318-56). Free-running crosshead speed was 12.7 mm (1/2 in.) per min.

Conversions—1 in. = 25.4 mm.
1 lb = 0.45 kg.
1 psi = 6.89 kPa.
1 oz/ft^2 = 0.30 kg/m^2.

3. A 392 Specification for Zinc-Coated Steel Chain-Link Fence Fabric (1955).
4. A 491 Specification for Aluminum-Coated Steel Chain-Link Fence Fabric (1963).
5. A 584 Specification for Aluminum-Coated Steel Farm-Field and Right-of-Way Fencing (1968).
6. A 585 Specification for Aluminum-Coated Steel Barbed Wire (1968).
7. A 586 Specification for Zinc-Coated Steel Structural Strand (1968).
8. B 341 Specification for Aluminum-Coated (Aluminized) Steel Core Wire for Aluminum Conductors, Steel Reinforced (ACSR) (1963).
9. B 498[1] Specification for Zinc-Coated (Galvanized) Steel Core Wire for Aluminum Conductors, Steel Reinforced (ACSR) (1969).

The first seven specifications listed were promulgated by Committee A-5, whereas the last two were sponsored by Committee B-1 on Wires for Electrical Conductors.

[1]This specification (B 498), issued in 1969 replaced specifications B 245 and B 261.

TABLE 5—*Description of aluminum wire used in fabrication of No. 4, 7/1 aluminum conductor, steel reinforced, conventional, and compacted.*

	Conventional		Compacted	
Physical Parameter	Specified	Actual	Specified	Actual
Avg diameter, in.	...	0.0767	...	0.0824
Elongation in 10 in., %	1.4	1.8	...	1.8
Avg bulk weight, lb	...	133	...	154.6
Avg tensile strength, psi	28 000	28 900	27 500	29 100
Conductivity (% of International Annealed Copper Standard)	61	62.1	61	62.2
Wrap test	5 turns	passed	5 turns	passed
Chemical Analysis, %				
Copper	...	0.02	...	0.02
Iron	...	0.12	...	0.13
Silicon	...	0.06	...	0.06
Boron	...	0.01	...	0.01
Manganese	...	0.004	...	0.004
Titanium	...	<0.002	...	<0.002
Vanadium	...	<0.002	...	<0.002
Magnesium	...	<0.001	...	<0.001
Chromium	...	<0.002	...	<0.002
Zinc	...	<0.01	...	<0.01
Gallium	...	0.01	...	0.01
Aluminum	...	99.77	...	99.76

Inspection of Wire and Wire Products

Visual Examination

Visual examination of the extent of corrosion was done almost annually. The time of exposure was recorded to the nearest 0.1 year. This report summarizes the observations made over a period of 20 years at all test sites except Warrington, England, where the test was terminated after 13 years. Observations were made by one or more inspectors and the consensus was reported. These data were published in ASTM Committee A-5 reports.[2] A summary of these observations is presented in Tables 6 through 10 covering all but the ACSR specimens. Table 11 of this report shows the abbreviations and symbols used to describe the nature of the corrosion. The extent of corrosion was estimated in terms of the percent of the area of the specimen affected. The corrosion rates in terms of kilograms per square meter (ounces of coating per

[2]Reports of Subcommittee A05.15 on Wire Tests, *Proceedings*, American Society for Testing and Materials.

TABLE 6—*1961 exposure of zinc and aluminum coated unfabricated wire*[a] *average of observed years until initial rust (IR) and complete rust (CR) or condition after approximately 20-year exposure and calculated corrosion rates (ounces per square foot per year) to initial rust (CIR) and to complete rust (CCR).*

Wire No. and Coating				Kure Beach, N.C., 800 ft					Newark, N.J.					State College, Pa.					Warrington, England[b]				
					Years To					Years To					Years To					Years To			
No.	Coating	Gage	oz/ft^2	20-Year Condition	IR	CIR	CR	CCR	20-Year Condition	IR	CIR	CR	CCR	20-Year Condition	IR	CIR	CR	CCR	20-Year Condition	IR	CIR	CR	CCR
1	Steel[c]	9	bare	100 R	0		0		100 R	0		0		100 R	0		0		closed 1977	0		0	
2	Zn	9	0.50	100 R	5.0	0.10	9.1	0.06	100 R	3.0	0.17	3.9	0.13	100 R	7.9	0.06	9.8	0.05	closed 1977	2.8	0.18	3.8	0.13
3	Zn	9	0.99	65 R, 25 wc, 10 Y	9.1	0.11			100 R	5.9	0.17	6.9	0.14	85 R, 15 G	17.0	0.06			closed 1977	4.7	0.21	4.7	0.21
4	Zn	9	2.84	90 wc, 10 Y					95 R, tr G, 5 Y	15.8	0.18			100 G					closed 1977	13.2	0.21		
5	Al	9	0.52	90 G, 10 wc, tr PPR					100 blk, tr PPR					2 PPR, 58 G, 40 Y	9.8	0.05			closed 1977	7.8	0.07		
6	Al	9	0.54	90 G, 10 wc, tr PPR					100 blk, mo, br					8 PPR, 12 G, 80 Y	8.9	0.06			closed 1977	10.9	0.05		
8	Al	9	2.44	80 G, 20 wc					100 G, blk, specs					100 MG					closed 1977				
9	Al	9	0.48	65 G, 35 wc					100 blk					98 G, 2 Y, tr PPR					closed 1977	8.5	0.06		

(continued)

TABLE 6—*(Continued)*.

Wire No. and Coating				Kure Beach, N.C., 800 ft					Newark, N.J.					State College, Pa.					Warrington, England[b]				
					Years To					Years To					Years To					Years To			
No.	Coating	Gage	oz/ft^2	20-Year Condition	IR	CIR	CR	CCR	20-Year Condition	IR	CIR	CR	CCR	20-Year Condition	IR	CIR	CR	CCR	20-Year Condition	IR	CIR	CR	CCR
10	Al	9	0.51	75 G, 25 wc, tr PPR					100 blk, mo, br					8 PHR, 85 G, 7 Y	8.9	0.06			closed 1977	7.8	0.06		
11	Al	9	0.27	7 PPR, 7 PPY, 75 G, 10 wc	10.0	0.03			20 PHR, 80 blk	8.9	0.03			22 PHR, 60 G, 13 Y	8.9	0.03			closed 1977	4.7	0.06	8.5	0.03
12	Al	9	0.48	56 G, 40 wc, 2 PPY, 2 PPR	20.2	0.02			100 blk					2 PPR, 88 G, 10 Y	11.0	0.04			closed 1977	9.4	0.05		
13	Al	9	0.63	80 G, 10 M, 10 wc					100 dk, G					100 MG, tr PPR					closed 1977				
17	Al	12-1/2	0.29	3 R, 10 Y, 52 G, 35 wc	10.0	0.03			15 PPR, 85 blk	19.1	0.02			10 PPR, 50 G, 40 Y	8.9	0.03			closed 1977	4.7	0.06	7.8	0.04
18	Al	12-1/2	0.43	60 G, 40 wc, tr PPY					100 blk					7 PPR, 53 G, 40 Y	9.8	0.04			closed 1977	5.8	0.07		
20	Al	12-1/2	0.37	25 R, 70 wc, 5 Y	9.1	0.04			SPPR, 95 blk	19.1	0.02			10 PPR, 10 G, 80 br stain	8.9	0.04			closed 1977	5.8	0.06		
21	Al	12-1/2	1.76	80 G, 20 wc					95 G, 5 blk, specs					100 MG					closed 1977				
22	Al	12-1/2	3.36	90 G, 10 wc					100 G					98 MG, 2 PP blk					closed 1977				

[a]Abbreviations and symbols explained in Table 11. Figures preceding abbreviations are average percentages.
[b]$oz/ft^2 = 0.30\ kg/m^2$.
[c]Copper bearing steel.
[d]Exposed in 1964.

TABLE 7—*1961 exposure of zinc and aluminum coated farm-field fence[a] average of observed years until initial rust (IR) and complete rust (CR) or condition after approximately 20-year exposure and calculated corrosion rates (ounces per square foot per year)[b] to initial rust (CIR) and to complete rust (CCR).*

Fence Number and Coating					Brazos River, Tex.					Kure Beach, N.C., 80 ft					Kure Beach, N.C., 800 ft				
						Years To					Years To					Years To			
No.	Coating	Item	Gage	oz/ft²	20-Year Condition	IR	CIR	CR	CCR	20-Year Condition	IR	CIR	CR	CCR	20-Year Condition	IR	CIR	CR	CCR
24	Zn	Top	9	0.49	destroyed	3.2	0.15	7.1	0.07	terminated 1973	3.0	0.16	6.3	0.08	terminated 1978	5.0	0.10	7.3	0.07
		Line	11	0.42	100 R	1.2	0.35	7.1	0.06	1973	2.0	0.21	7.3	0.06	1978	4.0	0.11	9.1	0.05
		Stay	11	0.36	100 R	2.2	0.16	7.1	0.05	1973	2.0	0.18	7.3	0.05	1978	4.0	0.09	7.3	0.05
		Bottom	9	0.49	destroyed	4.2	0.12	9.3	0.05	1973	4.0	0.12	7.3	0.07	1978	10.0	0.05	15.0	0.03
		Wraps[c]	...	...	100 R	2.0	...	7.1	...	1973	1.0	...	7.3	...	1978	5.0	...	9.1	...
		Cut ends[c]	...	...	100 R	1.2	...	4.2	...	1973	4.0	...	7.3	...	1978	7.3	...	7.3	...
25	Zn	Top	9	1.00	100 R	10.3	0.10	20.8	0.05	terminated 1976	2.0	0.50	15.0	0.07	100 R	5.0	0.20	17.1	0.06
		Line	9	1.00	100 R	10.3	0.10	20.8	0.05	1976	4.0	0.25	15.0	0.07	80 R, 20 wc	7.9	0.13		
		Stay	9	0.99	100 R	9.3	0.11	13.3	0.07	1976	4.0	0.25	15.0	0.07	100 R, tr Y	5.0	0.20	17.1	0.06
		Bottom	9	1.00	95 R	10.3	0.10			1976	7.3	0.14	15.0	0.07	20 wc, 80 G				
		Wraps[c]	...	...	80 R	10.3	...			1976	2.0	...	15.0	...	90 R, 10 wc	7.3	...		
		Cut ends[c]	...	...	100 R	1.2	...	8.2	...	1976	7.3	...	8.0	...	90 R, 10 G	9.1	...		
26	Al	Top	9	0.43	50 R, 20 Y	9.3	0.05			terminated 1976	9.1	0.05	15.0	0.03	28 G, 70 wc, 1 Y, 1 PPR	11.0	0.04		
		Line	11	0.38	10 R, 25 Y	19.0	0.02			1976	9.1	0.04	15.0	0.03	15 M, 55 G, 29 wc, 1R, tr Y	11.0	0.03		
		Stay	11	0.27	destroyed	2.2	0.12	10.3	0.03	1976	6.3	0.04	12.0	0.02	30 Y, 70 R	10.0	0.03		
		Bottom	9	0.43	10 R, 25 Y	11.3	0.04			1976	11.0	0.04	15.0	0.03	100 M, tr wc				
		Wraps[c]	...	...	100 R	3.2	...	10.2	...	1976	6.3	...	9.1	...	20 Y, 80 R	9.1	...		
		Cut ends[c]	...	...	100 R	1.2	...	3.2	...	1976	7.3	...	8.0	...	100 R	2.0	...	15.0	...

(continued)

TABLE 7—(*Continued*).

Fence Number and Coating					Manhattan, Kans.					Newark, N.J.					Point Reyes, Calif.				
						Years To					Years To					Years To			
No.	Coating	Item	Gage	oz/ft^2	20-Year Condition	IR	CIR	CR	CCR	20-Year Condition	IR	CIR	CR	CCR	20-Year Condition	IR	CIR	CR	CCR
24	Zn	Top	9	0.49	100 Y					terminated 1970	3.0	0.16	3.9	0.13	100 R	16.0	0.03	20.2	0.02
		Line	11	0.42	100 Y					1970	3.0	0.14	4.9	0.09	100 R	6.3	0.07	17.6	0.02
		Stay	11	0.36	100 Y					1970	1.9	0.19	4.9	0.07	100 R	10.3	0.03	14.3	0.03
		Bottom	9	0.49	100 Y					1970	5.9	0.08	6.9	0.07	70 wc, 30 R	20.2	0.02		
		Wraps[c]	...	...	100 Y					1970	3.0	...	4.9	...	100 R	12.1	...	14.3	...
		Cut ends[c]	...	...	100 Y					1970	1.9	...	5.9	...	100 R	10.3	...	14.3	...
25	Zn	Top	9	1.00	100 G					terminated 1970	4.9	0.20	6.9	0.14	100 R	14.3	0.07	20.2	0.05
		Line	9	1.00	100 G					1970	4.9	0.20	6.9	0.14	70 R, 30 wc	10.3	0.10		
		Stay	9	0.99	100 G					1970	4.9	0.20	8.9	0.11	90 R, 10 Y	6.3	0.16		
		Bottom	9	1.00	100 G					1970	6.9	0.14	8.9	0.11	100 wc, tr R				
		Wraps[c]	...	...	100 G					1970	5.9	...	8.9	...	75 R, 25 wc	10.3	...		
		Cut ends[c]	...	...	100 G					1970	3.0	...	7.9	...	100 R	6.3	...	10.3	...
26	Al	Top	9	0.43	50 M, 50 st					100 blk					3 R, 97 wc	20.2	0.02		
		Line	11	0.38	75 M, 25 st					100 blk					5 R, 95 wc	20.2	0.02		
		Stay	11	0.27	50 M, 50 st					5 PHR 95 blk	19.1	0.01			100 R	8.3	0.03	17.6	0.02
		Bottom	9	0.43	100 M					5 PHR 95 blk	9.8	0.04			5 R, 95 wc	20.2	0.02		
		Wraps[c]	...	...	100 Y					1 R 99 blk	20.2	...			100 R	6.3	...	10.3	...
		Cut ends[c]	...	...	100 R	1.1	...	10.2	...	100 blk					100 R	1.2	...	5.3	...

TABLE 7—(*Continued*).

Fence Number and Coating					State College, Pa.					Warrington, England[d]				
						Years To					Years To			
No.	Coating	Item	Gage	oz/ft²	20-Year Condition	IR	CIR	CR	CCR	20-Year Condition	IR	CIR	CR	CCR
24	Zn	Top	9	0.49	100 R	6.9	0.07	9.8	0.05	closed 1977	1.8	0.27	3.8	0.13
		Line	11	0.42	100 R	7.9	0.05	11.0	0.04	1977	1.8	0.23	3.8	0.11
		Stay	11	0.36	100 R	6.9	0.05	8.9	0.04	1977	1.8	0.20	3.8	0.09
		Bottom	9	0.49	100 R	9.8	0.05	13.8	0.04	1977	1.8	0.27	3.8	0.13
		Wraps[c]	...	...	100 R	5.9	...	11.0	...	1977	1.8	...	3.8	...
		Cut ends[c]	...	...	100 R	5.9	...	7.9	...	1977	0.8	...	3.8	...
25	Zn	Top	9	1.00	95 R, 5 Y	15.8	0.06			closed 1977	3.8	0.26	3.8	0.26
		Line	9	1.00	49 R, 39 Y 12 G	15.8	0.06			1977	3.8	0.26	4.7	0.21
		Stay	9	0.99	70 R, 30 Y	14.9	0.07			1977	3.8	0.26	3.8	0.26
		Bottom	9	1.00	1 Y, 99 G					1977	3.8	0.26	6.9	0.14
		Wraps[c]	...	...	70 Y, 30 G					1977	3.8	...	3.8	...
		Cut ends[c]	...	...	2 R, 98 Y	7.9	...			1977	2.8	...	3.8	...
26	Al	Top	9	0.43	90 G, 10 PPR	11.0	0.04			closed 1977	7.8	0.06		
		Line	11	0.38	97 G, 3 PPR	9.8	0.04			1977	7.8	0.05		
		Stay	11	0.27	85 br, 15 PPR	9.8	0.03			1977	5.8	0.05	7.8	0.03
		Bottom	9	0.43	100 MG, tr PPR					1977	7.8	0.06		
		Wraps[c]	...	...	65 br, 35 R	7.9	...			1977	6.9	...	7.8	...
		Cut ends[c]	...	...	100 R	0.9	...	7.9	...	1977	0.7	...	0.7	...

[a]Abbreviations and symbols explained in Table 11. Figures preceding abbreviations are average percentages.
[b]$1\ oz/ft^2 = 0.30\ kg/m^2$.
[c]Wraps and cut ends values are not included in evaluation of CR and CCR values.
[d]Exposed in 1964.

TABLE 8—*1961 exposure of zinc and aluminum-coated Lyman 4-point barbed wire*[a] *average of observed years until initial rust (IR) and complete rust (CR) or conditions after approximately 20-year exposure and calculated corrosion rates (ounces per square foot per year)*[b] *to initial rust (CIR) and to complete rust (CCR).*

Wire No. and Coating					Brazos River, Tex.					Kure Beach, N.C., 80 ft					Kure Beach, N.C., 800 ft				
						Years To					Years To					Years To			
No.	Coat-ing	Item	Gage	oz/ft^2	20-Year Condition	IR	CIR	CR	CCR	20-Year Condition	IR	CIR	CR	CCR	20-Year Condition	IR	CIR	CR	CCR
27	Zn	line	12-1/2	0.43	terminated 1980	1.2	0.36	7.1	0.06	terminated 1971	4.0	0.11	7.3	0.06	terminated 1981	4.0	0.11	8.0	0.05
		barb				1.2	0.36	6.3	0.07		1.2	0.36	2.2	0.20		2.0	0.22	7.3	0.06
28	Zn	line	12-1/2	0.97	100 R	6.3	0.15	20.8	0.05	terminated 1977	4.0	0.24	16.0	0.06	100 R	6.3	0.15	18.0	0.05
		barb			100 R	1.2	0.81	19.0	0.05		1.0	0.97	16.0	0.06	100 R	6.3	0.15	18.0	0.05
29	Al	line	12-1/2	0.25	terminated 1980	7.1	0.04	14.4	0.02	terminated 1974	7.3	0.03	10.0	0.02	90 R, 10 Y	7.3	0.03		
		barb	12-1/2			1.2	0.21	6.3	0.04		1.0	0.25	8.0	0.03	100 R	2.0	0.12	16.0	0.02
30	Al	line	12-1/2	0.42	15 R terminated 1980	6.3	0.07			30 Y, 40 R, 15 G, 15 wc.	9.1	0.05			tr R, 5 Y, 75G, 20 wc	7.3	0.06		
		barb		Al	...	...		...		...	...		...		...	...		...	
31	Al	line	12-1/2	0.39	95 R	6.3	0.06			10 Y, 90 R	6.3	0.06			15 Y, 10 R, 75 wc	7.3	0.05		
		barb		Al	...	...		...		...	...		...		...	...		...	

TABLE 8—(*Continued*).

Wire No. and Coating					Manhattan, Kans.					Newark, N.J.					Point Reyes, Calif.				
						Years To					Years To					Years To			
No.	Coating	Item	Gage	oz/ft^2	20-Year Condition	IR	CIR	CR	CCR	20-Year Condition	IR	CIR	CR	CCR	20-Year Condition	IR	CIR	CR	CCR
27	Zn	line	12-1/2	0.43	90 Y, 10 R	20.1	0.02			terminated 1970	3.0	0.14	3.9	0.11	terminated 1980	13.1	0.03	14.3	0.03
		barb			100 R	13.2	0.03	19.3	0.02		1.9	0.23	3.9	0.11		9.8	0.04	9.8	0.04
28	Zn	line	12-1/2	0.97	100 G					terminated 1970	4.9	0.20	6.9	0.14	terminated 1980	4.2	0.23	10.3	0.09
		barb			100 G						3.9	0.25	6.9	0.14		4.2	0.23	9.8	0.11
29	Al	line	12-1/2	0.25	75 M, 25 st					10 PPR, 90 blk	19.1	0.01			100 R	5.3	0.05	20.2	0.01
		barb			75 M, 22 st, 3 R	13.2	0.02			15 R, 85 st	9.8	0.03			100 R	1.2	0.21	11.0	0.02
30	Al	line	12-1/2	0.42	50 M, 50 st					100 blk					95 wc, 5 PPR	11.0	0.04		
		barb		Al	75 M, 25 st	...		...		100 blk	...		...		M, G	...		...	
31	Al	line	12-1/2	0.39	50 M, 50 st					100 blk, tr PPR					80 wc, 20 R	9.8	0.04		
		barb		Al	75 M, 25 st	...		...		100 blk	...		...		100 wc	...		...	

(*continued*)

TABLE 8—(*Continued*).

Wire No. and Coating					State College, Pa.					Warrington, England[c]				
						Years To					Years To			
No.	Coating	Item	Gage	oz/ft²	20-Year Condition	IR	CIR	CR	CCR	20-Year Condition	IR	CIR	CR	CCR
27	Zn	line	12-1/2	0.43	100 R	5.9	0.07	9.8	0.04	closed 1977	2.8	0.15	3.8	0.11
		barb			100 R	5.9	0.07	7.9	0.05		0.8	0.54	3.8	0.11
28	Zn	line	12-1/2	0.97	8 R, 87 Y, 5 G	19.1	0.05			closed 1977	3.8	0.26	4.7	0.21
		barb			95 R, 5 Y	13.8	0.07				0.8	1.21	3.8	0.26
29	Al	line	12-1/2	0.25	15 PPR, 84 Y br, 1 G	8.9	0.03			closed 1977	5.8	0.04	5.8	0.04
		barb			30 R, 70 Y br	8.9	0.03				0.8	0.31	5.8	0.04
30	Al	line	12-1/2	0.42	5 PPR, 80 G, 15 Y br	8.9	0.05			closed 1977	7.8	0.05		
		barb		Al	100 G	...		...			...		...	
31	Al	line	12-1/2	0.39	15 PPR, 5 G, 80 Y br	8.9	0.04			closed 1977	6.9	0.06	13.2	0.03
		barb		Al	100 MG	...		...			...		...	

[a]Abbreviations and symbols explained in Table 11. Figures preceding abbreviations are average percentages.
[b]1 $oz/ft^2 = 0.30\ kg/m^2$.
[c]Exposed in 1964.

TABLE 9—*1961 exposure of zinc and aluminum coated chain link fence[a] average of observed years until initial rust (IR) and complete rust (CR) or condition after approximately 20-year exposure and calculated corrosion rates (ounces per square foot per year)[b] to initial rust (CIR) and to complete rust (CCR).*

Fence Number and Coating					Brazos River, Tex.					Kure Beach, N.C., 80 ft					Kure Beach, N.C., 800 ft				
						Years To					Years To					Years To			
No.	Coating	Wire Item	Gage	oz/ft^2	20-Year Condition	IR	CIR	CR	CCR	20-Year Condition	IR	CIR	CR	CCR	20-Year Condition	IR	CIR	CR	CCR
32	Zn	barbs	9	1.77	100 R	9.3	0.19	19.0	0.09	buried at 17 year, 90 R	11.0	0.16			90 R, 10 wc	6.3	0.28		
		links			95 R	9.3	0.19			50 wc, 50 R	4.0	0.44			80 R, 10 wc, 10 G	5.0	0.35		
		knuckles			buried					50 wc, 50 R	5.0	0.35			buried	...	...		
33	Zn	barbs	9	2.81	20 R	19.0	0.15			buried					30 R, 70 wc	7.3	0.39		
		links			95 R	19.0	0.15			60 wc, 40 R	7.3	0.39			30 R, 60 wc, 10 G	7.3	0.39		
		knuckles			buried					80 wc, 20 R	7.3	0.39			buried				
34	Zn	barbs	9	1.53	10 R, 90 wc	8.2	0.19			terminated 1979					50 R, 50 wc	7.3	0.21		
		links			10 R, 90 wc	19.0	0.08				4.0	0.38	17.1	0.09	10 R, 15 Y, 70 wc, 5 G	11.0	0.14		
		knuckles			10 R, 90 wc	20.8	0.07				4.0	0.38	17.1	0.09	buried				
35	Zn	barbs	9	2.23	5 R, 95 wc	20.8	0.11			buried					10 R, 90 wc	9.1	0.25		
		links			5 R, 95 wc	20.8	0.11			80 R, 10 wc, 10 Y	5.0	0.45			2 R, 10 Y, 88 wc	19.2	0,12		
		knuckles			buried					75 R, 25 wc	5.0	0.45			buried				
36	Al	barbs	9	0.57	50 R, 50 wc	10.3	0.05			buried	...				20 R, 10 Y, 60 wc, 10 G	7.3	0.08		
		links			10 R	20.8	0.03			5 R, 95 G, Tr wc, Tr Y	10.0	0.06			tr R + Y, 5 wc, 85 G, 10 M				
		knuckles			buried					100 R	6.3	0.09	20.2	0.03	buried				
37	Al	barbs	9	0.44	100 R	10.3	0.04	14.4	0.03	buried					60 R, 10 Y, 10 wc, 20 G	6.3	0.07		
		links			15 R	19.0	0.02			10 R, 5 Y, 5 wc, 80 G	8.0	0.06			tr Y, 20 wc, 75 G, 5 M				
		knuckles			buried					30 R, 20 Y, 10 wc, 40 G	7.3	0.06			buried				
38	Al	barbs	9	0.54	65 R	10.3	0.05			buried	19.2	0.03			20 R, tr Y, 20 wc, 60 G	7.3	0.07		
		links			5 R	20.8	0.03			15 R, 10 Y, 75 G	9.1	0.06			tr Y, 20 wc, 70 G, 10 M	11.0[c]	0.05		
		knuckles			buried					60 R, 30 Y, 10 G	7.3	0.07			buried				

(continued)

TABLE 9—(*Continued*).

Fence Number and Coating					Manhattan, Kans.					Newark, N.J.					Point Reyes, Calif.				
						Years To					Years To					Years To			
No.	Coat-ing	Wire Item	Gage	oz/ft^2	20-Year Condition	IR	CIR	CR	CCR	20-Year Condition	IR	CIR	CR	CCR	20-Year Condition	IR	CIR	CR	CCR
32	Zn	barbs	9	1.77	100 G					20 R, 75 Y, 5 G	8.9	0.20			80 wc, 20 R	9.8	0.18		
		links			100 G					90 R, 10 Y	6.9	0.26			80 wc, 20 R	9.8	0.18		
		knuckles			100 G					buried	11.9	0.15			100 wc	9.8[c]	0.18		
33	Zn	barbs	9	2.81	100 G					90 R, 10 Y, tr G	9.8	0.29			90 wc, 10 Y, tr R				
		links			100 G					90 R, 10 Y	8.9	0.32			90 wc, 10 Y				
		knuckles			100 G					buried					100 wc				
34	Zn	barbs	9	1.53	100 G, R tips					100 R	5.9	0.26	8.9	0.17	75 wc, 25 R	20.2	0.08		
		links			100 G					98 R, 2 Y	5.9	0.26			75 wc, 25 R	17.6	0.09		
		knuckles			100 G					95 R, 5 Y	11.0	0.14			95 wc, 5 R	20.2	0.08		
35	Zn	barbs	9	2.23	100 G, R tips					100 R	8.9	0.25	19.0	0.12	100 wc				
		links			100 G					98 R, 2 Y	8.9	0.25			100 wc, tr R				
		knuckles			100 G					98 R, 2 Y	19.1	0.12			100 rc, tr R				
36	Al	barbs	9	0.57	75 M, 25 Y					100 blk					100 wc, tr R				
		links			100 M					100 blk					50 M, 25 G, 25 wc				
		knuckles			100 M					99 blk, 1 R	9.8	0.06			100 wc, tr R				
37	Al	barbs	9	0.44	50 R, 10 Y, 40 M	19.3	0.03			100 blk, tr PPR					70 wc, 30 R	10.3	0.04		
		links			100 M					100 blk					100 wc				
		knuckles			100 M					98 blk, 2 R	9.8	0.05			buried				
38	Al	barbs	9	0.54	50 R, 10 Y, 40 M	19.3	0.03			2 PPR, 98 blk	19.1	0.03			80 wc, 20 R	11.9	0.05		
		links			100 M					100 blk					100 wc, tr R				
		knuckles			100 M					8 R, 92 blk	9.8	0.06			100 wc				

TABLE 9—(*Continued*).

Fence Number and Coating					State College, Pa.					Warrington, England[d]				
						Years To					Years To			
No.	Coating	Wire Item	Gage	oz/ft²	20-Year Condition	IR	CIR	CR	CCR	20-Year Condition	IR	CIR	CR	CCR
32	Zn	barbs	9	1.77	100 G					closed 1977	7.8	0.23		
		links			15 R, 70 Y, 15 G	14.9	0.12				4.7	0.38	8.5	0.21
		knuckles			50 R, 45 Y, 5 G	14.9	0.12				5.8	0.31	9.4	0.19
33	Zn	barbs	9	2.81	100 G					closed 1977	7.8	0.36	9.4	0.30
		links			tr R, 92 Y, 8 G						6.9	0.41	9.4	0.30
		knuckles			99 Y, 1 G						7.8	0.36	9.4	0.30
34	Zn	barbs	9	1.53	100 G					closed 1977	6.9	0.22	7.8	0.20
		links			100 G						6.9	0.22	9.4	0.16
		knuckles			tr R, 1 Y, 99 G						6.9	0.22	8.5	0.18
35	Zn	barbs	9	2.23	100 G					closed 1977	8.5	0.26		
		links			100 G						7.8	0.29		
		knuckles			100 G						10.9	0.20	13.2	0.17
36	Al	barbs	9	0.57	100 MG					closed 1977				
		links			1 PPR, 99 MG	19.1	0.30							
		knuckles			2 R, 49 Y, 49 G	8.9	0.06							
37	Al	barbs	9	0.44	tr Y, 100 MG					closed 1977	8.5	0.05		
		links			10 PPR, 5 Y, 85 G	8.9	0.05				8.5	0.05		
		knuckles			1 PPR, 49 Y, 50 G	8.9	0.05				10.9	0.04		
38	Al	barbs	9	0.54	100 G					closed 1977	7.8	0.07	13.2	0.04
		links			10 PPR, 10 Y, 80 G	8.9	0.06				7.8	0.07		
		knuckles			1 PPR, 15 Y, 84 G	9.8	0.06				7.8	0.06		

[a]Abbreviations and symbols explained in Table 11. Figures preceding abbreviations are average percentages.
[b]$1\ oz/ft^2 = 0.30\ kg/m^2$.
[c]IR previously noted.
[d]Exposed in 1964.

TABLE 10—*1961 exposure of zinc and aluminum coated 7-wire strand[a] average of observed years until initial rust (IR) and complete rust (CR) or condition after approximately 20-year exposure and calculated corrosion rates (ounces per square foot per year)[b] to initial rust (IR) and to complete rust (CCR).*

Strand Number and Coating				Brazos River, Tex.					Kure Beach, N.C., 80 ft					Kure Beach, N.C., 800 ft					Manhattan, Kans.				
					Years To					Years To					Years To					Years To			
No.	Coating	Size	oz/ft²	20-Year Condition	IR	CIR	CR	CCR	20-Year Condition	IR	CIR	CR	CCR	20-Year Condition	IR	CIR	CR	CCR	20-Year Condition	IR	CIR	CR	CCR
39	Zn	9.53 mm (3/8 in.)	0.99	75 wc, 25 Y					40 R, 10 Y, 50 wc	7.3	0.14			10 Y, 38 wc, 50 G, 2 PPR	20.2	.05			100 G				
40	Zn	9.53 mm (3/8 in.)	2.98	90 wc, 10 Y					2 R, 98 wc, tr Y	20.2	0.15			40 wc, 60 G, tr Y					100 G				
41	Al	9.53 mm (3/8 in.)	0.43	100 M					tr R, 2 Y, 20 wc, 78 G					15 wc, 80 G, 5 M, tr Y					25 st, 75 M				
42	Al	7.94 mm (5/16 in.)	0.33	100 M					5 R, tr Y, 20 wc, 75 G	19.2	0.02			10 wc, 70 G, 20 M					15 st, 85 M				
43	Al	9.53 mm (3/8 in.)	0.49	3 R, 97 M	7.1	0.07			5 R, 2 Y, 30 wc, 63 G	10.0	0.05			15 wc, tr Y, 70 G, 15 M					25 st, 75 M				
44	Al	9.53 mm (3/8 in.)	4.54	100 M					25 wc, 70 G, 5 M					15 wc, 85 G, tr M					80 M, 20 st				
45	Al	9.53 mm (3/8 in.)	2.26	100 M					25 wc, 70 G, 5 M					5 wc, 85 G, 10 M					50 M, 50 st				
59	Al drawn after coating	(5/16 in.)	0.39	15 R, 15 Y, 70 G	10.3	0.04			5 R, 5 Y, 40 wc, 50 G	8.0	0.05			5 Y, 25 wc, 70 G	11.0[c]	.04			50 M, 50 st				

TABLE 10—(*Continued*).

Strand Number and Coating				Newark, N.J.					Point Reyes, Calif.					State College, Pa.					Warrington, England[d]				
					Years To					Years To					Years To					Years To			
No.	Coating	Size	oz/ft²	20-Year Condition	IR	CIR	CR	CCR	20-Year Condition	IR	CIR	CR	CCR	20-Year Condition	IR	CIR	CR	CCR	20-Year Condition	IR	CIR	CR	CCR
39	Zn	9.525 mm (3/8 in.)	0.99	98 R, 2 Y	6.9	0.14			25 R, 75 wc	6.9	0.14			100 G					closed 1977	5.8	0.17	9.4	0.11
40	Zn	9.525 mm (3/8 in.)	2.98	100 G					97 wc, 3 R	20.2	0.15			100 G					closed 1977				
41	Al	9.525 mm (3/8 in.)	0.43	2 PPR, 98 blk	8.9	0.05			100 R	9.8	0.04	14.3	0.03	5 PPR, 5 Y, 90 G	8.9	0.05			closed 1977				
42	Al	7.9375 mm (5/16 in.)	0.33	10 PHR, 90 blk	8.9	0.04			60 R, 40 st	9.8	0.03			7 PPR, tr Y, 93 G	8.9	0.04			closed 1977	8.5	0.04		
43	Al	9.525 mm (3/8 in.)	0.49	2 PHR, 98 blk	8.9	0.06			100 R	8.3	0.06	9.8	0.05	5 PPR, 8 Y, 87 G	9.8	0.05			closed 1977				
44	Al	9.525 mm (3/8 in.)	4.54	100 G					100 wc					100 MG					closed 1977				
45	Al	9.525 mm (3/8 in.)	2.26	100 G					100 G					100 G					closed 1977				
59	Al drawn after coating	(5/16 in.)	0.39	20 PPR, 80 blk	11.0	0.04			15 R, 70 wc, 15 st	·11.0	0.04			18 PPR, 17 Y, 65 G	7.9	0.05			closed 1977	6.9	0.06		

[a]Abbreviations and symbols explained in Table 11. Figures preceding abbreviations are average percentages.
[b]1 oz/ft^2 = 0.30 kg/m^2.
[c]IR previously noted.
[d]Exposed in 1964.

TABLE 11—*Aluminum-coated wire test abbreviations and symbols used in Tables 6 through 10.*

M =	metallic
G =	gray
MG =	intermediate between "metallic" and gray
GY =	predominantly gray but showing indications of yellow
Y =	yellowed or rust stained but not showing actual rust of base metal
R =	rough rust of base metal
rg =	reddish gold discoloration
mo =	mottled—various shadings of gray
e =	etch—loss of metallic brightness
blk =	black surface discoloration
s =	soil—dark or dirty accumulation adhering to test specimens
wc =	white corrosion product
l =	light
m =	medium
h =	heavy
vh =	very heavy
tr =	trace
occ =	occasional
scat =	scattered (more extensive than occasional)
PP =	pinpoint < 3.18 mm (1/8 in.) in diameter
PH =	pinhead > 3.18 mm (1/8 in.) in diameter
10, 30, 50 etc. =	percentage of surface
bal =	balance
mech =	mechanical damage
br =	brown
dk =	dark
st =	surface discoloration including soil or gold patina, black, mottling, etc.

square foot) of surface to initial rust (CIR) and to complete rust (CCR) were calculated as follows:

$$(a)\ \text{CIR} = \frac{\text{weight of coating kg/m}^2\ (\text{oz/ft}^2)\text{ of surface}}{\text{years to initial rust}}$$

$$(b)\ \text{CCR} = \frac{\text{weight of coating kg/m}^2\ (\text{oz/ft}^2)\text{ of surface}}{\text{years to complete rust}}$$

Analysis

The average corrosion rate to initial rust for each aluminum-coated product and each zinc-coated product are shown in Tables 12 and 13. An all products average and standard deviation for each location are also shown. The all products average corrosion rates were calculated using the individual corrosion rates for each product at each location from Tables 6 through 10. The standard deviation is a measure of the spread of the individual results around the average. The large standard deviations for the all products averages are

TABLE 12—*Average corrosion rates to initial rusting (CIR) (ounces of coating per square foot per year)*[a] *for each aluminum-coated product exposed at each location for approximately 20 years.*

Location	Aluminum Coated: Unfabricated Wire	Field Fence	Barbed Wire (line)[c]	Chain-Link Fence	Wire Strand	All Products: Average	Standard Deviation
Brazos River, Tex.	...[b]	0.06	0.06	0.04	0.06	0.05	0.025
Kure Beach, N.C., 80 ft	...[b]	0.04	0.05	0.06	0.04	0.05	0.017
Kure Beach, N.C., 800 ft	0.03	0.03	0.05	0.07	...[d]	0.04	0.018
Manhattan, Kans.	...[b]	...[d]	...[d]	0.03	...[d]	0.02	0.006
Newark N.J.	0.02	0.03	...[d]	0.05	0.05	0.04	0.018
Point Reyes, Calif.	...[b]	0.02	0.04	0.05	0.04	0.04	0.012
State College, Pa.	0.04	0.04	0.04	0.05	0.05	0.04	0.011
Warrington,[e] England	0.07	0.06	0.05	0.06	0.05	0.06	0.009

[a] $1\ oz/ft^2 = 0.30\ kg/m^2$.
[b] No specimens exposed.
[c] Average figures for line wires only since 2 of the 3 specimens had aluminum barbs.
[d] Insufficient data.
[e] Exposed in 1964. Test site closed in 1977.

not surprising considering the large differences among the individual product averages. Therefore, caution should be used in the interpretation of these average rates. All the data necessary for a more indepth analysis is contained within this report.

Steel Reinforced Aluminum Conductors

The ACSR specimens did not show any sign of initial rust after the 20-year exposure. In some instances, slight discoloration of the aluminum wire was reported.

Breaking Strength Loss

At four of the eight exposure sites, unfabricated tension test specimens were exposed, and 276 of the original specimens exposed in 1961 (1964 at Warrington) have been removed and tested for breaking load. Tables 15 through 31, tabulate the results.

Although the data are minimal, statistically meaningful results were obtained from 12 location-code number sets. Table 14 tabulates the linear regression equation and the coefficient of linear correlation for each set. The

TABLE 13—*Average corrosion rates to initial rusting (CIR) (ounces of coating per square foot per year)*[a] *for each zinc-coated product exposed at each location for approximately 20 years.*

Location	Zinc Coated						
						All Products	
	Unfabricated Wire	Field Fence	Barbed Wire (line)[c]	Chain-Link Fence	Wire Strand	Average	Standard Deviation
Brazos River, Tex.	...[b]	0.15	0.29[d]	0.14	...[e]	0.17[d]	0.090[d]
Kure Beach, N.C., 80 ft	...[b]	0.23	0.24[d,f]	0.38	0.14[g]	0.28[d]	0.128[d]
Kure Beach, N.C., 800 ft	0.10[g]	0.13	0.16	0.27	...[e]	0.18	0.105
Manhattan, Kans.	...	b[h]	0.03[g]	...[e]	...[e]	0.03[g]	0.007[g]
Newark N.J.	0.17	0.16	0.20[i]	0.23	...[e]	0.20	0.058
Point Reyes, Calif.	...[b]	0.07	0.13[j]	0.13	0.15[g]	0.11	0.069
State College, Pa.	0.06[g]	0.06	0.07	0.12[g]	...[e]	0.07	0.022
Warrington, England[k,m]	0.20	0.25	0.32	0.29	...[e]	0.27[d]	0.083[d]

[a] 1 $oz/ft^2 = 0.30\ kg/m^2$.
[b] No specimens exposed.
[c] Results are averages of line wires and barbs.
[d] Excludes one outlandish value.
[e] Insufficient or no data.
[f] Specimen No. 27 terminated in 1971.
[g] Based on two values only.
[h] No initial rust reported.
[i] Specimen Nos. 27 & 28 terminated in 1970.
[j] Specimen Nos. 27 & 28 terminated in 1980.
[k] Exposed in 1964.
[m] Test site closed in 1977.

coefficient of linear correlation is the measure of the strength of the linear relationship between two variables. Higher ordered equations were considered but rejected, based on the good results obtained by the linear assumption as indicated by the high correlation coefficients. The two variables used in the analysis were the total years of exposure (years exposed) and the percent loss in breaking load (loss percent). Because no loss in breaking load was expected before initial rust occurred, an initial point of years to initial rust and zero percent loss in breaking load was added to each data set. An alternate initial point, years to complete rust and zero percent loss, was considered but rejected because of the possibility of loss in strength between initial and complete rust, particularly for the aluminum-coated wires. For three data sets, points not consistent with the data were removed before the linear equations were generated. These points are indicated in the notes with Table 14.

The statistical analysis of the tensile data showed that the percent loss in breaking load for bare, zinc-coated, and aluminum-coated wires increased linearly with the years of exposure.

TABLE 14—*Results of linear regression analysis of loss in breaking load.*

Location	Wire Code No.	Gage	Type Coating	Coating Weight,[a] oz/ft^2	Linear[b] Equation	Coefficient of Linear Correlation, r	Sample Size
Kure Beach	1	9	Bare	0.00	Y = 2.71X + 0.19	1.00	10
Newark	1	9	Bare	0.00	Y = 1.12X + 5.07	0.91	8
State College	1	9	Bare	0.00	Y = 1.37X + 1.68	0.97	8
Warrington	1	9	Bare	0.00	Y = 4.47X + 3.80	0.99	9
Kure Beach[c]	2	9	ZN	0.50	Y = 4.32X − 29.9	0.89	7
Newark[d]	2	9	ZN	0.50	Y = 1.94X + 4.89	0.88	7
State College	2	9	ZN	0.50	Y = 1.76X − 12.24	0.95	7
Warrington	2	9	ZN	0.50	Y = 7.44X − 14.60	0.98	5
Newark	3	9	ZN	0.99	Y = 0.83X + 0.20	0.85	8
Warrington	3	9	ZN	0.99	Y = 4.99X − 21.28	0.99	8
Warrington	11	9	AL	0.27	Y = 3.17X − 17.03	0.97	8
Warrington[e]	17	12½	AL	0.29	Y = 5.61X − 28.63	0.97	6

[a] 1 oz/ft^2 = 0.30 kg/m^2.
[b] X denotes the years of exposures and Y denotes the percent loss in breaking load.
[c] Does not include point (8.0 years, 31.2%).
[d] Does not include point (11.9 years, 52.2%).
[e] Does not include points (10.0 years, 53.0%) and (12.6 years, 23.0%).

To aid in the interpretation of the results, a graph for each test site is included (see Figs. 8 through 11). The calculated line extends only over the period for which data exist, that is, from the initial rust (IR) point to the most recent test value.

At all four sites both the Code 1, 9 gage bare copper-bearing wire, and the Code 2, 9 gage with 0.15 kg/m^2 (0.5 oz/ft^2) zinc-coated wire, had sufficient data to establish a meaningful equation.

The rate of loss of breaking loads per year is the slope of the calculated line. For uncoated and zinc-coated wire the rate was different for different locations. The maximum difference for bare wire was a ratio of 4:1 for Warrington and Newark. The maximum difference for zinc coated wire was a ratio of 4.2:1 for Warrington and State College.

At two sites, Code 1 wire performed better than Code 2 wire. This result appears to contradict what would be expected. However, the light zinc coat on Code 2 wire offered only a few years of protection. Past that point the comparison is between an uncoated copper-bearing steel and an uncoated noncopper-bearing steel. It appears that the copper-bearing wire, Code 1, outperformed the noncopper-bearing wire, Code 2.

At two sites the Code 3, 9 gage, 0.30 kg/m^2 (0.99 oz/ft^2) zinc-coated wire, had sufficient data to establish a meaningful equation. The Code 3 wire per-

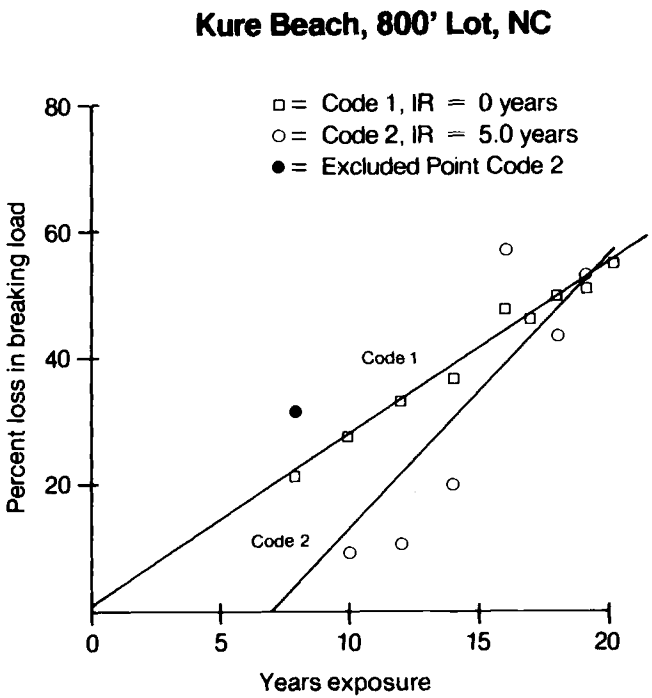


FIG. 8—*Loss in breaking load of unfabricated wires versus years of exposure at Kure Beach, North Carolina, 800 ft lot.*

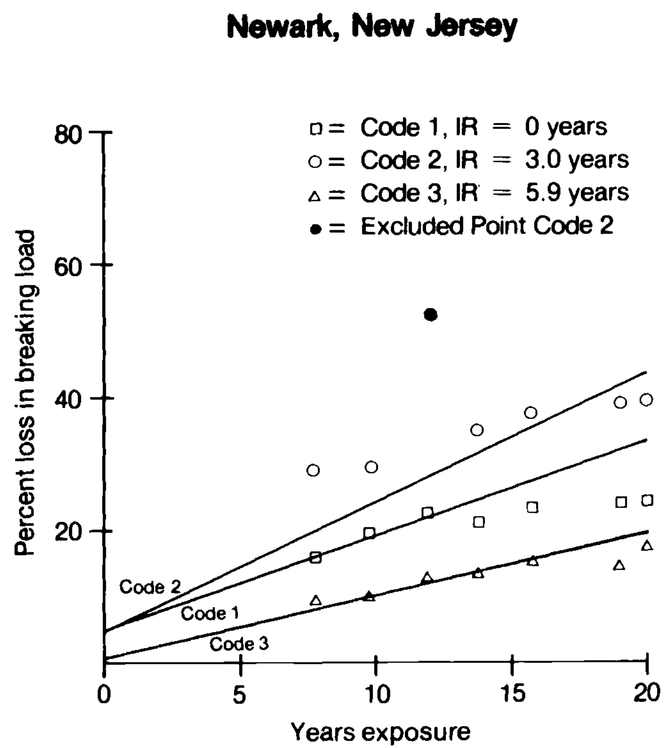


FIG. 9—*Loss in breaking load of unfabricated wires versus years of exposure at Newark, New Jersey.*

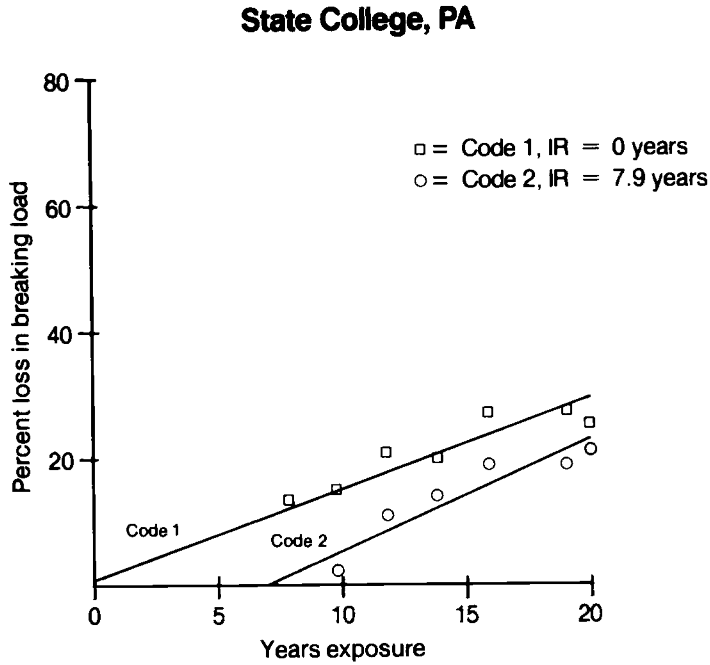


FIG. 10—*Loss in breaking load of unfabricated wires versus years of exposure at State College, Pennsylvania.*

formed better than the lighter zinc-coated Code 2 wire. This results indicates that the rate of loss of breaking loads per year for zinc-coated wire decreased with increase in coating weight.

At the Warrington site Code 11, 9 gage, 0.08 kg/m^2 (0.27 oz/ft^2) aluminum-coated wire, and Code 17, 12½ gage, 0.09 kg/m^2 (0.29 oz/ft^2) aluminum-coated wire, had sufficient data to establish meaningful equations. At this site, the Code 11 wire outperformed the Code 17 wire. This result indicates that the rate of loss of breaking loads per year for aluminum-coated wire decreased with increased wire diameter.

While the conclusions drawn here are based on a small sample, they are supported by the earlier work done by Reinhart.[3]

Breaking Loads

Tables 15 through 31 give a summary of breaking loads.

[3]Reinhart, F. M., *Twenty-Year Atmospheric Corrosion Investigation of Zinc-Coated and Uncoated Wire and Wire Products, ASTM STP 290*, American Society for Testing and Materials, 1961.

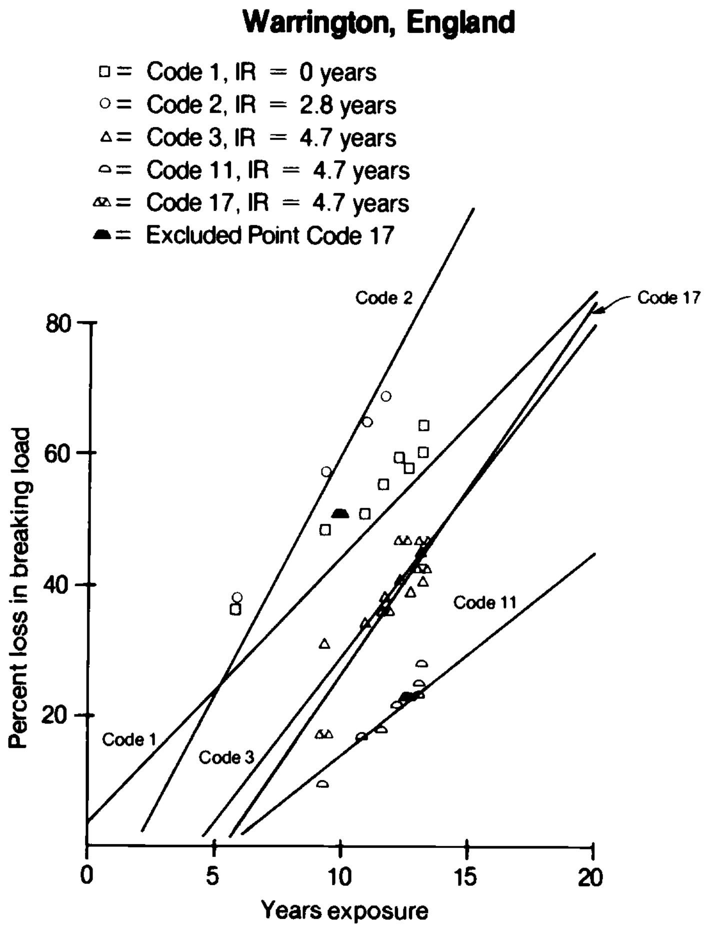


FIG. 11—*Loss in breaking load of unfabricated wires versus years of exposure at Warrington, England.*

TABLE 15—*Breaking loads of wires removed during the 20-year period 1961 to 1981. Code No. 1—9 gage uncoated copper-bearing steel wire, original breaking load 1723 lb.*[a]

Location	Years Exposed	Years to IR	Years Since IR	R, %	Breaking Load Exposed, lb	Loss, %	% per Year Since IR
Kure Beach, 800 ft lot	8.0	0	8.0	100	1353	21.5	2.7
	10.0	0	10.0	100	1258	27.0	2.7
	12.0	0	12.0	100	1150	33.3	2.8
	14.0	0	14.0	100	1088	36.9	2.6
	16.0	0	16.0	100	901	47.7	3.0
	17.1	0	17.1	100	930	46.0	2.7
	18.2	0	18.2	100	863	49.9	2.7
	19.2	0	19.2	100	853	50.5	2.6
	20.2	0	20.2	100	787	54.3	2.6
Newark	7.9	0	7.9	100	1448	16.0	2.0
	9.8	0	9.8	100	1382	19.8	2.0
	11.9	0	11.9	100	1331	22.8	1.9
	13.8	0	13.8	100	1355	21.4	1.6
	15.8	0	15.8	100	1333	22.6	1.4
	19.1	0	19.1	100	1310	24.0	1.3
	20.0	0	20.0	100	1307	24.1	1.2
State College	7.9	0	7.9	100	1490	13.5	1.7
	9.8	0	9.8	100	1477	14.3	1.5
	11.9	0	11.9	100	1376	20.1	1.7
	13.8	0	13.8	100	1378	20.0	1.4
	15.8	0	15.8	100	1257	27.0	1.7
	19.1	0	19.1	100	1257	27.0	1.4
	20.0	0	20.0	100	1276	25.9	1.3
Warrington	5.8	0	5.8	100	1102	36.0	6.2
	9.4	0	9.4	100	895	48.1	5.1
	10.9	0	10.9	100	838	51.4	4.7
	11.6	0	11.6	100	772	55.2	4.8
	12.4	0	12.4	100	711	58.7	4.7
	12.6	0	12.6	100	722	58.1	4.6
	13.2	0	13.2	100	608	64.7	4.9
	13.2	0	13.2	100	684	60.3	4.6

[a] 1 lb = 0.45 kg.

TABLE 16—*Breaking loads of wires removed during the 20-year period 1961 to 1981. Code No. 2—9 gage zinc-coated steel wire 0.50 oz/ft²,[a] original breaking load 1487 lb.*[b]

Location	Years Exposed	Years to IR	Years Since IR	R, %	Breaking Load Exposed, lb	Loss, %	% per Year Since IR
Kure Beach, 800 ft lot	8.0	5.0	3.0	99	1023	31.2	10.4
	10.0	5.0	5.0	100	1350	9.2	1.8
	12.0	5.0	7.0	100	1330	10.6	1.5
	14.0	5.0	9.0	100	1190	20.0	2.2
	16.0	5.0	11.0	100	631	57.6	5.2
	17.1	5.0	12.1	100	835	43.8	3.6
	19.2	5.0	14.2	100	699	53.0	3.7
Newark	7.9	3.0	4.9	100	1065	28.4	5.8
	9.8	3.0	6.8	100	1048	29.5	4.3
	11.9	3.0	8.9	100	711	52.2	5.9
	13.8	3.0	10.8	100	967	35.0	3.2
	15.8	3.0	12.8	100	931	37.4	2.9
	19.1	3.0	16.1	100	917	38.3	2.4
	20.0	3.0	17.0	100	909	38.9	2.3
State College	9.8	7.9	1.9	100	1455	2.2	1.2
	11.9	7.9	4.0	100	1316	11.5	2.9
	13.8	7.9	5.9	100	1276	14.2	2.4
	15.8	7.9	7.9	100	1203	19.1	2.4
	19.1	7.9	11.2	100	1204	19.0	1.7
	20.0	7.9	12.1	100	1170	21.3	1.8
Warrington	5.8	2.8	3.0	100	930	37.5	12.5
	9.4	2.8	6.6	100	633	57.4	8.7
	10.9	2.8	8.1	100	523	64.8	8.0
	11.6	2.8	8.8	100	464	68.8	7.8

[a] 1 oz/ft² = 0.30 kg/m².
[b] 1 lb = 0.45 kg.

TABLE 17—*Breaking loads of wires removed during the 20-year period 1961 to 1981. Code No. 3—9 gage zinc-coated steel wire 0.99 oz/ft²,[a] original breaking load 1058 lb.[b]*

Location	Years Exposed	Years to IR	Years Since IR	R, %	Breaking Load Exposed, lb	Loss, %	% per Year Since IR
Kure Beach, 800 ft lot	16.0	9.1	6.9	20	1010	4.5	0.7
	17.1	9.1	8.0	40	1046	1.1	0.1
	18.2	9.1	9.1	65	1063	−0.5	−0.05
	19.2	9.1	10.1	65	1029	2.7	0.3
	20.2	9.1	11.1	65	1049	0.9	0.1
Newark	7.9	5.9	2.0	100	962	9.1	4.6
	9.8	5.9	3.9	100	960	9.3	2.4
	11.9	5.9	6.0	100	923	12.8	2.1
	13.8	5.9	7.9	100	920	13.0	1.6
	15.8	5.9	9.9	100	903	14.7	1.5
	19.1	5.9	13.2	100	911	13.9	1.0
	20.0	5.9	14.2	100	895	15.4	1.1
State College	15.8	...	0	0	1062	−0.4	...
	19.1	17.0	2.1	75	1085	−2.5	−1.5
	20.0	17.0	3.0	85	1038	1.9	0.6
Warrington	9.4	4.7	4.7	100	749	29.2	6.2
	10.9	4.7	6.2	100	694	34.4	5.5
	11.6	4.7	6.9	100	653	38.3	5.6
	12.4	4.7	7.7	100	622	41.2	5.4
	12.6	4.7	7.9	100	640	39.5	5.0
	13.2	4.7	8.5	100	586	44.6	5.2
	13.2	4.7	8.5	100	617	41.7	4.9

[a] 1 oz/ft² = 0.30 kg/m².
[b] 1 lb = 0.45 kg.

TABLE 18—*Breaking loads of wires removed during the 20-year period 1961 to 1981. Code No. 4—9 gage zinc-coated steel wire 2.84 oz/ft²,[a] original breaking load 1030 lb.[b]*

Location	Years Exposed	Years to IR	Years Since IR	R, %	Breaking Load Exposed, lb	Loss, %	% per Year Since IR
Kure Beach, 800 ft lot	16.0	...	0	0	1024	0.6	...
	17.1	...	0	0	1036	−0.6	...
Newark	15.8	15.8	0	5	1026	0.4	...
	19.1	15.8	3.3	95	980	4.9	1.5
	20.0	15.8	4.2	95	085	4.4	1.0
State College	15.8	...	0	0	1016	1.4	...
	19.1	...	0	0	1057	−2.6	...
	20.0	...	0	0	1038	−0.8	...
Warrington	13.2	13.2	0	1	987	4.2	...
	13.2	13.2	0	1	1016	1.4	...

[a] 1 oz/ft² = 0.30 kg/m².
[b] 1 lb = 0.45 kg.

TABLE 19—*Breaking loads of wires removed during the 20-year period 1961 to 1981. Code No. 5—9 gage aluminum-coated steel wire 0.52 oz/ft²,[a] original breaking load 1040 lb.[b]*

Location	Years Exposed	Years to IR	Years Since IR	R, %	Breaking Load Exposed, lb	Loss, %	% per Year Since IR
Kure Beach, 800 ft lot	16.0	...	0	0	1011	2.8	...
	17.1	...	0	0	1050	−1.0	...
Newark	15.8	...	0	0	1048	−0.8	...
	19.1	...	0	0	1054	−1.3	...
	20.0	...	0	0	1038	0.2	...
State College	15.8	9.8	6.0	3	1040	0	0
	19.1	9.8	9.3	2	1063	−2.2	−0.2
	20.0	9.8	10.2	2	1043	−0.3	−0.03
Warrington	13.2	7.8	5.4	15	995	4.3	0.8
	13.2	7.8	5.4	15	1054	−1.3	−0.2

[a] 1 oz/ft² = 0.30 kg/m².
[b] 1 lb = 0.45 kg.

TABLE 20—*Breaking loads of wires removed during the 20-year period 1961 to 1981. Code No. 6—9 gage aluminum-coated steel wire 0.54 oz/ft^2,[a] original breaking load 2885 lb.*[b]

Location	Years Exposed	Years to IR	Years Since IR	R, %	Breaking Load Exposed, lb	Loss, %	% per Year Since IR
Kure Beach,	16.0	...	0	0	2836	1.7	...
800 ft lot	17.1	...	0	0	2940	−1.9	...
Newark	15.8	...	0	0	2940	−1.9	...
	19.1	...	0	0	2909	−0.8	...
	20.0	...	0	0	2896	−0.4	...
State College	15.8	8.9	6.9	5	2860	−0.8	−0.1
	19.1	8.9	10.2	5	2927	−1.5	−0.1
	20.0	8.9	11.9	8	2879	0.2	0.02
Warrington	13.2	10.9	2.3	5	2795	3.1	1.3
	13.2	10.9	2.3	5	2905	−0.7	−0.3

[a] 1 oz/ft^2 = 0.30 kg/m^2.
[b] 1 lb = 0.45 kg.

TABLE 21—*Breaking loads of wires removed during the 20-year period 1961 to 1981. Code No. 8—9 gage aluminum-coated steel wire 2.44 oz/ft^2,[a] original breaking load 3077 lb.*[b]

Location	Years Exposed	Years to IR	Years Since IR	R, %	Breaking Load Exposed, lb	Loss, %	% per Year Since IR
Kure Beach,	16.0	...	0	0	3091	−0.4	...
800 ft lot	17.1	...	0	0	3106	−0.9	...
Newark	15.8	...	0	0	3181	−3.4	...
	19.1	...	0	0	3149	−2.4	...
	20.0	...	0	0	3115	−1.2	...
State College	15.8	...	0	0	3056	0.7	...
	19.1	...	0	0	3156	−2.6	...
	20.0	...	0	0	3093	−0.5	0
Warrington	13.2	...	0	0	2987	2.9	...
	13.2	...	0	0	3130	−1.7	...

[a] 1 oz/ft^2 = 0.30 kg/m^2.
[b] 1 lb = 0.45 kg.

TABLE 22—*Breaking loads of wires removed during the 20-year period 1961 to 1981. Code No. 9—9 gage aluminum-coated steel wire 0.48 oz/ft²,[a] original breaking load 1617 lb.[b]*

Location	Years Exposed	Years to IR	Years Since IR	R, %	Breaking Load Exposed, lb	Loss, %	% per Year Since IR
Kure Beach, 800 ft lot	16.0	...	0	0	1388	14.2	...
	17.1	...	0	0	1465	9.4	...
	18.2	...	0	0	1463	9.5	...
Newark	15.8	...	0	0	1460	9.7	...
	19.1	...	0	0	1395	13.7	...
	20.0	...	0	0	1459	9.8	...
State College	15.8	...	0	0	1291	20.2	...
	19.1	...	0	0	1504	7.0	...
	20.0	...	0	0	1510	6.6	...
Warrington	13.2	8.5	4.7	10	1447	10.5	2.2
	13.2	8.5	4.7	10	1531	5.3	1.1

[a] 1 $oz/ft^2 = 0.30\ kg/m^2$.
[b] 1 lb = 0.45 kg.

TABLE 23—*Breaking loads of wires removed during the 20-year period 1961 to 1981. Code No. 10—9 gage aluminum-coated steel wire 0.51 oz/ft²,[a] original breaking load 1488 lb.[b]*

Location	Years Exposed	Years to IR	Years Since IR	R, %	Breaking Load Exposed, lb	Loss, %	% per Year Since IR
Kure Beach, 800 ft lot	16.0	...	0	0	1440	−0.1	...
	17.1	...	0	0	1450	−0.8	...
Newark	15.8	...	0	0	1491	−3.7	...
	19.1	...	0	0	1428	0.7	...
	20.0	...	0	0	1459	−1.5	...
State College	15.8	8.9	6.8	10	1376	4.3	0.6
	19.1	8.9	10.2	8	1445	−0.5	0.1
	20.0	8.9	11.1	8	1510	−5.0	0.4
Warrington	13.2	7.8	5.4	10	1360	5.4	1.0
	13.2	7.8	5.4	10	1473	−2.4	−0.4

[a] 1 $oz/ft^2 = 0.30\ kg/m^2$.
[b] 1 lb = 0.45 kg.

TABLE 24—*Breaking loads of wires removed during the 20-year period 1961 to 1981. Code No. 11—9 gage aluminum-coated steel wire 0.27 oz/ft²,[a] original breaking load 1488 lb.*[b]

Location	Years Exposed	Years to IR	Years Since IR	R, %[c]	Breaking Load Exposed, lb	Loss, %	% per Year Since IR
Kure Beach, 800 ft lot	16.0	10.0	6.0	5	1403	5.7	1.0
	17.1	10.0	7.1	tr R	1468	1.7	0.2
	20.2	10.0	10.2	7	1505	−1.1	−0.1
Newark	15.8	8.9	6.9	2 PPR	1483	0.3	0.04
	19.1	8.9	10.2	20 PHR	1474	0.9	0.09
	20.0	8.9	11.1	20 PHR	1447	2.8	0.25
State College	15.8	8.9	6.9	25 PHR	1445	2.9	−0.4
	19.1	8.9	10.2	20 PHR	1524	−2.4	−0.2
	20.0	8.9	11.1	22 PHR	1485	0.2	0.02
Warrington	9.4	4.7	4.7	100	1356	9.5	2.0
	10.9	4.7	6.2	100	1242	16.5	2.7
	11.6	4.7	6.9	100	1220	18.0	2.6
	12.4	4.7	7.7	100	1161	22.0	2.9
	12.6	4.7	6.9	100	1148	22.8	2.9
	13.2	4.7	8.5	100	1065	28.4	3.3
	13.2	4.7	8.5	100	1105	25.7	3.0

[a] 1 oz/ft² = 0.30 kg/m².
[b] 1 lb = 0.45 kg.
[c] See Table 11 for symbol definitions.

TABLE 25—*Breaking loads of wires removed during the 20-year period 1961 to 1981. Code No. 12—9 gage aluminum-coated steel wire 0.48 oz/ft²,[a] original breaking load 1407 lb.*[b]

Location	Years Exposed	Years to IR	Years Since IR	R, %[c]	Breaking Load Exposed, lb	Loss, %	% per Year Since IR
Kure Beach, 800 ft lot	16.0	...	0	0	1350	4.1	...
	17.1	...	0	0	1310	6.9	...
	19.2	...	0	0	1427	−1.4	...
	20.2	20.2	0	2 PPR	1347	4.3	...
Newark	15.8	...	0	0	1395	0.9	...
	19.1	...	0	0	1350	3.1	...
	20.0	...	0	0	1360	3.3	...
State College	20.0	11.0	4.8	2	1358	3.5	0.7
	19.1	11.0	8.1	1 PHR	1385	1.6	0.2
	20.0	11.0	9.1	2 PPR	1383	1.7	0.2
Warrington	13.2	9.4	3.8	5	1350	4.1	1.1
	13.2	9.4	3.8	5	1373	2.4	0.6

[a] 1 oz/ft² = 0.30 kg/m².
[b] 1 lb = 0.45 kg.
[c] See Table 11 for symbol definitions.

TABLE 26—*Breaking loads of wires removed during the 20-year period 1961 to 1981. Code No. 13—9 gage aluminum-coated steel wire 0.63 oz/ft²,[a] original breaking load 1423 lb.[b]*

Location	Years Exposed	Years to IR	Years Since IR	R, %	Breaking Load Exposed, lb	Loss, %	% per Year Since IR
Kure Beach,	16.0	...	0	0	1373	3.5	...
800 ft lot	17.1	...	0	0	1409	1.0	...
Newark	15.8	...	0	0	1413	0.7	...
	19.1	...	0	0	1417	0.4	...
	20.0	...	0	0	1417	0.4	...
State College	15.8	...	0	0	1380	3.0	...
	19.1	...	0	0	1439	−1.1	...
	20.0	...	0	0	1405	1.3	...
Warrington	13.2	...	0	0	1343	5.6	...
	13.2	...	0	0	1395	2.0	...

[a] 1 oz/ft² = 0.30 kg/m².
[b] 1 lb = 0.45 kg.

TABLE 27—*Breaking loads of wires removed during the 20-year period 1961 to 1981. Code No. 17—12½ gage aluminum-coated steel wire 0.29 oz/ft²,[a] original breaking load 487 lb.[b]*

Location	Years Exposed	Years to IR	Years Since IR	R, %[c]	Breaking Load Exposed, lb	Loss, %	% per Year Since IR
Kure Beach,	16.0	10	6.0	1 PPR	485	0.4	0.1
800 ft lot	17.1	10	7.1	1 PPR	481	1.2	0.2
	19.2	10	9.2	2	511	−4.9	0.5
	20.2	10	10.2	3	482	1.0	0.1
Newark	15.8	...	0	0	479	1.6	...
	19.1	19.1	0	2 PPR	511	−4.9	...
	20.0	19.1	0.9	15 PPR	497	−2.1	−2.3
State College	15.8	8.9	6.9	45 PHR	496	−1.8	−0.3
	19.1	8.9	10.2	10 PPR	488	−0.2	−0.02
	20.0	8.9	11.1	10 PPR	484	0.6	0.05
Warrington	9.4	4.7	4.7	100	402	17.5	3.7
	10.0	4.7	6.2	100	229	53.0	8.5
	11.6	4.7	6.9	100	308	36.8	5.3
	12.4	4.7	7.7	100	254	47.8	6.2
	12.6	4.7	7.9	100	375	23.0	2.9
	13.2	4.7	8.5	100	274	43.7	5.1
	13.2	4.7	8.5	100	271	44.4	5.2

[a] 1 oz/ft² = 0.30 kg/m².
[b] 1 lb = 0.45 kg.
[c] See Table 11 for symbol definitions.

TABLE 28—*Breaking loads of wires removed during the 20-year period 1961 to 1981. Code No. 18—12½ gage aluminum-coated steel wire 0.43 oz/ft²,[a] original breaking load 490 lb.[b]*

Location	Years Exposed	Years to IR	Years Since IR	R, %[c]	Breaking Load Exposed, lb	Loss, %	% per Year Since IR
Kure Beach,	16.0	...	0	0	477	2.7	...
800 ft lot	17.1	...	0	0	485	1.0	...
Newark	15.8	...	0	0	507	−3.5	...
	19.1	...	0	0	510	−4.1	...
	20.0	...	0	0	498	−1.6	...
State College	15.8	9.8	6.0	5	488	0.4	0.1
	19.1	9.8	9.3	7	515	−5.1	−0.5
	20.0	9.8	10.2	7 PPR	509	−3.9	−0.4
Warrington	13.2	5.8	7.4	40	455	7.1	1.0
	13.2	5.8	7.4	40	484	1.2	0.2

[a] 1 oz/ft² = 0.30 kg/m².
[b] 1 lb = 0.45 kg.
[c] See Table 11 for symbol definitions.

TABLE 29—*Breaking loads of wires removed during the 20-year period 1961 to 1981. Code No. 20—12½ gage aluminum-coated steel wire 0.37 oz/ft²,[a] original breaking load 565 lb.[b]*

Location	Years Exposed	Years to IR	Years Since IR	R, %[c]	Breaking Load Exposed, lb	Loss, %	% per Year Since IR
Kure Beach,	16.0	9.1	6.9	15	587	−3.9	−0.6
800 ft lot	17.1	9.1	8.0	15	571	−1.1	−0.1
	19.2	9.1	10.2	20	586	−3.7	−0.4
	20.2	9.1	11.1	25	568	−0.5	...
Newark	15.8	...	0	0	567	−0.4	...
	19.1	19.1	...	3 PPR	589	−4.2	−4.2
	20.0	19.1	0.9	5 PPR	566	−0.2	−0.2
State College	15.8	8.9	6.9	10	546	3.4	0.5
	19.1	8.9	10.2	10 PPR	606	−7.3	−0.7
	20.0	8.9	11.1	10 PPR	586	−3.7	−0.3
Warrington	13.2	5.8	7.4	75	509	9.9	1.3
	13.2	5.8	7.4	75	528	6.5	0.9

[a] 1 oz/ft² = 0.30 kg/m².
[b] 1 lb = 0.45 kg.
[c] See Table 11 for symbol definitions.

TABLE 30—*Breaking loads of wires removed during the 20-year period 1961 to 1981. Code No. 21—12½ gage aluminum-coated steel wire 0.37 oz/ft²,[a] original breaking load 768 lb.[b]*

Location	Years Exposed	Years to IR	Years Since IR	R, %	Breaking Load Exposed, lb	Loss, %	% per Year Since IR
Kure Beach, 800 ft lot	16.0	...	0	0	757	1.4	...
	17.1	...	0	0	548	28.7	...
	18.2	...	0	0	784	−2.1	...
Newark	15.8	...	0	0	787	−2.5	...
	19.1	...	0	0	796	−3.6	...
	20.0	...	0	0	764	0.5	...
State College	15.8	...	0	0	750	2.3	...
	19.1	...	0	0	798	−3.9	...
	20.0	...	0	0	791	−3.0	...
Warrington	13.2	...	0	0	729	5.1	...
	13.2	...	0	0	788	−2.6	...

[a] 1 oz/ft² = 0.30 kg/m².
[b] 1 lb = 0.45 kg.

TABLE 31—*Breaking loads of wires removed during the 20-year period 1961 to 1981. Code No. 22—12½ gage aluminum-coated steel wire 3.36 oz/ft²,[a] original breaking load 1012 lb.[b]*

Location	Years Exposed	Years to IR	Years Since IR	R, %	Breaking Load Exposed, lb	Loss, %	% per Year Since IR
Kure Beach, 800 ft lot	16.6	...	0	0	1009	0.3	...
	17.4	...	0	0	1084	−7.1	...
Newark	15.8	...	0	0	1047	−3.5	...
	19.1	...	0	0	1055	−4.2	...
	20.0	...	0	0	1041	−2.9	...
State College	15.8	...	0	0	1005	0.7	...
	19.1	...	0	0	1053	−4.1	...
	20.0	...	0	0	1040	−2.8	...
Warrington	13.2	...	0	0	950	6.1	...
	13.2	...	0	0	1035	−2.3	...

[a] 1 oz/ft² = 0.30 kg/m².
[b] 1 lb = 0.45 kg.

Summary

This atmospheric exposure investigation of aluminum-coated and zinc-coated wire and wire products was conducted by ASTM Committee A-5 on Metallic-Coated Iron and Steel Products. The data for the 20-year exposure in the U.S. and 13-year exposure in England were the basis for this report.

From the visual observations and the tension tests on unfabricated and fabricated wire and wire products the following information has been obtained:

1. The average corrosion rates to initial rusting (CIR) for aluminum-coated products, Table 12, and zinc-coated products, Table 13, were different for different locations.
2. Based on the all products average initial rusting rate on the aluminum-coated products, Table 12, the Warrington, England, site has the highest corrosion rate and Manhattan, Kansas, the lowest.
3. With the zinc-coated products, the all products average initial rusting rate, Table 13, is highest at Kure Beach (80 ft), North Carolina, and lowest at Manhattan, Kansas.
4. The statistical analysis of the tensile data showed a linear relationship between the percent loss of breaking load and years of exposure. The loss of breaking load increased as the years of exposure increased.
5. The rate of loss of breaking load per year for uncoated and zinc-coated wire were different for different locations. The maximum difference for bare wire was a ratio of 4:1 for Warrington and Newark, New Jersey. The maximum difference for zinc-coated wire was a ratio of 4.2:1 for Warrington and State College, Pennsylvania.
6. The rate of loss of breaking load per year for zinc-coated wire decreased with increase in coating weight.
7. The rate of loss of breaking load per year for aluminum-coated wire decreased with increase in wire diameter.
8. The copper-containing steel wire is more resistant to corrosion than the copper-free steel wire.

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