CORROSION RESISTANCE OF THE AUSTENITIC CHROMIUM-NICKEL STAINLESS STEELS IN ATMOSPHERIC ENVIRONMENTS

A PRACTICAL GUIDE TO THE USE OF NICKEL-CONTAINING ALLOYS

Nº 318

Produced by
INCO

Distributed by
NICKEL
INSTITUTE

Nickel
INSTITUTE
knowledge for a brighter future

CORROSION RESISTANCE OF THE AUSTENITIC CHROMIUM-NICKEL STAINLESS STEELS IN ATMOSPHERIC ENVIRONMENTS

A PRACTICAL GUIDE TO THE USE
OF NICKEL-CONTAINING ALLOYS
Nº 318

Originally, this data book was published in 1963 by INCO, The International Nickel Company Inc. Today this company is part of Vale S.A.
The Nickel Institute republished the handbook in 2022. Despite the age of this publication the information herein is considered to be generally valid.

Nickel Institute

communications@nickelinstitute.org
www.nickelinstitute.org

AISI and ACI Standard Composition Ranges for Wrought and Cast Chromium-Nickel Stainless Steels

American Iron and Steel Institute Classification of Chromium-Nickel Stainless Steels

AISI Type	Composition, %								
	C max	Mn max	P max	S max	Si max	Cr	Ni	Mo	Other
201	0.15	5.50–7.50	.060	.030	1.00	16.00–18.00	3.50–5.50	—	N 0.25 max
202	0.15	7.50–10.00	.060	.030	1.00	17.00–19.00	4.00–6.00	—	N 0.25 max
301	0.15	2.00	.045	.030	1.00	16.00–18.00	6.00–8.00	—	—
302	0.15	2.00	.045	.030	1.00	17.00–19.00	8.00–10.00	—	—
302B	0.15	2.00	.045	.030	2.00–3.00	17.00–19.00	8.00–10.00	—	—
303	0.15	2.00	0.20	0.15 min	1.00	17.00–19.00	8.00–10.00	0.60 max	—
303Se	0.15	2.00	0.20	.06	1.00	17.00–19.00	8.00–10.00	—	Se 0.15 min
304	.08	2.00	.045	.030	1.00	18.00–20.00	8.00–12.00	—	—
304L	.03	2.00	.045	.030	1.00	18.00–20.00	8.00–12.00	—	—
305	0.12	2.00	.045	.030	1.00	17.00–19.00	10.00–13.00	—	—
308	.08	2.00	.045	.030	1.00	19.00–21.00	10.00–12.00	—	—
309	0.20	2.00	.045	.030	1.00	22.00–24.00	12.00–15.00	—	—
309S	.08	2.00	.045	.030	1.00	22.00–24.00	12.00–15.00	—	—
310	0.25	2.00	.045	.030	1.50	24.00–26.00	19.00–22.00	—	—
310S	.08	2.00	.045	.030	1.50	24.00–26.00	19.00–22.00	—	—
314	0.25	2.00	.045	.030	1.50–3.00	23.00–26.00	19.00–22.00	—	—
316	.08	2.00	.045	.030	1.00	16.00–18.00	10.00–14.00	2.00–3.00	—
316L	.03	2.00	.045	.030	1.00	16.00–18.00	10.00–14.00	2.00–3.00	—
317	.08	2.00	.045	.030	1.00	18.00–20.00	11.00–15.00	3.00–4.00	—
D319	.07	2.00	.045	.030	1.00	17.50–19.50	11.00–15.00	2.25–3.00	—
321	.08	2.00	.045	.030	1.00	17.00–19.00	9.00–12.00	—	Ti 5 x C min
347	.08	2.00	.045	.030	1.00	17.00–19.00	9.00–13.00	—	Cb-Ta 10 x C min
348	.08	2.00	.045	.030	1.00	17.00–19.00	9.00–13.00	—	Cb-Ta 10 x C min; Ta 0.10 max; Co 0.20 max
384	.08	2.00	.045	.030	1.00	15.00–17.00	17.00–19.00	—	—
385	.08	2.00	.045	.030	1.00	11.50–13.50	14.00–16.00	—	—

Alloy Casting Institute Division (SFSA) Classification of Chromium-Nickel Stainless Steel Castings

Cast Alloy Designation	Wrought Alloy Type[1]	Composition, %								
		C max	Mn max	P max	S max	Si max	Cr	Ni	Mo	Other
CA-6NM	—	.06	1.00	.04	.04	1.00	11.5–14	3.5–4.5	0.40–1.0	—
CD-4MCu	—	.04	1.00	.04	.04	1.00	25–26.5	4.75–6.00	1.75–2.25	Cu 2.75–3.25
CE-30	—	0.30	1.50	.04	.04	2.00	26–30	8–11	—	—
CF-3	304L	.03	1.50	.04	.04	2.00	17–21	8–12	—	—
CF-8	304	.08	1.50	.04	.04	2.00	18–21	8–11	—	—
CF-20	302	0.20	1.50	.04	.04	2.00	18–21	8–11	—	—
CF-3M	316L	.03	1.50	.04	.04	1.50	17–21	9–13	2.0–3.0	—
CF-8M	316	.08	1.50	.04	.04	1.50	18–21	9–12	2.0–3.0	—
CF-12M	316	0.12	1.50	.04	.04	1.50	18–21	9–12	2.0–3.0	—
CF-8C	347	.08	1.50	.04	.04	2.00	18–21	9–12	—	Cb 8 x C min, 1.0 max or Cb-Ta 10 x C min, 1.35 max
CF-16F	303	0.16	1.50	0.17	.04	2.00	18–21	9–12	1.5 max	Se 0.20–0.35
CG-8M	317	.08	1.50	.04	.04	1.50	18–21	9–13	3.0–4.0	—
CH-20	309	0.20	1.50	.04	.04	2.00	22–26	12–15	—	—
CK-20	310	0.20	1.50	.04	.04	2.00	23–27	19–22	—	—
CN-7M	—	.07	1.50	.04	.04	1.50	18–22	27.5–30.5	2.0–3.0	Cu 3–4

[1]Wrought alloy type numbers are included only for the convenience of those who wish to determine corresponding wrought and cast grades. The chemical composition ranges of the wrought materials differ from those of the cast grades.

Corrosion Resistance of the Austenitic Chromium-Nickel Stainless Steels in Atmospheric Environments

INTERPRETING CORROSION TEST DATA

The quantitative data secured in corrosion tests are often of a very low order of magnitude. When the corrosion rate is of the order of less than 0.1 mils penetration per year, the actual numbers carry little significance. If, for example, a test indicates a corrosion rate of .001 mils penetration per year for steel A, and .002 for steel B, it should not be concluded that steel A is twice as good as steel B, but rather that both steels are entirely suitable for service in the environment.

* * *

SELECTION of stainless steels to resist atmospheric corrosion is generally based on good initial appearance, easily maintained, together with durability. The behavior of most metals in these respects can be influenced by many factors, such as relative humidity, quantity and frequency of rainfall, proximity to the ocean, extent and type of industrial pollution, velocity and direction of prevailing winds, and the average ambient air temperature. Behavior can be further complicated by the type of exposure of the material, which may be bold or sheltered. In addition to atmospheric conditions, other factors such as surface condition, fabrication procedures, general design and the mating of dissimilar materials may have a pronounced influence.

The austenitic stainless steels possess an ability to retain a substantially unchanged appearance after long exposure to the atmosphere under many conditions. In outdoor architectural applications, for example, extraneous films of soot and dirt may deposit, but when they are removed the stainless steel is usually found to be unattacked and to have retained its lustrous appearance (see Table I).

SURFACE PREPARATION

Despite their inherent integrity, these steels are not fool-proof. Proper surface preparation is important for achieving the best results in atmospheric applications. A clean metal surface, free of defects and foreign matter, is required for optimum performance. Generally, a highly polished surface will have greater resistance to corrosion than one not so perfectly finished.

Metal surfaces may become contaminated during machining or fabricating operations. Small particles of steel from tools and other foreign matter can become embedded in the stainless surface and promote localized pitting and rust staining during atmospheric exposure. Non-metallic abrasives should be used for grinding operations, and wire brushing should be done with brushes having stainless steel bristles.

Elimination of surface contamination on stainless steels can be achieved by pickling the metal in 20 per cent nitric acid or a 25 per cent nitric acid-2 per cent sodium dichromate solution maintained at 120 F.[2] The data in Table II illustrate the effect of pickling on the performance of several stainless steels in the marine atmosphere at Kure Beach, N. C.

RURAL ATMOSPHERES

There is no corrosion problem in the use of austenitic stainless steels for service in rural or other uncontaminated atmospheres. Any of these steels will serve indefinitely without significant changes in appearance or losses in strength even in areas where the relative humidity approaches 100 per cent. The results of tests in rural locations in the United States, Canada and the Canal Zone are included in Tables III[3], IV[4], XIV[5] and XV[6]. Selection for such applications can be based on cost, availability in the sizes and shapes required, mechanical properties, ease of fabrication and appearance.

INDUSTRIAL ATMOSPHERES

The excellent resistance of the chromium-nickel stainless steels to changes in appearance during long exposures to industrial atmospheres is clearly indicated by the data in Table V[7]. Even after 26 years of exposure, all are free from complete rusting and show only moderate rust staining. The corrosion is so slight that it is impractical to measure it by such means as the weight loss determination commonly used with more vulnerable materials. Furthermore, determinations of changes in tensile strength and ductility usually fail to show any significant structural damage after long periods. For example, there was substantially no change in the tensile strength and the elon-

TABLE I

Appearance of Austenitic Stainless Steels After Exposure in Architectural and Structural Applications

AISI Type	Exposure Time, years	Location	Appearance
Office Buildings			
302	30	New York, N. Y.	Exterior trim: No corrosion (cleaned twice yearly) Tower surface: Covered with black deposit, no rusting (not cleaned)
302	29	New York, N. Y.	Exterior trim: Practically no deterioration since the building was erected
302	5	New York, N. Y.	Interior: No corrosion (cleaned nightly) Exterior: Still sparkles in sunshine (cleaned yearly)
302	18	Philadelphia, Pa.	Interior: Retains original appearance (cleaned regularly) Exterior: No signs of corrosion
302	11	Philadelphia, Pa.	Exterior: No signs of corrosion (cleaned frequently)
202	2	Chicago, Ill.	Exterior: No signs of corrosion (cleaned monthly)
302	—	Chicago, Ill.	Exterior: Excellent condition (frequent cleaning); slight pits (infrequent cleaning)
302	10	Pittsburgh, Pa.	Interior: Excellent condition (cleaned regularly) Exterior: Traces of rust and a few pits on window sills (dirt contained chlorides), slight pits on spandrels
302	6	Cleveland, Ohio	Interior: Excellent condition (cleaned regularly) Exterior: No corrosion (not cleaned since shortly after erection)
302	14	Miami Beach, Fla.	Exterior: No corrosion although located 1200 ft from ocean (cleaned regularly)
302	10	Miami Beach, Fla.	Exterior: No corrosion although located 1000 ft from ocean (cleaned regularly)
Industrial Buildings			
301	10	Cleveland, Ohio	Exterior: Superficial rust spots caused by salt used in winter, otherwise no corrosion (never cleaned)
302	1	Indian River, Fla.	Exterior: Slight staining typical of chloride atmosphere (cleaned once)

Report of ASTM Committee A-10[1]

TABLE II

Effect of Pickling on Performance of Stainless Steels in the Atmosphere 734 Days—800 ft from Ocean, Kure Beach, N. C.

AISI Type	% of Surface Covered by Light Rust Stain	
	Not Pickled	Pickled*
202	20–85	20
302	20–55	8–20
316	5–35	2–10

* Specimens cleaned in HNO_3 before exposure.
International Nickel Company data.

TABLE III

Atmospheric Corrosion of Austenitic Stainless Steels in Canadian Locations[1]

Site	Atmosphere	Corrosion Rate, mpy	
		Type 302	Type 316
Ottawa	Semi-rural	nil	nil
Saskatoon	Rural	nil	nil
Montreal	Industrial	nil	nil
Halifax	Industrial	.019	.013
Halifax	Rural-marine	nil	nil
Norman Wells	90 Miles South of Arctic Circle	nil	nil
Esquimault	Rural-marine	nil	nil
Trail	Semi-rural	nil	nil

[1] Examined after 2 years exposure. Gibbons [3]

TABLE IV

Appearance of Austenitic Stainless Steels After 8 Years Exposure in Tropical Atmospheres

AISI Type	Marine Atmosphere, Cristobal, C.Z.	Inland Atmosphere, Miraflores, C.Z.
301	No significant damage, no pitting	No significant damage, no pitting
316	No significant damage, no pitting	No significant damage, no pitting
321	No significant damage, no pitting	No significant damage, no pitting

Alexander, Southwell, and Forgeson [4]

gation of Type 302 stainless steel after 15 years of exposure in New York City, where the SO_2 content of the air was abnormally high. The data from these tests are summarized in Table VII[9].

Exposure of specimens with considerable internal stress resulting from severe cold deformation has shown no susceptibility to stress corrosion cracking in the atmosphere[10, 11, 12].

When chlorides are present in an industrial atmosphere, they may lead to more intensive attack on the stainless steels, as indicated in Table VIII[13]. Specimens in mid-town New York City remained practically unaffected for more than 25 years; whereas specimens near Niagara Falls near chemical plants producing chlorine and hydrochloric acid showed marked rusting in much shorter periods. These severe conditions were highly localized even in Niagara Falls. Specimens exposed for several years at a location two miles north of these same chemical plants were practically unchanged.

Specimens of several stainless steels were exposed to the highly polluted atmosphere of a steel works in Sheffield, England[14]. In this location the molybdenum modified 18-8 alloy demonstrated an advantage over the straight 18-8 composition with respect to localized attack under the accumulated dirt. The depth of attack after five years did not exceed 5 mils with the 18-8 alloy, while it was no deeper than 0.2 mils with the alloy that contained 2½ per cent molybdenum.

If the stainless steel in an industrial atmosphere is partially sheltered so that deposits are not washed away by rain, these deposits may be sufficiently hygroscopic and corrosive to lead to some attack that would not otherwise be encountered in the same location. The effects of such shelter are shown in Table VI[7, 8]. The boldly exposed specimens remained virtually unattacked. In the locations sheltered by a roof only the Types 316 and 317 stainless steels, which contain molybdenum, remain unattacked. These data further demonstrate the effectiveness of molybdenum in reducing pitting as well as general corrosion.

MARINE ATMOSPHERES

In marine atmospheres the ordinary 18-8 alloys may develop superficial staining in the form of scattered patches of yellowish-brown films with little evidence of attack beneath the films. This discoloration develops during the first few months of exposure, after which it does not appear to progress much further. The extent of development of these rust stains in a short period is illustrated in Table IX by inspection notes on the appearance of several austenitic stainless steels after exposure for one year in the marine atmosphere at Kure Beach, N. C. As indicated in

TABLE V

Appearance of Some Chromium-Nickel Stainless Steels Exposed at Bayonne, N. J., for 26 Years

Composition, %						Total Number of Specimens	Number of Specimens With Appearance Indicated		
Cr	Ni	C	Mn	Si	Other		Slightly Affected	Rust Spotted	Completely Rusted
19.9	6.9	0.15	0.35	0.38	2.5 Mo	9	9	0	0
19.8	7.0	0.16	0.50	0.59	—	9	9	0	0
20.8	6.8	0.18	0.34	0.38	3.0 Cu	9	8	1	0
20.1	—	0.27	.09	0.46	1.1 Cu	9	8	1	0
17.7	8.1	0.14	0.17	0.34	—	9	6	3	0
15.1	16.0	0.14	1.0	0.93	1.7 Ti	8	2	6	0
15.6	10.3	0.12	0.41	0.38	—	6	1	5	0

Copson [7]

TABLE VI

Effect of Shelter on the Corrosion of Stainless Steels in an Industrial Atmosphere Exposed Vertically at Bayonne, N. J., 11.88 years

AISI Type	Composition, %			Sheltered		Bold	
	Cr	Ni	Other	mpy	Pit Depth, mils	mpy	Pit Depth, mils
301	17.7	8.1	—	<.001	3	Nil	Nil
302	18.6	10.1	—	<.001	5	Nil	Nil
304	18.4	8.9	—	.011	7	Nil	Nil
321	18.7	9.7	0.48 Ti	.007	6	Nil	Nil
347	18.6	11.2	0.78 Cb	.008	6	Nil	Nil
316	17.8	13.1	2.8 Mo	Nil	<1	Nil	Nil
317	18.6	14.1	3.5 Mo	Nil	<1	Nil	Nil
308	20.4	10.7	—	.003	7	Nil	Nil
309	23.6	13.6	—	<.001	1	Nil	Nil
310	24.1	19.8	—	.001	6	Nil	Nil

Copson [7, 8]

TABLE VII

Performance of Type 302 Stainless Steel in a Severe Industrial Atmosphere
15-Year Exposure in New York City

Corrosion Rate (Average of 8 Specimens)	Tensile Strength, psi		Elongation (2 in.), %	
	Control	Exposed 15 yr	Control	Exposed 15 yr
.001 mpy	101,300	104,200	58	57
	114,500	103,800	57	60
	102,300	99,300	60	64

Williams and Compton [9]

TABLE VIII

Corrosion of Austenitic Stainless Steels* in Industrial Atmospheres

AISI Type	New York City		Niagara Falls, N. Y.	
	Exposure Time, years	Surface Condition	Exposure Time, years	Surface Condition
302	5	No rust stains	<2/3	Rust stains
302	26	No rust stains	—	—
304	26	No rust stains	<1	Rust stains
304	—	—	6	Covered with rust, pitted
310	—	—	<1	Rust stains
310	—	—	6	Rust spots, pitted
316	23	No rust stains	<2/3	Slight stains
316	—	—	6	Slight rust spots, slight pitting
317	—	—	<2/3	Slight stains
317	—	—	6	Slight stains
347	26	No rust stains	—	—

* Sheet 1/16 in. thick, solution annealed. Metals Handbook [13]

Table X, the rust stain is easily removed even after 15 years to reveal a bright surface which has suffered very little attack. The staining is reduced appreciably in the highly alloyed Type 309 stainless steel composition and is practically eliminated in Types 310 and 316.

The shallow pitting that was observed in no way detracted from the appearance of the surface after removal of the rust stains and had no effect on the mechanical properties of the material. This is illustrated in Table XI by the tensile data for Type 302 stainless steel before and after this 15-year exposure.

The intensity of staining is greatly diminished as distance from the ocean increases, although Type 316, which contains molybdenum, remains almost free from stain for long periods of time even when exposed as close as 80 feet from the ocean.

TABLE IX

Appearance of Austenitic Stainless Steels After Exposure in a Marine Atmosphere for One Year, 800 ft from Ocean, Kure Beach, N. C.

AISI Type	Appearance
301	Scattered faint rusting, several well developed rust spots.
302	Scattered general rusty discoloration over entire surface.
304	Scattered faint rusting.
308	Scattered faint rusting, about the same as Type 304.
309	Scattered faint rusting with several well developed rust spots, but less than with Type 304.
310	Scattered faint rusting, about the same as on Types 316 and 317.
316	Scattered faint rusting, much less than on Type 304.
317	Scattered faint rusting, much less than on Type 304.
321	Scattered faint rusting with several well developed rust spots.
347	Scattered faint rusting with several well developed rust spots.

International Nickel Company data.

TABLE X

Performance of Stainless Steels in a Marine Atmosphere 15 Years, 800 ft from Ocean, Kure Beach, N. C.

AISI Type	Average Corrosion Rate, mpy	Average Depth of Pits, mils	Appearance*
301	<.001	1.6	Light rust and rust stain on 20% of surface.
302	<.001	1.2	Spotted with rust stain on 10% of surface.
304	<.001	1.1	Spotted with slight rust stain on 15% of surface.
321	<.001	2.6	Spotted with slight rust stain on 15% of surface.
347	.001	3.4	Spotted with moderate rust stain on 20% of surface.
316	<.001	1.0	Extremely slight rust stain on 15% of surface.
317	<.001	1.1	Extremely slight rust stain on 20% of surface.
308	<.001	1.6	Spotted by rust stain on 25% of surface.
309	<.001	1.1	Spotted by slight rust stain on 25% of surface.
310	<.001	0.4	Spotted by slight rust stain on 20% of surface.

* All stains easily removed to reveal bright surface.
International Nickel Company data.

TABLE XI

Effect of a Marine Atmosphere on the Tensile Properties of Type 302 Stainless Steel

(15 years at Kure Beach, 800 ft from ocean)

	Before Exposure	After Exposure
Tensile Strength, psi	164,000	164,000
	159,000	168,600
		168,600
		166,500
Yield Strength (0.2% offset), psi	129,300	130,800
	127,500	132,100
		136,100
		133,600
Elongation (2 in.), %	22	22.6
	23	22.6
		22.6
		22.6

International Nickel Company data.

TABLE XII

Galvanic Corrosion of Magnesium When Coupled to Type 304 Stainless Steel in ASTM "Button" Tests

Location	Duration of Test, years	Weight Loss of Magnesium, grams		% Increase of Weight Loss Due to Couple
		Control	Coupled to Type 304	
New York	4.19	0.143	0.218	52
State College	2.54	.034	.062	83
Kure Beach	2.48	.024	.089	271
Canal Zone	2.85	.027	.032	19

Teeple [15]

As a general rule, any of the austenitic stainless steels can be used in marine atmospheres if they are cleaned periodically. If this cleaning is not practical, the greatest resistance to staining would be achieved by using the molybdenum-containing Type 316.

GALVANIC CORROSION

Even in polluted, humid atmospheres, austenitic stainless steels usually do not corrode when coupled to other metals. The rate of attack on the other member of the couple may or may not increase. For example, austenitic stainless steels and aluminum alloys are used together as architectural trim in high humidity atmospheres with no serious corrosion problems.

In six-year exposure tests at Kure Beach, joints made with Type 302 stainless steel rivets in several aluminum alloys showed very small losses in strength. On the other hand, "button" tests show (Table XII) that coupling magnesium with Type 302 stainless can greatly increase the corrosion of magnesium[15].

In a similar series of five-year button tests of stainless steels in contact with several other metals and alloys, Types 304 and 316 stainless steels showed negligible weight losses at four locations that represented rural, industrial and marine atmospheres[16]. The other metals in the couples suffered some galvanic corrosion. The results of these tests are summarized in Table XIII as the ratio of weight losses of coupled to uncoupled specimens. It may be noted that the galvanic effects on other metals of the two stainless steels are quite similar.

ARCHITECTURAL AND STRUCTURAL APPLICATIONS

A task group of ASTM Committee A-10 inspects various buildings periodically to determine the effects of atmospheric exposure on the stainless steel components[17,18,19]. The results of an inspection in 1960 are reported in Table I[1].

Type 302 stainless steel has been exposed as architectural paneling on such buildings as the Chrysler Building for periods up to 30 years. Although the surfaces became covered with dirt, they were found, after cleaning, to be virtually free of corrosion. Inspection of buildings in New York, Pittsburgh, Chicago, Cleveland and Philadelphia shows that Types 301, 302 and 202

TABLE XIII

Galvanic Corrosion of Several Materials When Coupled to Types 304 and 316 Stainless Steels

(Ratio of Corrosion of Coupled to Uncoupled Specimens—see Text)

Material	Exposed to Atmospheres at:							
	New York, N. Y.		Altoona, Pa.		State College, Pa.		Kure Beach, N. C.	
	Coupled to:		Coupled to:		Coupled to:		Coupled to:	
	304	316	304	316	304	316	304	316
Aluminum	3.0	3.9	0.75	0.75	2.5	1.5	1.1	0.75
Aluminum Alloy 2024	4.5	4.6	2.6	2.9	2.1	1.0	2.3	2.0
Aluminum Alloy 5053	1.8	1.8	2.5	3.8	2.0	1.7	5.2	4.8
Copper	1.9	1.9	—	2.1	2.2	2.3	1.5	1.9
Architectural Bronze	1.5	1.5	1.4	1.4	1.8	1.8	1.4	1.5
Lead	1.8	2.1	2.3	1.7	2.5	2.6	2.1	2.2
Zinc	2.2	2.2	2.5	2.5	2.2	2.2	1.8	2.0
*Monel** Alloy 400	1.5	1.5	1.7	1.6	2.3	1.7	1.9	1.9
Mild Steel	1.4	1.3	2.0	1.2	1.5	1.3	2.2	2.2

* Inco Registered Trademark   Report ASTM Committee B-3, Subcommittee VIII [16]

TABLE XIV

Atmospheric Behavior of 18 Cr-8 Ni Stainless Steel Wire

(20-Year Tests)

Location	Type of Atmosphere	Fabricated Wire	Chain Link Fence	Farm Field Fence
Pittsburgh, Pa.	Severe Industrial	D[b]	D[c]	—
Sandy Hook, N. J.[a]	Seacoast	MG	G	—
Bridgeport, Conn.	Industrial	G	MG	G
State College, Pa.	Rural	MG	MG	MG
Lafayette, Ind.	Rural	M	M	M
Ithaca, N. Y.	Rural	M	M	M
Ames, Iowa	Rural	MG	—	M
Manhattan, Kansas	Rural	M	—	M
College Station, Texas	Rural	GY	—	M, SY
Santa Cruz, Calif.	Rural (marine)	MG	MG	MG
Davis, Calif.	Rural	MG	MG	MG

[a] Site abandoned after 14.4 years of exposure.
[b] Few scattered pits under black soot.
[c] Discontinued after 10 years of exposure.

Code:
M = metallic.
G = gray.
MG = intermediate between metallic and gray.
Y = yellowed or rust stained, but not showing actual rust of base metal.
SY = speckled appearance of rust or yellowing.
GY = predominantly gray but showing indication of Y.
D = dark or dirt or soot excluding a better observation.

Report of ASTM Committee A-5, Subcommittee XV [5]

will give dependable service in industrial atmospheres. If chlorides are present, as in the Florida sites, there is some staining; but periodic cleaning will maintain a bright surface. In close proximity to the sea, Type 316 is superior to Types 301, 302 and 202.

TRANSPORTATION

Selection of steel for mobile equipment on land presents a problem because of the varied conditions of exposure. The austenitic stainless steels are usually satisfactory for such service and may be required when the vehicle is exposed to salt laden streets, sea spray or severely contaminated atmospheres.

A number of all-stainless steel passenger railroad cars were constructed of Type 301 as early as 1937. Others were built later of Type 201. More than one hundred of these cars are still free of pitting and other serious corrosion on roofs and panels. These cars have been subjected not only to a wide range of atmospheric conditions but also to a variety of chemical cleaning agents.

TABLE XV

Results of Tests on Type 316 Stainless Steel Insect Screens

Location	Time, years	Average Loss in Strength, %	
		Partly Sheltered	Unsheltered
Moderate Industrial (Bayonne, N. J.)	2.7	0	0
	4.6	0	0
	8.0	0	0
	26.0	0	0
Heavy Industrial (Steam Railroad Terminal)	2.2	0	0
	3.8	0	0
	7.7	0	1
Marine (Block Island)	3.3[a]	0[c]	3
	3.3[b]	3[c]	6
Rural	4.8	0	0

[a] Facing landward. [b] Facing seaward.
[c] Completely sheltered from rain.

Wesley and Copson [6]

Truck trailers, made of Types 201 and 301, have remained free of rust despite exposure to road dirt, salts, spray and other severe service conditions.

WIRE AND WIRE SCREENS

A subcommittee of the ASTM on Atmospheric Exposure Tests of Wire and Wire Products reported on the behavior of 18Cr-8Ni stainless steel wire after 20 years in a number of locations. A summary of this inspection is given in Table XIV[5]. In only one location did any sign of rust staining appear. Additional tests of Type 316 stainless steel insect screens in the marine atmosphere at Kure Beach have shown negligible staining even after 14 years in both boldly exposed and partially sheltered locations 80 feet and 800 feet from the ocean[6]. Tests of Type 316 screens in other locations have provided confirming data, as shown in Table XV.

Because of the absence of corrosion, the Type 316 stainless steel insect screens offer an important advantage, in that they do not form soluble corrosion products that will run down and stain paint or stucco below the screens.

SMALL BOAT HARDWARE

Austenitic stainless steel deck fittings exposed to marine atmospheres with occasional wetting by sea water show only superficial rusting, which can be removed with most household cleaners. In a four-year exposure test at Kure Beach, N. C., boat hardware of Type CF-20 (cast counterpart of Type 302) showed only small rust spots, stains and incipient pits, even though the specimens received no cleaning attention during the test. All rust was readily removed with a mild abrasive at the end of the test period. Other results of exposure of boat hardware are given in Table XVI.

TABLE XVI

Appearance of Austenitic Stainless Steel Boat Hardware After Three Years Exposure 80 Feet from the Ocean at Kure Beach, N. C.

Fitting	Material	Condition
Plain Block	Sides, Strap: Type 304 Becket Rivets: Type 303 (All components were electropolished)	Rust stains darkest on burred ends of rivets. Surfaces 25 to 60% covered by rust stains; remaining surface tarnished. Metal surfaces remained in good condition and could be cleaned easily with a mild abrasive. Sheave turned freely.
Swivel Block	Sides, Strap: Type 304 Becket Rivets: Type 303 (All components were electropolished and buffed)	General appearance much the same as above but rust stain was lighter, excepting on swivel rivet and washers. Sheave was frozen but could be freed easily.
Barrel	Type 303 Tubing (Pickled, annealed, electropolished and buffed)	Metal surface in good condition. Rust stains covered 75% of surface and were heaviest at the ends; remaining 25% of surface had a dull finish. Stains could be removed easily with a mild abrasive.
Goose-Neck	Strap: Type 304 Clevis Pins: Type 303 (All components were electropolished)	Rust stains covered 50 to 60% of the surface and were heaviest at the clevis pins and adjacent areas; remaining surface tarnished. All components functioned freely. Stains could be removed easily with a mild abrasive.

International Nickel Company data.

REFERENCES

1. "Report of Inspection of Corrosion Resistant Steels in Architectural and Structural Applications," Appendix to ASTM Committee A-10, Proc. ASTM, *61,* 1961, p 188.
2. "Recommended Practice for Descaling and Cleaning Stainless Steel Surfaces," ASTM Designation A 380-57, ASTM Standards 1961, p 1182.
3. Gibbons, E. V., "The Corrosion Behavior of the Major Architectural and Structural Metals in Canadian Atmospheres—Summary of Two-Year Results," Report of Subcomm. C-Atmospheric Corrosion Testing, Nat. Research Council of Canada, February 24, 1959.
4. Alexander, A. L., Southwell, C. R., and Forgeson, B. W., "Corrosion of Metals in Tropical Environments," Corrosion, *17,* 1961, p 345T.
5. "Report of ASTM Committee A-5, Subcommittee XV on Atmospheric Tests of Wire and Wire Products," Proc. ASTM, *61,* 1961, p 142.
6. Wesley, W. A., and Copson, H. R., "Weathering Behavior of Corrosion Resistant Steel Insect Screens," Proc. ASTM, *46,* 1946, p 652.
7. Copson, H. R., "Atmospheric Corrosion Behavior of Some Nickel Alloys," Symposium on Atmospheric Corrosion of Non-Ferrous Metals, ASTM Spec. Tech. Pub. No. 175, 1955, p 155.
8. Copson, H. R., "Design and Interpretation of Atmospheric Corrosion Tests," Corrosion, *15,* 1959, p 533T.
9. Williams, I. V., and Compton, K. G., "Results of 15 Years' Exposure Tests on Corrosion Resistant Steels," Symposium on Atmospheric Weathering of Corrosion Resistant Steels, Proc. ASTM, *46,* 1946, p 673.
10. Franks, R., Binder, W. O., and Brown, C. M., "The Susceptibility of Austenitic Stainless Steels to Stress-Corrosion Cracking," ASTM-AIME Symposium on Stress-Corrosion Cracking, 1945, p 411.
11. Ellis, O. B., "Some Examples of Stress-Corrosion Cracking of Austenitic Stainless Steel," ASTM-AIME Symposium on Stress-Corrosion Cracking, 1945, p 421.
12. Field, A. L., "Joint Discussion on Stainless Steel," ASTM-AIME Symposium on Stress-Corrosion Cracking, 1945, p 426.
13. Metals Handbook—Volume 1, pub. by Am. Soc. Metals, 1961, p 555.
14. Shirley, H. T., and Truman, J. E., "A Study of the Corrosion Resistance of High Alloy Steels to an Industrial Atmosphere," J. Iron Steel Inst. *160,* 1948, p 367.
15. Teeple, H. O., "Atmospheric Corrosion of Magnesium Coupled to Other Metals," Symposium on Atmospheric Corrosion of Non-Ferrous Metals, ASTM Spec. Tech. Pub. No. 175, 1955, p 93.
16. "Report of Subcommittee VIII on Galvanic and Electrolytic Corrosion," Proc. ASTM, *48,* 1948, p 167
17. "Report of the Special Subcommittee on Inspection of Stainless Steel Architectural Structures," Proc. ASTM, *39,* 1939, p 197.
18. "Supplementary Report on Inspection of Stainless Steel Architectural Structures," Proc. ASTM, *40,* 1940, p 118.
19. "Report of ASTM Committee A-10 Task Group Inspections of Corrosion Resistant Steels in Architectural and Structural Applications," Proc. ASTM, *55,* 1955, p 160.