...-2228 (NBS)

The Corrosion Behavior of Selected Stainless Steels in Soil Environments

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Center for Materials Science
U.S. Department of Commerce
National Bureau of Standards
Washington, DC 20234

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American Iron and Steel Institute
...0 16th Street, N.W.
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ERRATA TO ACCOMPANY NBS REPORT, NBSIR 81-2228 (NBS), THE CORROSION BEHAVIOR OF SELECTED STAINLESS STEELS IN SOIL ENVIRONMENTS BY W. F. GERHOLD, E. ESCALANTE AND B. T. SANDERSON

PAGE	LINE	NOW READS IN PART	SHOULD READ
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FIGURE	LINE	NOW READS IN PART	SHOULD READ
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27	6	(lower right corner)	(upper right corner)
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U.S. DEPARTMENT OF COMMERCE, Malcolm Baldrige, *Secretary*
NATIONAL BUREAU OF STANDARDS, Ernest Ambler, *Director*

A. INTRODUCTION

Stainless steels* have been successfully used in limited applications (such as for pipe clamps on cast-iron sewer lines) in soil environments for many years. In recent years, other applications in use or under test include ground rods, transformer cases, submerged switches, underground residential distribution equipment, gas lines [1, 2], water lines, caskets, culverts, residential sewage disposal systems, etc.

Corrosion data for selected annealed, unstressed austenitic, martensitic and ferritic stainless steels, buried in various soils, have been reported in NBS Circular 579 [3]. Tests conducted for 14 years in various soils in the United States by NBS showed that austenitic Type 304 (containing Ni) and Type 316 (containing Ni and Mo) stainless steels were highly resistant to both pitting corrosion and general attack. Type 304 was susceptible to pitting corrosion in certain highly aggressive soils, while Type 316 was relatively unaffected by corrosion. The martensitic Type 410 (12% Cr) and the ferritic Type 430 (17% Cr) stainless steels were found to be fully resistant in only one-third of those soils where they were exposed. Branch [1] and Steinmetz and Hoxie [2] have reported on the suitability of stainless steels for some underground uses. Stress corrosion cracking has not been reported to be a problem with Types 304 or 316 in actual underground applications [1]. In a 2 year exposure to various soils in and around Baltimore, Maryland, Type 304 gas service lines [50 for a total length of 1 mile (1.61 km)] were

*The term "stainless steel" is broadly used in industry to describe a number of different alloys of widely varying composition, corrosion resistance, mechanical properties and microstructures. The essential alloying element added to iron to form stainless steels is chromium, which is present from 10 - 30 percent. In many stainless steels, additional alloying elements are used such as nickel and/or molybdenum to enhance corrosion resistance.

reported to have suffered no corrosion effects [2]. However, one of these lines had failed after a little over five years of service in an area close to a road where deicing salts were used. Because of the critical nature of the service, it was decided to cathodically protect the remaining lines [4].

In order to evaluate more fully the corrosion and stress corrosion behavior of some of the different types of stainless steels considered for use in soil environments, NBS in cooperation with the Committee of Stainless Steel Producers, American Iron and Steel Institute, initiated in 1970 a soil burial program in corrosive soils utilizing 9 stainless steels in both the annealed and cold worked conditions with various treatments. Test specimens incorporated welds, crevices, galvanic couples and specimens which had been sensitized to induce carbide precipitation. In 1971 and in 1972, this program was expanded to include additional stainless steels. The results obtained for specimens buried in the soils for up to 4 years were reported in 1976 [5]. This report contains the results obtained for specimens buried at the NBS soil test sites for up to 8 years.

B. EXPERIMENTAL PROCEDURE

1. Soils at NBS Test Sites

Some of the properties of the soils at the NBS test sites are given in Table 1. The relative corrosivity of these soils on plain carbon steel is shown in Fig. 1. However, the corrosivity of these soils towards stainless steels may not necessarily be the same as with carbon steel. The following are detailed descriptions of the soils at the test sites which have been selected by NBS from 128 test sites previously evaluated to represent the range of soil properties having a bearing on the corrosivity of metals in soils:

Sagemoor Sandy Loam (Site A) is a well-drained alkaline soil with a resistivity of 400 ohm-cm and a pH of 8.8 and is typical of that found in vast areas of eastern Washington and Oregon. The site is located on the Yakima Indian Reservation near Toppenish, Washington. The soil is consistent in composition to a depth of at least 7 feet (2.13 m) and supports an abundant growth of sage-brush.

Hagerstown Loam (Site B) is a well-drained soil representative of the majority of well-developed soils found in the eastern part of the United States. The site is located at the Loch Raven Reservoir of the Baltimore Water Department. The soil consists of a brown loam about 1 foot (0.30 m) deep, underlain by reddish-brown clay that extends about 5 feet (1.52 m) or more to underlying rock. The soil has a resistivity in the range of 12,600 to 37,300 ohm-cm and a pH of 5.3. Practically all of the materials that have been investigated in the extensive NBS soil corrosion tests have been exposed at this site which, therefore, can serve as a reference site for the correlation of data obtained for specimens in the present program with data obtained from the earlier tests.

Clay (Site C) is located in a large clay pit on level land at the U. S. Coast Guard Receiving Center, Cape May, New Jersey, and is subject to flooding during heavy rains. The soil consists of a plastic gray clay to a depth of 6 inches (15.24 cm) underlain by gray clay mixed with patches of brown clay to a depth of 12 inches (30.48 cm). This is underlain by a poorly drained very heavy plastic clay in which the specimens are exposed. The soil has a resistivity which ranges from 400 to 1150 ohm-cm and a pH of 4.3.

Lakewook Sand (Site D) is a white, loose sand with some black streaks occurring in places and supports an abundant growth of beach grasses. The site is located in a well-drained rolling area on the property of the U. S. Coast Guard Electronic Engineering Station, Wildwood, New Jersey. This site is not subject to overflow from the ocean except under unusual flood conditions. The sand has a pH of 5.7 and the resistivity ranges from 13,800 to 57,500 ohm-cm.

Coastal Sand (Site E) is a typical white, coastal beach sand with a high content of black sand; at this site, however, the sand is constantly damp and is occasionally flooded with sea-water. The site is located on the Two-Mile Beach on the property of the U. S. Coast Guard Electronic Engineering Station, Wildwood, New Jersey. The sand has a pH of 7.1 and the resistivity ranges from 1,320 to 49,500 ohm-cm.

Tidal Marsh (Site G) is a soil typical of the poorly-drained marsh soils that are found along the Atlantic and Gulf coasts. The site is located along a creek (Pine Hill Run) that empties into the Chesapeake Bay at the Patuxent Naval Air Station, Lexington Park, Maryland. The soil is naturally charged with hydrogen sulfide and has a resistivity in the range from 400 to 15,500 ohm-cm and a pH of 6.0.

2. Materials, Treatment and Preparation

In order to simulate some of the conditions that may be encountered with components fabricated from stainless steels, materials for these soil corrosion studies included stressed and unstressed flat sheet specimens with and without welds, welded tube specimens, coated specimens, sensitized specimens, and stressed and unstressed galvanically coupled specimens.

Descriptions of the various stainless steel systems buried at each test site including treatments and preparation are given in Table 2. The chemical analyses and mechanical properties of each alloy are given in Tables 3 and 4. Typical microstructures for each alloy are shown in Figs. 2 and 3.

Upon receipt of the specimens from the stainless steel producers, the specimens were first stamped with identification numbers using chromium plated steel dies. All of the flat sheet materials [approximately 0.06 inch (0.15 cm) thick] were supplied with sheared edges which had been deburred. In some instances further deburring was necessary. All of the materials to be exposed unstressed were then degreased in trichlorethylene vapor, passivated (using procedures described in Table 2), scrubbed with a fiber brush, thoroughly rinsed with water and then air dried.

Of the total number of coated [coal-tar epoxy, 16 mils (0.04 cm) per side] specimens (System No. 61), half were scored diagonally from the corners, twice on one surface, by cutting through the coating to the base material with a sharp pointed instrument. The other half of the coated specimens were exposed in the "as coated" condition.

The cross-bead welded flat sheet materials (System Nos. 3, 9, 11 and 54) were prepared in accordance with Welding Research Council recommendations. Typical microstructures for welded materials are given in Figs. 4 and 5.

Type 304 tube (System No. 57) was prepared in accordance with ASTM Specification A249. Type 409 tube (System Nos. 62 and 63) was tested in the "as-welded" condition. Except for cleaning and passivating, the proprietary alloys were tested as supplied by the producers. The ends of the tube specimens were plugged with rubber stoppers and then plastic or rubber caps were placed on each end to create a crevice.

All of the sheet materials to be stressed as either single or double U-bends had oblong holes, 1/4 inch x 1/2 inch (0.64 cm x 1.27 cm), punched near each end so as to be self aligning after bending. Specimens to be connected to a dissimilar metal (galvanic couples) had an additional hole 0.093 inch (0.236 cm) drilled 1/4 inch (0.64 cm) from the end and side for wire connections.

The specimens to be stressed were initially bent using a die (shown in Fig. 6) to about 20° (internal angle). The only portions of the die in contact with the specimens during the forming operation were fabricated from Type 304 stainless steel. The specimens were then cleaned and passivated using the same procedures noted above for unstressed specimens.

Single U-bend specimens were then formed by bending the two ends in a wooden jig so that they were parallel [the inside diameter at the bend was approximately 1 inch (2.54 cm)] and clamping them in this position with a Type 316 stainless steel nut and bolt. Double U-bend specimens for crevice and stress corrosion studies were formed in the same manner except that some were spot welded together (see Fig. 7) prior to the bending operation. They were then bent at the same time to form the U and clamped at the ends with Type 316 stainless steel fasteners.

For the galvanic couple studies, specimens were connected to steel (iron), zinc or magnesium anodes or to copper strips. Connection was made by soldering 14 gauge stranded copper wire to the specimen at the drilled hole using 50-50 acid core solder.

The iron anode consisted of a 1 foot (0.3 m) length of a cold finished steel (AISI 1017-1018) 3/4 inch (1.90 cm) hexagonal shaped rod with a hole [0.093 inch (0.236 cm)] drilled in the rod mid-way between each end for the electrical connection. The copper wire from the specimen was inserted in this hole and then soldered to the iron anode using 50-50 acid core solder.

The magnesium anode [4 feet (1.2 m) long and bent in the form of a horseshoe] was of the commercial flexible extruded type with an oval shaped cross-section 3/4 inch x 3/8 inch (1.90 cm x 0.95 cm) and a continuous centrally located 1/8 inch (0.32 cm) diameter iron wire core. The copper wire from the specimen was soldered to a 1 inch (2.54 cm) extension of the iron wire core using 50-50 acid core solder. In addition a bituminous (coal-tar epoxy) coating was applied to both 3/4 inch (1.90 cm) faces of the anode to extend its effective life.

The zinc anode [1 foot (0.30 m) long] was also of the commercial flexible extruded type with a diamond shaped cross section [5/8 inch x 7/8 inch (1.59 cm x 2.22 cm)] and a continuous centrally located 0.1 inch)0.25 cm) diameter zinc-coated (galvanized) iron wire core. The stranded copper wire from the specimen was soldered to an extension of the galvanized wire core.

Copper strips which were electrically coupled to the unstressed stainless steel specimens were cut from cold-rolled copper sheet, 0.065 inch (1.651 cm) thick and of the same dimensions as the stainless steel specimen [1 inch x 12 inches (2.54 cm x 30.48 cm)].

The areas at all soldered joints, including any exposed portions of the copper wire, were covered with a bituminous (coal-tar epoxy) coating.

3. Exposure

At each test site, the specimens were buried in trenches approximately 2-1/2 feet (0.76 m) deep and 2 feet (0.61 m) wide. The specimens were placed about 1 foot (0.30 m) apart. The 8 inch x 12 inch (20.32 cm x

30.48 cm) sheets buried in 1970 were placed in the trench in a vertical position with the short dimension horizontal, while those buried in 1971 and 1972 were placed in a vertical position with the long dimension horizontal. The specimens electrically connected to the steel and zinc anodes and to the copper strips were placed in the trench with the dissimilar metal parallel to the specimen and separated by approximately 1 foot (0.30 m). Specimens electrically connected to the horseshoe shaped magnesium anodes were placed at the center of the horseshoe. Upon backfilling the trenches, the insulated wires soldered to those specimens to be used in potential and corrosion current (couple corrosion) determinations were connected above ground to terminal strips mounted on 4 inch x 4 inch x 6 foot (10.16 cm x 1.83 m) wooden posts. Leads from the anodes and copper strips were connected to leads from the specimens at the terminal strips (potential and current measurements).

Sufficient specimens were buried at each of the 6 test sites to permit recovery of a complete set at specified intervals (1, 2, 4 and 8 years) and a final set to be removed at a later date to be determined. Each set of the 8 inch x 12 inch (20.32 cm x 30.48 cm) flat sheet systems and welded tube systems consisted of 4 specimens, while for the stressed and unstressed 1 inch x 12 inch (0.254 cm x 30.48 cm) sheet systems, each set consisted of 2 specimens.

The burial order for each test site is shown in Figs. 8a, b and c. One thousand fifty four (1054) specimens were buried at each test site for a total of 6324 specimens at the six test sites.

4. Electrochemical Measurements

All electrochemical measurements (potential, couple current, and corrosion current) were made at time of burial and subsequently 3 times a year when possible with the exception of Site A where measurements were usually made once a year.

Electrochemical potentials of the specimens and couples vs. a Cu-$CuSO_4$ half cell were measured using a high precision portable pH meter as a millivoltmeter. The half cell was placed in a remote area (usually at the edge of the test area) and shielded from light to prevent photochemical effects.

The couple currents of the anode systems and the stainless steel-copper systems were measured using a zero impedance circuit employing an operational amplifier (Fig. 9) for small currents and a commercially available zero resistance ammeter for larger currents.

Corrosion currents were measured using a modification of the linear polarization technique based on the following relationship derived by Stern and Geary [6]:

$$\frac{\Delta E}{\Delta I} = \frac{1}{2.31\ (I_{corr})} \frac{B_a B_c}{B_a + B_c}$$

where ΔE is the overvoltage of the corroding specimen produced by a polarizing current, ΔI. B_a and B_c are the slopes of the anodic and cathodic polarization curves, respectively, in the Tafel region and I_{corr} is the corrosion current. Assuming B_a and B_c equal to 0.1 V in this investigation (the error will usually be about 20% or less, as established by Stern and Weisert [7]), the following equation was derived:

$$I_{corr}\ (mA) = \frac{2.7\ \Delta I\ (mA)}{\Delta E\ (mV)}$$

The electrical circuit described previously [8], but minus the bridge circuit was employed. A soil auger was utilized as the auxiliary electrode. The change in potential was measured directly using the pH meter or an electrometer (0-10 mV scale) plus a battery and variable resistor (to null the initial potential) and a Cu-$CuSO_4$ reference electrode. Electrodes (auxiliary and reference) were placed so that the specimen was between them or at approximately right angles to them. In making these measurements, an increment of current was applied to the specimen until a stable overpotential of usually 2 to 10 mV occurred. The potential and current readings were then recorded.

Occasionally the open circuit potential of the stainless steel alloy was found to fluctuate and the corrosion current measurements could not be made. At other times, extremely humid or rainy conditions prevented these measurements.

5. Examination of Specimens After Exposure

Upon removal from the trench after burial for 1, 2, 4 or 8 years, each of the stressed specimens was examined for indications of failure by cracking. All specimens were then returned to the laboratory for cleaning and a more thorough examination.

In the laboratory, the specimens were rinsed in tap water to remove adhering soil particles. They were then examined visually prior to further cleaning. The stressed U-bend specimens were disassembled by removing the Type 316 stainless steel fasteners. The copper wires were unsoldered from those specimens that had been coupled to dissimilar metals.

All specimens, except the coated ones (System No. 61) and the composites (System Nos. 14, 15 and 16), were then further cleaned ultrasonically using a 10% nitric acid solution heated to 120° - 130 °F (49° - 54 °C) for 20 to 30 minutes. Specimens from System Nos. 14 and

16 were ultrasonically cleaned using an aqueous 10% ammonium citrate solution heated to 175° to 185 °F (73° - 85 °C). The time for cleaning these specimens varied and was dependent upon the tenacity of the corrosion scale. The specimens from System No. 15 were ultrasonically cleaned for approximately 30 minutes using an aqueous ammonium chloride solution at 175° - 185 °F (79° - 85 °C). After cleaning, the specimens were rinsed in hot tap water and then air dried. The unstressed sheet [8 inches x 12 inches (20.32 cm x 30.48 cm)] and tube specimens were then weighed twice and their weight loss was determined. The average loss in weight of similar unexposed (control) specimens given the identical cleaning process was subtracted from the weight loss of the exposed specimens.

Pit depth determinations were obtained for all of the unstressed tube and 8 inch x 12 inch (20.32 cm x 30.48 cm) sheet specimens.

C. RESULTS AND DISCUSSION

Table 5 summarizes the results obtained from visual examination of the unstressed non-welded sheet materials. The results obtained for welded sheet and tube materials are summarized in Table 6. The results obtained from average weight loss and pit depth determinations are given in Tables 7 through 12 and are shown graphically in Figs. 10 through 14.

Data given for each alloy system are a compilation of results obtained from either 2 or 4 specimens depending upon the number of specimens of each system that was exposed. The weight loss for a given alloy system exposed in a particular soil may appear to be extremely small in comparison to the observed corrosion. This occurs because the corrosion of stainless steels in some environments can often be localized and confined to a very small area. Similarly, one specimen may have only one corrosion pit which caused perforation of the specimen, while there was little or no corrosion observed on companion specimens exposed for the same period of time in the same environment.

Corrosion of stainless steels is generally attributed to a breakdown of the passive film at the surface of the material at localized or selective areas. If corrosion occurs it may often be influenced by one or more of the following:

1. Inhomogeneities of the metal surface.
2. Concentration cell effects due to adhering soil particles or crevices where stagnant conditions may exist.
3. Presence of chlorides in the soil.
4. Microbiological organisms.
5. Abrasion of the metal surface by soil particles or foreign debris.

A break in the passive film at the localized area results in a small anodic site. The larger surrounding area is the cathode. The electrolytic cell formed could result in localized pitting corrosion, which can rapidly penetrate the thickness of the metal. However, a stainless steel with adequate alloying content for the environment would repassivate without degradation. Concentration cells formed at stagnant areas beneath soil deposits or at crevice areas can also result in localized corrosion. An unusual form of pitting corrosion, tunneling, is normally associated with edges and can be increased by gravity flow of corrosion products. All flat sheet specimens were buried with either the long dimension [12 inch (30.48 cm)] or the short dimension [8 inch (20.3 cm)] in the upright (vertical) position in the trenches, thus increasing the propensity for tunneling.

Typical examples of the degradation observed are shown in Figures 15 through 36.

1. GENERAL CORROSION BEHAVIOR

Materials Exposed in 1970

AISI 200 Series

Corrosion of the annealed Type 201 and 202 stainless steels (system Nos. 50 and 51) was nil or superficial** for specimens buried up to 8 years in alkaline soil (site A) and Hagerstown loam (Site B). Of these steels buried in Lakewood sand (Site D), one Type 201 specimen exhibited pitting corrosion at the edge after exposure for 4 years while specimens of both systems were perforated due to corrosion after burial for 8 years. Specimens of both systems, buried for up to 8 years in acid clay (Site C), coastal sand (Site E) and tidal marsh (Site G) were perforated due to localized corrosion. The time to perforation for specimens of both systems buried at Sites C and E was less than one year while time to perforation for specimens puried at Site G was in excess of one year. Specimens of both systems exhibited tunneling corrosion at Sites C, D, E and G.

AISI 300 Series

Annealed Materials - In general, corrosion was nil or superficial for the annealed austenitic stainless steels buried for up to 8 years at Sites A, B and D. Annealed Type 316 was susceptible to slight localized pitting corrosion at Site C while specimens buried at Sites E and G were perforated due to localized pitting corrosion. Annealed Types 301 and 304 stainless steels buried at Sites C, E and G were perforated due to corrosion after exposure for up to 8 years. Of the annealed 300 series

**Many of the specimens examined exhibited incipient pitting and various forms of discoloration, e.g., iridescence, rust and dark to black stains. However, no other degradation was observed on these specimens nor was there any loss in weight due to exposure in the soil environment. Corrosion of these specimens was considered to be nil or superficial.

alloys all buried at Sites E and G, Types 301 and 304 buried at Sites C and annealed Type 304 buried at Site D exhibited tunneling corrosion.

Sensitized Materials - Degradation of the sensitized 300 series alloys buried for approximately 8 years at Sites A and B, was nil or negligible. However, some slight etching and pitting corrosion was noted at areas on some of the specimens buried at these sites. Of the sensitized materials buried at Site C, all were susceptible to pitting corrosion with Type 316 being the least susceptible. Sensitized Type 304 and Type 316 buried at this site were also susceptible to tunneling corrosion. Small blister-like eruptions at surface areas were noted on some of the sensitized Type 301 and Type 304 buried at Sites D and E. These appeared to be very small corrosion pits. Of the sensitized 300 series materials buried at these sites, degradation due to corrosion was most severe on Type 301 and Type 304 buried at Site E.

Degradation of sensitized Type 301 and Type 304 buried at Site G was generally due to severe etching and non-uniform corrosive attack. Corrosion was most severe on the Type 301. Cracking, due to mechanical damage incurred during removal from the trench, was noted on specimens of both materials. Sensitized Type 316 specimens buried at this site for approximately 8 years, while relatively free from degradation, were susceptible to pitting corrosion particularly at the edges. Tunneling corrosion was also noted on specimens of this material exposed at this site.

Welded Materials - Corrosion of the cross-bead welded Type 301 sheet and heliarc welded Type 304 tube specimens buried at Sites A, B and D for up to approximately 8 years was in general nil or superficial. Pitting corrosion was noted at and adjacent to the weld bead on the cross-bead welded Type 301 sheet specimens buried at Sites C, E and G. Pitting corrosion was also observed at and adjacent to the weld seam of Type 304 tube specimens buried at Site C. However, pitting corrosion was also noted at areas remote from the weld. Metallographic examination of areas adjacent to the weld did not reveal sensitization at these areas. This would indicate that the pitting corrosion observed adjacent to the weld was not due to sensitization. Of the Type 304 tube specimens buried at Sites C, E and G, corrosion was observed at areas adjacent to the caps and at crevice areas (under the end caps).

AISI 400 Series

Materials in this series include the martensitic Type 410 and ferritic Type 409, 430 and 434 stainless steels.

Specimens of Type 409 (non-coated - annealed or welded) and Type 410 (annealed) were perforated by corrosion after burial for 4 years in 5 of the 6 soils. The time to first perforation (generally 1 or 2 years) for the non-coated Type 409 materials was less for specimens buried at Sites C, E and G. Corrosion of both Type 409 and 410 materials was nil or superficial at Site B. The coal-tar epoxy coated Type 409 sheet specimens were relatively unaffected by corrosion.

Types 430 and 434 were relatively unaffected by corrosion after burial for approximately 8 years at Sites A and B. Specimens of these materials buried at Sites C, E and G were perforated by corrosion generally in less than one year while for specimens buried at Site D, the first perforation was noted after exposure for 4 years.

Materials Exposed in 1971 and 1972

Steels in this portion of the investigation include newer stainless steels and composite materials. The proprietary stainless steels may be grouped as follows according to major alloying constituents.

1. Cr Stainless Steels

   26 Cr - 1 Mo

   18 Cr - 2 Mo

   18 Cr - 2 Mo (Nb)

   18 Cr - (Ti)

2. Cr-Ni Stainless Steels

   26 Cr - 6.5 Ni

   20 Cr - 24-Ni - 6.5 Mo

   18 Cr - 8 Ni (N)

The results obtained from visual examination of these materials after burial in the various soils for up to 7 years are summarized in Tables 5 and 6.

Cr Stainless Steels - Alloy 26 Cr - 1 Mo [in the annealed condition (System No. 1)] was relatively unaffected by corrosion in any of the soils after burial for approximately 7 years. Pitting corrosion was noted particularly at or adjacent to crevice areas on some of the heliarc welded Alloy 26 Cr - 1 Mo specimens buried at Sites A, C, E and G.

Corrosion of annealed Alloy 18 Cr - 2 Mo (System No. 6) was nil or superficial for specimens buried for up to 7 years at Sites A, B and D. Scattered pitting corrosion with subsequent perforation of the material was observed on specimens buried at Sites C, E and G. Corrosion of annealed Alloy 18 Cr - 2 Mo (Nb)(System No. 7) specimens was in general nil or superficial after burial for up to approximately 6 years in 5 of the 6 soils. Specimens of this material buried at Site G had perforated due to corrosion. Pitting corrosion was noted at weld areas on cross-bead welded sheet specimens (System No. 11) buried for up to approximately

3 years at Sites A, C, D, E and G and at weld areas on heliarc welded tube specimens (System 12) buried for approximately 3 years at Sites B, C and D. Tunneling corrosion was also noted at weld areas of specimens of System No. 11 buried at Sites C and G. Specimens of System 11 buried at Sites C, E and G were perforated due to corrosion. Of the alloy 18 Cr (Ti) (System Nos. 2, 3 and 18) materials exposed for up to 3 years, corrosion of specimens of Systems Nos. 3 and 18 buried at Sites A, B and D and System No. 2 buried at Sites A and B was in general nil or superficial. Some specimens buried at Sites C, E and G were perforated due to corrosion.

Cr-Ni Stainless Steels - The annealed Alloy 18 Cr - 8 Ni (N) specimens (System No. 8) were in general unaffected by corrosion after burial for approximately 7 years at Sites A, B, C and D, while specimens of this material buried at Site E for 8 years and Site G for 7 years were relatively unaffected by corrosion. Companion specimens buried at Site E for 3 years and Site G for 2 years were perforated due to corrosion. Sheet specimens of this alloy having a cross-bead weld (System No. 9) and buried at Site C for 7 years and Site E for 3 years were perforated due to corrosion. Of the specimens of this system buried for 3 and 7 years at Site G, corrosion was nil or superficial while pitting corrosion was noted on companion specimens after exposure for 1 and 2 years. Specimens of this system buried at Sites A, B and D were relatively unaffected by corrosion.

There was little or no appreciable corrosive attack on the annealed (System No. 4), sensitized (System No. 5) or heliarc welded (System No. 19) Alloy 20 Cr - 24 Ni - 6.5 Mo specimens buried for up to approximately 8 years at the six soil sites.

Corrosion of annealed Alloy 26 Cr - 6.5 Ni (System 10) specimens buried at Sites A and B was in general negligible. Companion specimens of this material buried at Sites C, E and G were perforated due to corrosion in less than one year, while the time to first perforation for this material buried at Site D was in excess of 3 years.

Composite Materials - The composite systems are sandwich materials where outer layers of carbon steel are metallurgically bonded to a thin core of stainless steel [total thickness approximately 0.120 in (0.305 cm)]. Composites A and B (System Nos. 14 and 15) were fabricated with Type 430 stainless steel as a core material while Composite C (System No. 16) utilizes Type 304 stainless steel. In addition, Composite B specimens were individually hot-dip zinc coated [galvanized, 4.5 to 5 oz/ft^2 (1377 to 1528 gms/m^2) zinc]. This was a thicker coating than would normally be used on carbon steel products.

In general, there was little difference in the corrosion behavior of System Nos. 14 and 16 buried in the same soil environment for approximately 7 years. Pitting corrosion of the carbon steel outer layers was observed on all specimens buried at the six sites. The carbon steel was perforated by corrosion on specimens buried at Sites A, B and G which thus exposed the stainless steel core of both composite materials. While there was no apparent significant corrosion of the stainless steel core of these specimens, degradation of the carbon steel was more severe for specimens buried at Site G.

The hot-dip zinc coating on specimens of System No. 16 provided protection to the underlying carbon steel and stainless steel core in all of the soils. There was some dissipation of the zinc in all of the soils. However, there was some zinc remaining on all of the specimens after burial for up to 7 years in the 6 soil environments.

2. Stress Corrosion Behavior

The results of visual and micro examinations made to determine failure of the various systems due to stress corrosion cracking are given in Table 13 for nongalvanically coupled specimens.

Materials Exposed in 1970

AISI 300 Series

Type 301 stainless steel in the half-hard condition was relatively immune to stress corrosion cracking in all of the soils after exposure for approximately 8 years. Micro-cracking was noted on one specimen buried for 2 years at Site C. Sensitization of the half-hard alloy increased the susceptibility to stress corrosion cracking in all of the soil environments. The same alloy in the full-hard condition was in general also immune to stress corrosion cracking in all of the soils after exposure for approximately 8 years. However, micro-cracking was noted on one specimen exposed for approximately 2 years in the soil at Site G. No failures were observed on stressed Type 304, annealed or half-hard specimens buried for up to approximately 8 years in the soils at the six sites. Cracking of the sensitized Type 304 stressed material was observed on specimens buried at Site C for 2 years and Site E for 1 year. Companion specimens of this material buried at these sites and at Sites A, B, D and G had not failed after exposure in the soils for approximately 8 years. No stress cracking was observed on annealed or sensitized Type 316 stainless steel after exposure for approximately 8 years in the various soils.

AISI 400 Series

Type 434 stainless steel was the only alloy in this series exposed in the soils. There were no failures after burial for 8 years in any of the soils.

Materials Exposed in 1971 and 1972

Steels in this category included Alloys 26 Cr-1 Mo, 18 Cr-2 Mo, 20 Cr-24 Ni -6.5 Mo, 8 Cr-8 Ni (N) and 26 Cr-6.5 Ni. There were no failures of these steels after exposure for up to 7 years at Sites A, B, C, D and G and approximately 8 years at Site E.

3. Stressed Dissimilar Metal Couples

The results for the stressed galvanically coupled specimens have been reported elsewhere [9]. Table 14 in this report summarizes the results obtained for specimens buried for approximately 4 years.

Materials Exposed in 1970

AISI 300 Series

There were no failures noted for Type 304 in the annealed condition when coupled to zinc, magnesium or iron (steel). Type 301 full-hard and Type 301 half-hard have a tendency to stress crack. As shown in Table 14 all of the stressed Type 301 full-hard stainless steel specimens and all but one of the Type 301 half-hard specimens coupled to magnesium failed in the four years of exposure. When coupled to iron, these materials were resistant to cracking at 4 of the 6 sites (Sites A, B, D and E). One Type 301 full-hard specimen buried at Site G had failed while Type 301 half-hard specimens buried at this site had not failed. Both materials when coupled to zinc had failed at all of the sites except for those buried at Site A. The largest currents were generated by magnesium followed by zinc and iron. It was noted that below 1 $\mu A/cm^2$

all Type 301 full-hard specimens failed. The fact that the number of failures increased with increasing cathodic current indicates that hydrogen embrittlement was the mode of failure.

Materials Exposed in 1971 and 1972

There were no failures of the 26 Cr-1 Mo or the 26 Cr-6.5 Ni alloys galvanically coupled to zinc, magnesium or iron after exposure for approximately 3 years in the soils.

4. Unstressed Dissimilar Metal Couples

The results obtained for unstressed stainless coupled to a dissimilar metal (copper) and buried for up to approximately 4 years have been reported elsewhere [10]. Table 15 in this report summarizes the results obtained on an annual basis for these stainless steels coupled to copper over an exposure period of up to approximately 10 years. The average galvanic current and the average potential are given for these stainless steels when connected to copper and buried in the soil at each of the 6 sites. The direction of current flow between the electrodes is denoted by the sign of the current [(-) indicated the stainless is cathodic to the copper].

In general, the galvanic currents measured are small, and average less than 0.1 $\mu A/cm^2$ in every case where stainless was anodic to copper. It was noted that the galvanic currents measured reversed direction of flow from one year to the next. This indicates that the potentials of these stainless steels is very similar to that of copper when buried in the soil. There is a lack of tendency for either electrode to be sacrificial to the other. The potential of any given couple was found to be stable with fluctuations of less than 100 mv over the period measured. No correlation was found between potential and direction of current flow.

In summary, there should be little or no corrosion damage of Type 304, Type 409 or Alloy 26 Cr-6.5 Ni stainless steels as a result of being coupled to copper. This is indicated by the small galvanic currents generated.

D. SUMMARY

1. Materials Exposed in 1970

a. AISI 200 Series

Both of the annealed austenitic 200 series stainless steels exhibited good resistance to corrosion after burial for approximately 8 years in alkaline soil (Site A) and Hagerstown loam (Site B). These stainless steels were susceptible to corrosion in acid clay (Site C), Lakewood sand (Site D), coastal sand (Site E) and tidal marsh (Site G). Degradation was generally due to pitting or tunneling corrosion with subsequent perforation at these localized areas on materials buried at Sites C, E and G.

b. AISI 300 Series

In general the austenitic 300 series stainless steels exhibited good resistance to corrosion after burial for up to approximately 8 years in the soils at Sites A, B and D. These stainless steels were susceptible to corrosion at Sites C, E and G. Type 316 (annealed) was the least susceptible to corrosion in the six soils investigated. Degradation of the 300 series stainless steels was generally due to pitting or tunneling corrosion or a combination of both with subsequent perforation of the specimens at localized areas. For some of the materials buried in the tidal marsh (Site G), corrosion was observed at large areas on the specimens and was attributed to severe etching or general corrosion of the metal surfaces. Sensitization by heat treatment of the 300 series stainless steels studied in this program generally resulted in increased susceptibility to corrosion in all of the soils. Pitting corrosion was observed at or adjacent to the weld bead on cross-bead welded Type 301 sheet specimens buried at Sites C, D, E and G and at or adjacent to the weld seams on Type 304 tube specimens buried at Sites A, C, E and G. However, pitting corrosion was also observed at other areas remote from the welds on specimens of these materials. Metallographic examination of areas adjacent to the welds indicated that sensitization was not a factor in the cause of the corrosion observed. Type 304 tube specimens buried at Sites C, D, E and G were also susceptible to crevice corrosion.

With some exceptions, the non-galvanic coupled stressed 300 series alloys exhibited good resistance to stress corrosion cracking in all of the soils. Type 316 in the annealed or sensitized condition was immune to stress corrosion cracking in all of the soils after exposure for 8 years. Type 301 in the half-hard condition was susceptible to cracking at Site G. Sensitization of Type 301 half-hard increased the susceptibility to stress corrosion cracking in all of the soils. Type 304 (annealed) was immune to stress corrosion, but sensitization of this material made the alloy susceptible to stress corrosion at Sites C and E.

c. AISI 400 Series

The martensitic Type 410 and the ferritic Types 409, 430 and 434 stainless steels were in general susceptible to pitting or tunneling corrosion or a combination of both at Sites A, C, D and E and to severe etching or general attack at Site G. Of these materials buried at Site A, all except Types 430 and 434 were perforated due to corrosion while corrosion of the 400 series stainless steels buried at Site B was nil or superficial. Areas at or adjacent to the weld seam on the heliarc welded and high-frequency welded Type 409 buried at Sites C, D, E and G were susceptible to pitting corrosion. Pitting corrosion was also observed at crevice areas on these materials buried at Sites A, C, D, E and G. The coal-tar epoxy coating applied to the Type 409 stainless steel was effective in providing protection from corrosion at all sites. However, some superficial degradation of the metal surfaces was observed, particularly at areas where the epoxy coating had blistered, where the coating was mechanically damaged and at some areas where the coating had been scored to bare metal prior to burial.

Type 434 was the only stainless steel in the 400 series included in the stress corrosion study. No failures were observed for non-galvanically coupled stressed specimens of this material in any of the soil environments.

2. Materials Exposed in 1971 and 1972

Annealed, sensitized and heliarc-welded alloy 20 Cr-24 Ni-6.5 Mo was in general resistant to corrosion in all 6 of the soils after burial for up to approximately 7 years.

There was little or no degradation due to corrosion of annealed Alloy 26 Cr-1 Mo after exposure for up to approximately 7 years at the 6 soil test sites. Heliarc-welded alloy 26 Cr-1 Mo was susceptible to pitting or crevice corrosion in 4 of the 6 soils. This material was not exposed in the sensitized condition.

Alloy 18 Cr-2 Mo (Nb) (annealed and cross-bead welded sheet and heliarc welded tube materials), buried for up to approximately 6 years, was resistant to corrosion in 3 of the 6 soils (Sites A, B and D).

Annealed and cross-bead welded Alloy 18 Cr-8 Ni (N) stainless steel, buried for up to approximately 7 years, was also resistant to corrosion at Sites A, B and D and similarly was also susceptible to pitting corrosion at Sites C, E and G.

Alloy 26 Cr-6.5 Ni in the annealed condition and buried for up to approximately 7 years was susceptible to pitting corrosion in 5 of the 6 soils (Sites A, C, D, E and G), but was relatively unaffected by corrosion at Site B.

Corrosion of Alloy 18 Cr (Ti) was nil or superficial for annealed and cross-bead welded sheet materials exposed for up to approximately 7 years at Sites A, B and D. Heliarc welded tube material of this alloy was resistant to corrosion at Sites A, B, D and E. These materials were severely corroded in the other soils in which they were buried.

Of these proprietary steels included in the stress corrosion study, there were no failures of either galvanically coupled or non-galvanically coupled specimens after exposure for up to 4 years in any of the soils.

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U. S. Department of Interior
Portland, Oregon 97208

Baltimore Bureau of Water Supply
Baltimore, Maryland 21217

U. S. Coast Guard Training Center
Cape May, New Jersey 08204

Patuxent Naval Air Station
Lexington Park, Maryland 20653

U. S. Coast Guard Electronics Engineering Station
Wildwood, New Jersey 08260

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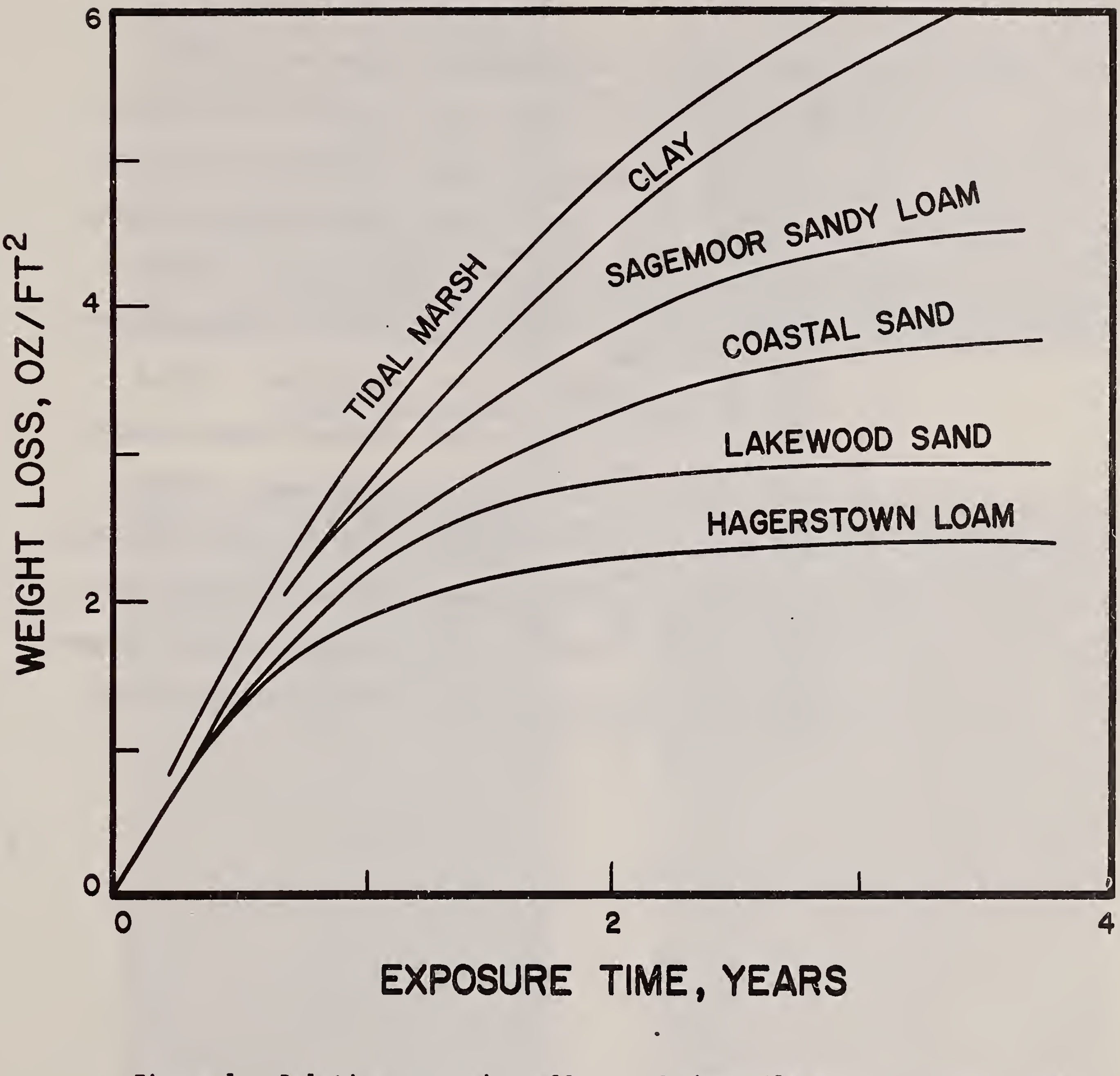
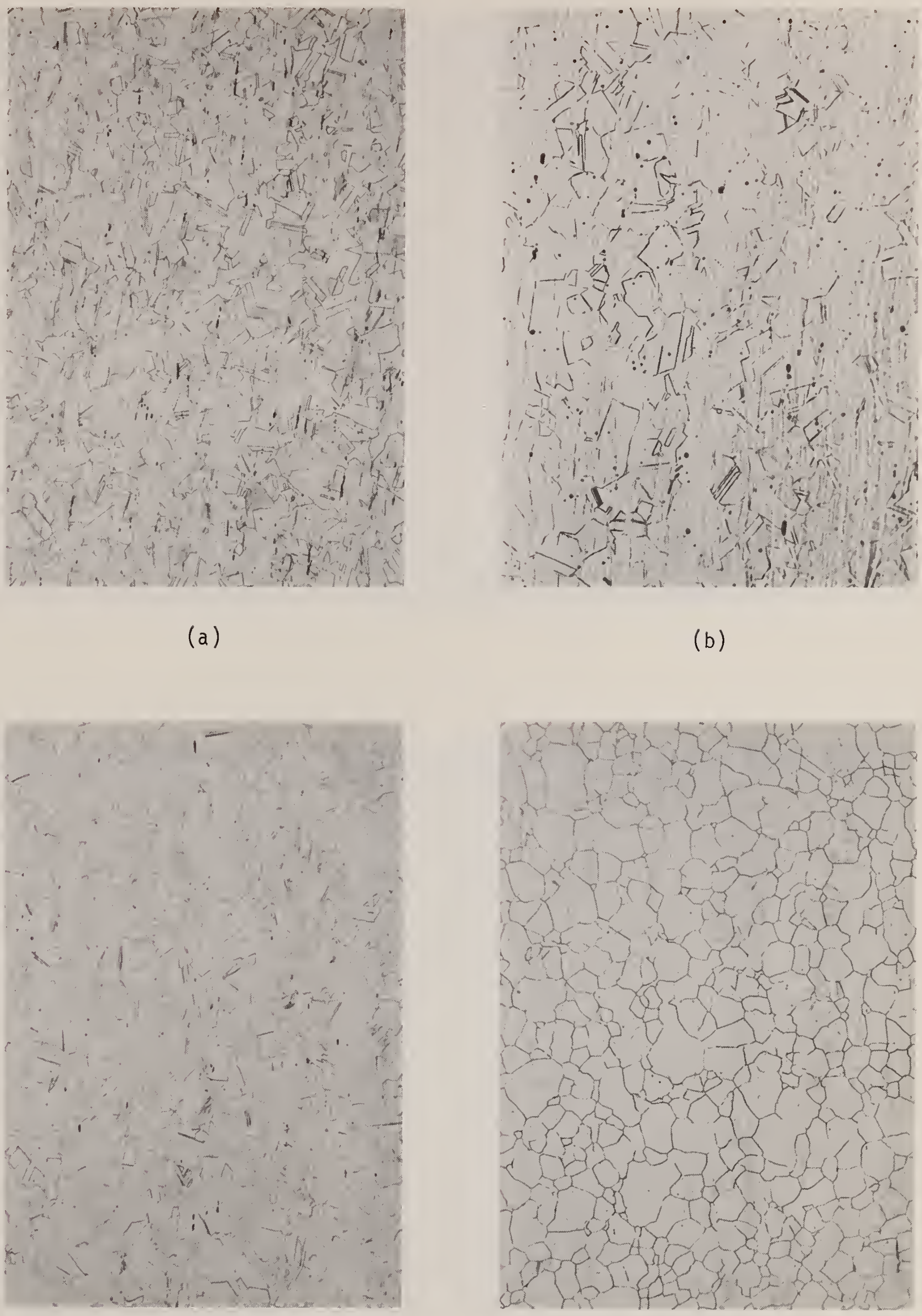


Figure 1. Relative corrosion effects of the soils at the six NBS Test Sites on carbon steel.

Figure 2. Transverse sections showing typical microstructures for standard stainless steels.

(a) AISI Type 201 stainless steel. Etched electrolytically, 10% oxalic acid. X100.
(b) AISI Type 202 stainless steel. Etched electrolytically, 10% oxalic acid. X200.
(c) AISI Type 301 stainless steel. Etched electrolytically, 10% oxalic acid. X200.
(d) AISI Type 301 stainless steel (sensitized). Etched electrolytically, 10% oxalic acid. X200.
(e) AISI Type 304 stainless steel. Etched, acetic acid, HCl, glycerol and HNO_3. X200.
(f) AISI Type 304 stainless steel (sensitized). Etched electrolytically, 10% oxalic acid. X200.
(g) AISI Type 316 stainless steel. Etched electrolytically, 10% chromic acid. X200.
(h) AISI Type 316 stainless steel (sensitized). Etched, lactic acid, methanol and HCl. X200.
(i) AISI Type 409 stainless steel. Etched, acetic acid, HCl, glycerol and HNO_3. X200.
(j) AISI Type 410 stainless steel. Etched electrolytically, methanol and HCl. X200.
(k) AISI Type 430 stainless steel. Etched, Vilella's Reagent. X200.
(l) AISI Type 434 stainless steel. Etched electrolytically, methanol and HCl. X200.

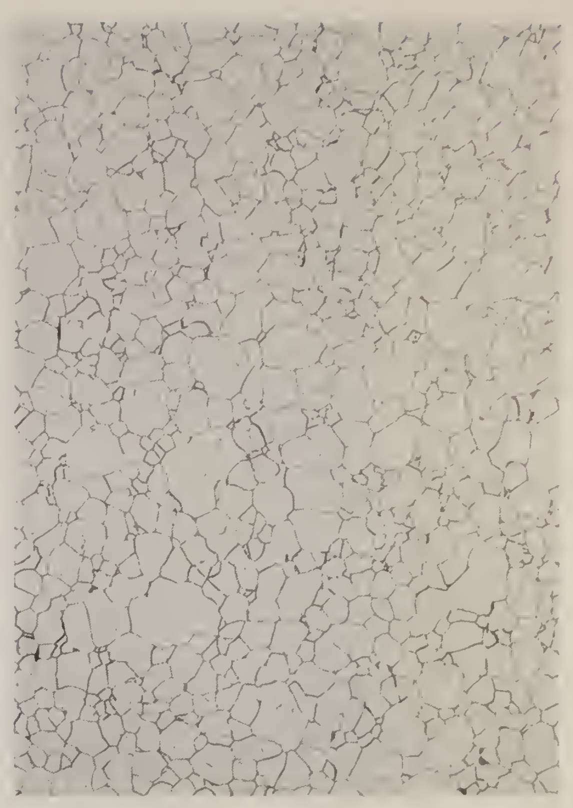


(a) (b)

(c) (d)

FIGURE 2

(e)

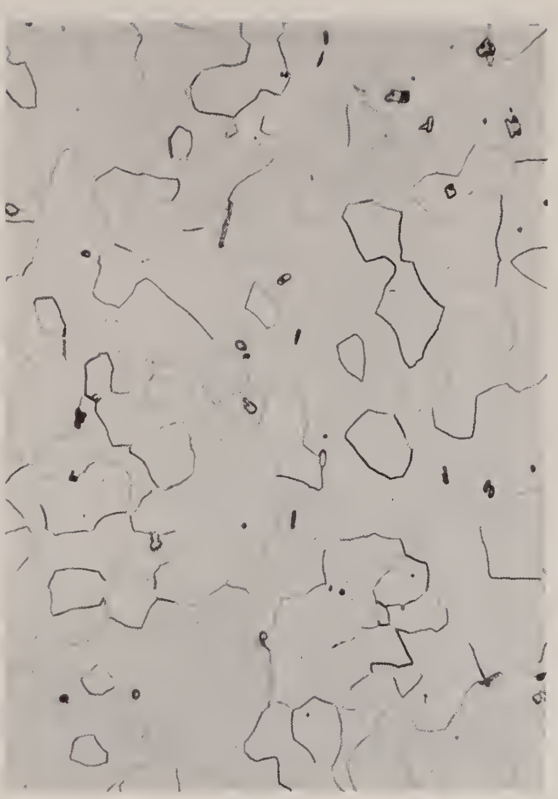


(f)

(g)

(h)

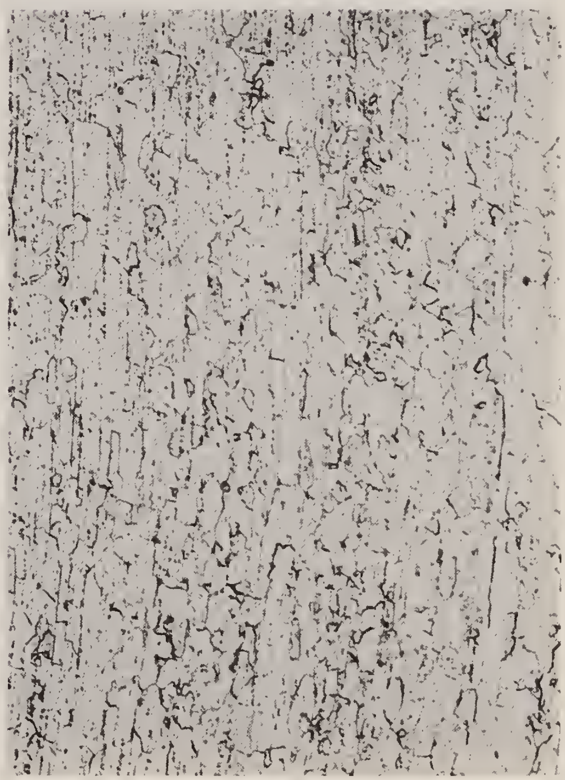
FIGURE 2



(i)

(j)

(k)



(l)

FIGURE 2

Figure 3. Transverse sections showing typical microstructures for alloy stainless steels.

(a) Alloy 26 Cr-1 Mo. Etched electrolytically, 10% oxalic acid. X100.

(b) Alloy 18 Cr-2 Mo. Etched, lactic acid, HF, HCl and HNO_3. X200.

(c) Alloy 18 Cr-2 Mo (Nb). Etched electrolytically, 10% oxalic acid. X100.

(d) Alloy 18 Cr (Ti). Etched, aqua regia. X100.

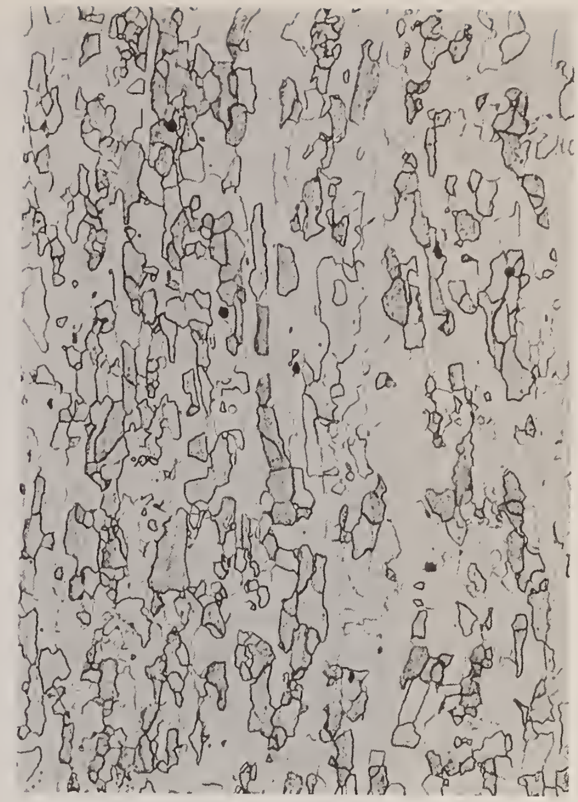
(e) Alloy 26 Cr-6.5 Ni. Etched electrolytically, 10% oxalic acid. X100.

(f) Alloy 20 Cr-24 Ni-6.5 Mo. Etched, aqua regia. X100.

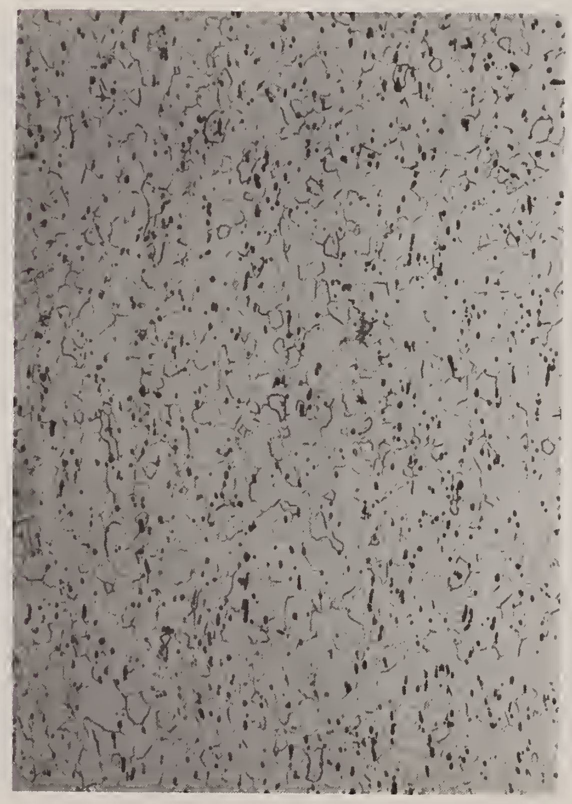
(g) Alloy 20 Cr-24 Ni-6.5 Mo (sensitized). Etched, lactic acid, HF, HCl, and HNO_3. X100.

(h) Alloy 18 Cr-8 Ni (N). Etched, 10% oxalic acid. X200.

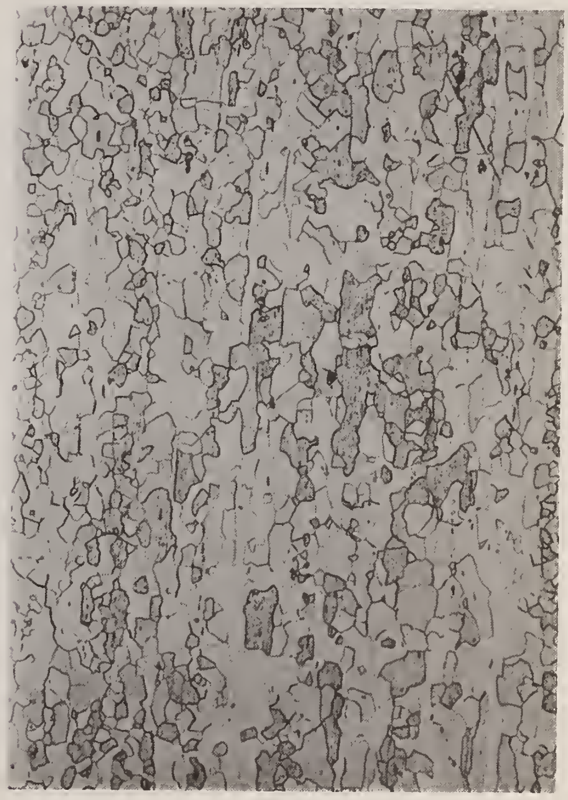
(a)



(b)



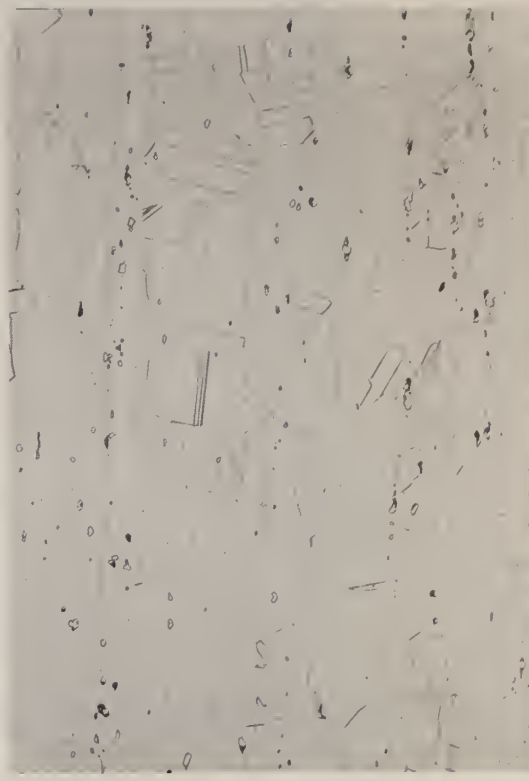
(c)



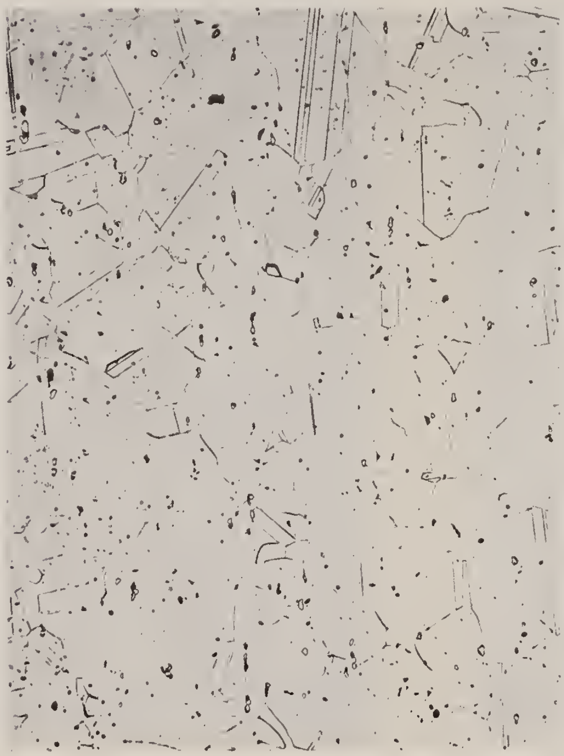
(d)

FIGURE 3

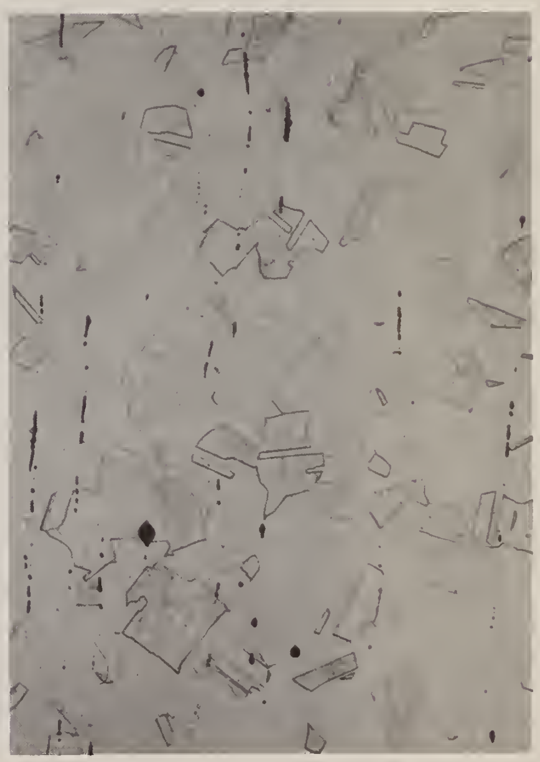
(e)



(f)



(g)



(h)

FIGURE 3

Figure 4. Section from a Type 304 stainless steel specimen at the weld bead area showing little or no apparent heat affected zone adjacent to the weld bead. This was typical for all cross-bead welded materials examined in this study. Etched, 10% oxalic acid. X50.

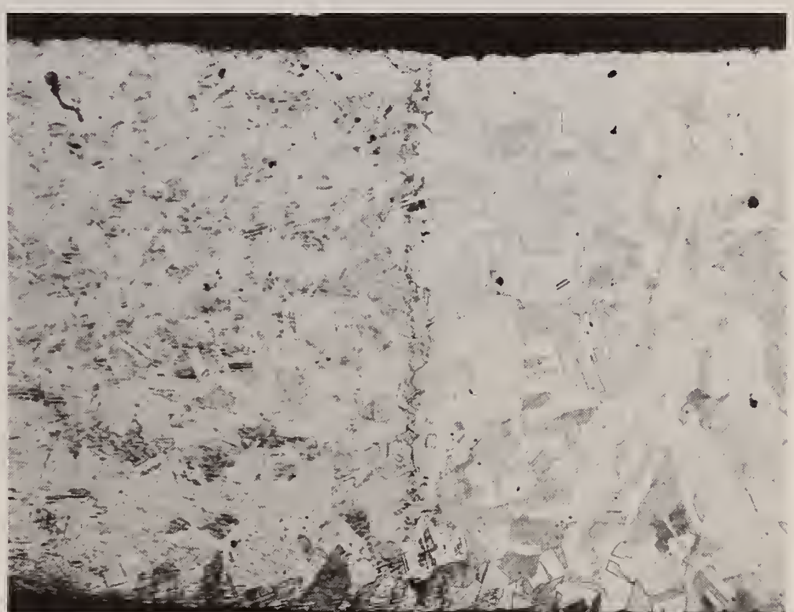


Figure 5. Section from a Type 304 stainless steel tube specimen at the heliarc weld seam showing a narrow band (heat affected zone) between the weld metal and the tube material. This was typical for all elded tube materials examined in this study. Etched, 10% oxalic acid. X50.

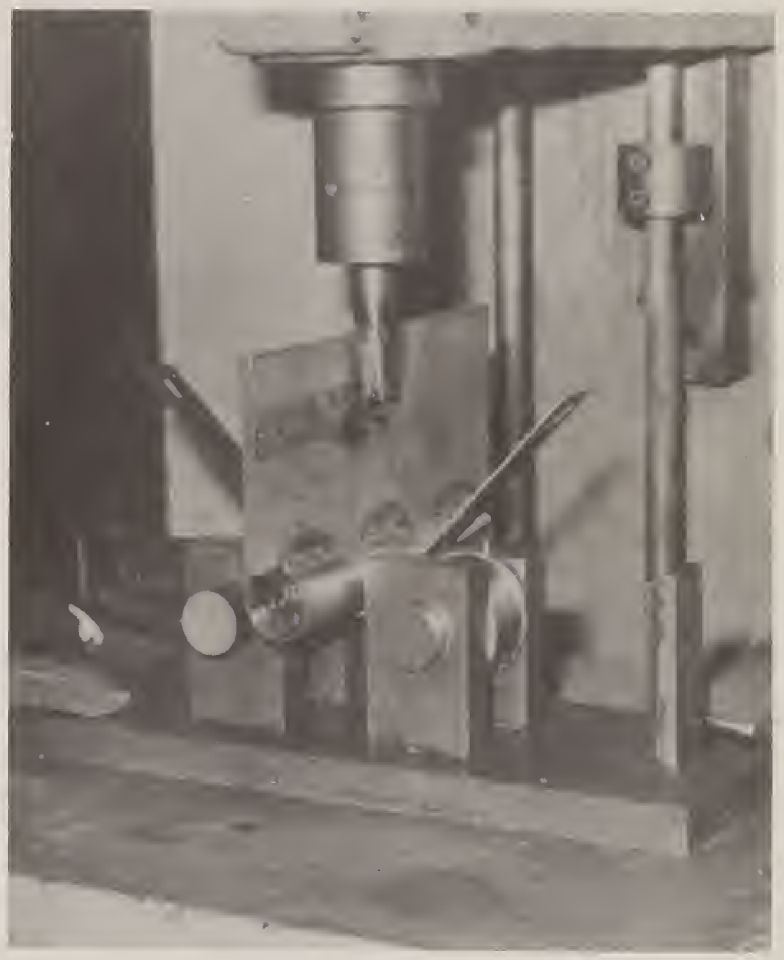


Figure 6. Die for forming U-bend specimens.

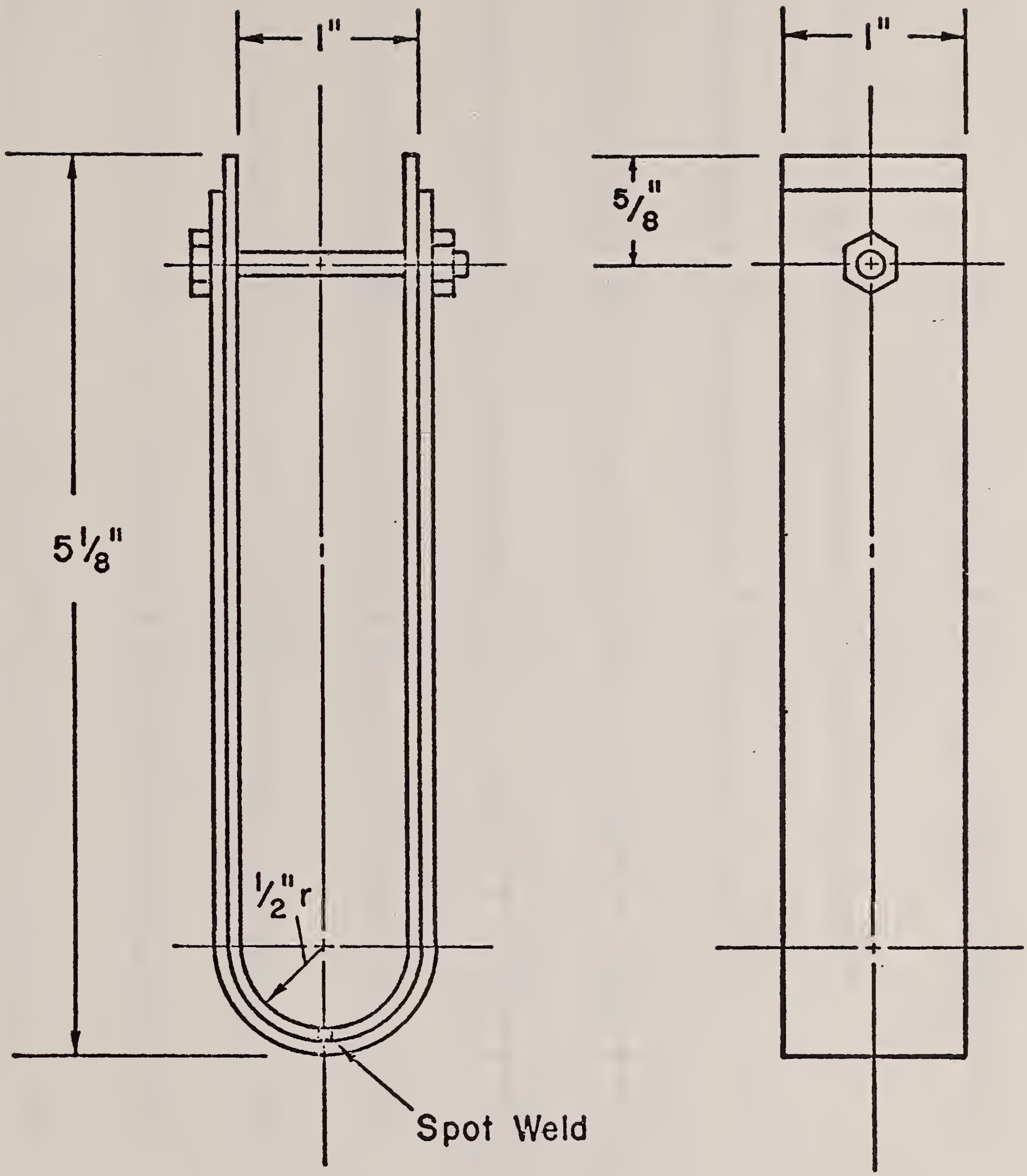


Figure 7. Double or crevice U-bend specimens for underground corrosion.

Figure 8a. Map showing burial order for specimens exposed in 1970 at the various sites.

First Removal (1 Yr)		Second Removal (2 Yr)		Third Removal (4 Yr)		Fourth Removal (8 Yr)		Fifth Removal (X Yr)	
■	■	■	■	■	■	■	■	■	■
50x01*	50x03*	50x05*	50x07*	50x09*	50x11*	50x13*	50x15*	50x17*	50x19*
51	51	51	51	51	51	51	51	51	51
52	52	52	52	52	52	52	52	52	52
53	53	53	53	53	53	53	53	53	53
54	54	54	54	54	54	54	54	54	54
55	55	55	55	55	55	55	55	55	55
56	56	56	56	56	56	56	56	56	56
57	57	57	57	57	57	57	57	57	57
58	58	58	58	58	58	58	58	58	58
59	59	59	59	59	59	59	59	59	59
60	60	60	60	60	60	60	60	60	60
61	61	61	61	61	61	61	61	61	61
62	62	62	62	62	62	62	62	62	62
63	63	63	63	63	63	63	63	63	63
64	64	64	64	64	64	64	64	64	64
65	65	65	65	65	65	65	65	65	65
66x01	66x03	66x05	66x07	66x09	66x11	66x13	66x15	66x17	66x19
50x02	50x04	50x06	50x08	50x10	50x12	50x14	50x16	50x18	50x20
51	51	51	51	51	51	51	51	51	51
52	52	52	52	52	52	52	52	52	52
53	53	53	53	53	53	53	53	53	53
54	54	54	54	54	54	54	54	54	54
55	55	55	55	55	55	55	55	55	55
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62	62	62	62	62	62	62	62	62	62
63	63	63	63	63	63	63	63	63	63
64	64	64	64	64	64	64	64	64	64
65	65	65	65	65	65	65	65	65	65
66x02	66x04	66x06	66x08	66x10	66x12	66x14	66x16	66x18	66x20
■	■	■	■	■	■	■	■	■	■
67x02	67x04	67x06	67x08	68x10	68x12	67x14	67x16	68x18	68x20
68	68	68	68	69	69	68	68	69	69
69	69	69	69	71	71	69	69	71	71
70	70	70	70	73	73	70	70	73	73
71	71	71	71	74	74	71	71	74	74
72	72	72	72	75	75	72	72	75	75
73	73	73	73	76	76	73	73	76	76
74	74	74	74	78	78	74	74	78	78
75	75	75	75	79	79	75	75	79	79
76	76	76	76	81x10	81x12	76	76	81x18	81x20
77	77	77	77	67x10	67x12	77	77	67x18	67x20
78	78	78	78	70x10	70x12	78	78	70x18	70x20
79	79	79	79	■	■	79	79	■	■
80	80	80	80	72x10	72x12	80	80	72x18	72x20
81	81	81	81	77x10	77x12	81	81	77x18	77x20
82	82	82	82	80x10	80x12	91	91	80x18	80x20
83	83	83	83	82x10	82x12	92x14	92x16	91x18	91x20
84	84	84	84	■	■	■	■	■	■
85	85	85	85	83x10	83x12			92x18	92x20
86	86	86	86	84x10	84x12				
87	87	87	87	85x10	85x12				
88	88	88	88	86x10	86x12				
89	89	89	89	■	■				
90	90	90	90	87x10	87x12				
91	91	91	91	88x10	88x12				
92x02	92x04	92x06	92x08	89x10	89x12				
■	■	■	■	90x10	90x12				
				■	■				
				91x10	91x12				
				92x10	92x12				

■ 4"x4" Post

→■ Wire terminal to post for electrical measurements

⇉■ Wire terminals (galvanic couple) to post for electrical measurements.

*Specimen identification: Digits preceding "x" denote system number (see Table 2) "x" represents site designation. Would be A, B, C, D, E or G depending upon where specimen was exposed. Digits following "x" are specimen numbers.

Figure 8b. Map showing burial order for specimens exposed in 1971 at the various sites.

First Removal (1 yr)		Second Removal (2 yr)		Third Removal (4 yr)		Fourth Removal (8 yr)		Fifth Removal (X yr)	
■	■	■	■	■	■	■	■	■	■
1x01*	1x03*	1x05*	1x07*	1x09*	1x11*	1x13*	1x15*	1x17*	1x19*
2x	2x	2x	2x	2x	2x	2x	2x	2x	2x
3x	3x	3x	3x	3x	3x	3x	3x	3x	3x
4x	4x	4x	4x	4x	4x	4x	4x	4x	4x
5x	5x	5x	5x	5x	5x	5x	5x	5x	5x
6x	6x	6x	6x	6x	6x	6x	6x	6x	6x
8x	8x	8x	8x	8x	8x	8x	8x	8x	8x
9x	9x	9x	9x	9x	9x	9x	9x	9x	9x
10x	10x	10x	10x	10x	10x	10x	10x	10x	10x
14x	14x	14x	14x	14x	14x	14x	14x	14x	14x
15x	15x	15x	15x	15x	15x	15x	15x	15x	15x
16x	16x	16x	16x	16x	16x	16x	16x	16x	16x
17x	17x	17x	17x	17x	17x	17x	17x	17x	17x
18x	18x	18x	18x	18x	18x	18x	18x	18x	18x
19x01	19x03	19x05	19x07	19x09	19x11	19x13	19x15	19x17	19x19
1x02	1x04	1x06	1x08	1x10	1x12	1x14	1x16	1x18	1x20
2x	2x	2x	2x	2x	2x	2x	2x	2x	2x
3x	3x	3x	3x	3x	3x	3x	3x	3x	3x
4x	4x	4x	4x	4x	4x	4x	4x	4x	4x
5x	5x	5x	5x	5x	5x	5x	5x	5x	5x
6x	6x	6x	6x	6x	6x	6x	6x	6x	6x
8x	8x	8x	8x	8x	8x	8x	8x	8x	8x
9x	9x	9x	9x	9x	9x	9x	9x	9x	9x
10x	10x	10x	10x	10x	10x	10x	10x	10x	10x
14x	14x	14x	14x	14x	14x	14x	14x	14x	14x
15x	15x	15x	15x	15x	15x	15x	15x	15x	15x
16x	16x	16x	16x	16x	16x	16x	16x	16x	16x
17x	17x	17x	17x	17x	17x	17x	17x	17x	17x
18x	18x	18x	18x	18x	18x	18x	18x	18x	18x
19x02	19x04	19x06	19x08	19x10	19x12	19x14	19x16	19x18	19x20
■	■	■	■	■	■	■	■	■	■
20x02	20x04	20x06	20x08	20x10	20x12	20x14	20x16	20x18	20x20
21x	21x	21x	21x	22x	22x	21x	21x	22x	22x
22x	22x	22x	22x	24x	24x	22x	22x	24x	24x
23x	23x	23x	23x	25x	25x	23x	23x	25x	25x
24x	24x	24x	24x	27x	27x	24x	24x	27x	27x
25x	25x	25x	25x	21x	21x	25x	25x	21x	21x
26x	26x	26x	26x	23x10	23x12	26x	26x	23x18	23x20
27x	27x	27x	27x			27x	27x		
28x	28x	28x	28x	■	■	28x	28x	■	■
30x	30x	30x	30x			30x	30x		
33x	33x	33x	33x			42x	42x		
34x	34x	24x	34x	26x10	26x12	43x	43x	26x18	26x20
35x	35x	35x	35x	28x	28x	44x	44x	28x	28x
36x	36x	36x	36x	30x	30x	45x14	45x16	30x	30x
37x	37x	37x	37x	33x10	33x12			42x18	42x20
38x	38x	38x	38x						
42x	42x	42x	42x						
				■	■	■	■	■	■
■	■	■	■						
				34x10	34x12				
				35x	35x				
				36x	36x				
				37x	37x				
				■	■				
				38x10	38x12				
				42x	42x				

■ 4"x4" post

——→ ■ Wire terminal to post for electrical measurements

⟹ ■ Wire terminals (galvanic couple) to post for electrical measurements.

*Specimen identification: Digits preceding "x" denote system number (see Table 2) "x" represents site designation. Would be A, B, C, D, E or G depending upon where specimen was exposed. Digits following "x" are specimen numbers.

Figure 8c. Map showing burial order for specimens exposed in 1972 at the various sites.

First Removal (1 Yr)		Second Removal (2 Yr)		Third Removal (4 Yr)		Fourth Removal (8 Yr)		Fifth Removal (X Yr)	
■	■	■	■	■	■	■	■	■	■
7x01*	7x03*	7x05*	7x07*	7x09*	7x11*	7x13*	7x15*	7x17*	7x19*
11	11	11	11	11	11	11	11	11	11
12	12	12	12	12	12	12	12	12	12
7x02	7x04	7x06	7x08	7x10	7x12	7x14	7x16	7x18	7x20
11	11	11	11	11	11	11	11	11	11
12	12	12	12	12	12	12	12	12	12
■	■	■	■	■	■	■	■	■	■

■ - 4"x4" post

*Specimen identification:
Digits preceding "x" denote system number (See Table 2) "x" represents site designation. Would be A, B, C, D, E, or G depending upon where specimen was exposed. Digits following "x" are specimen numbers.

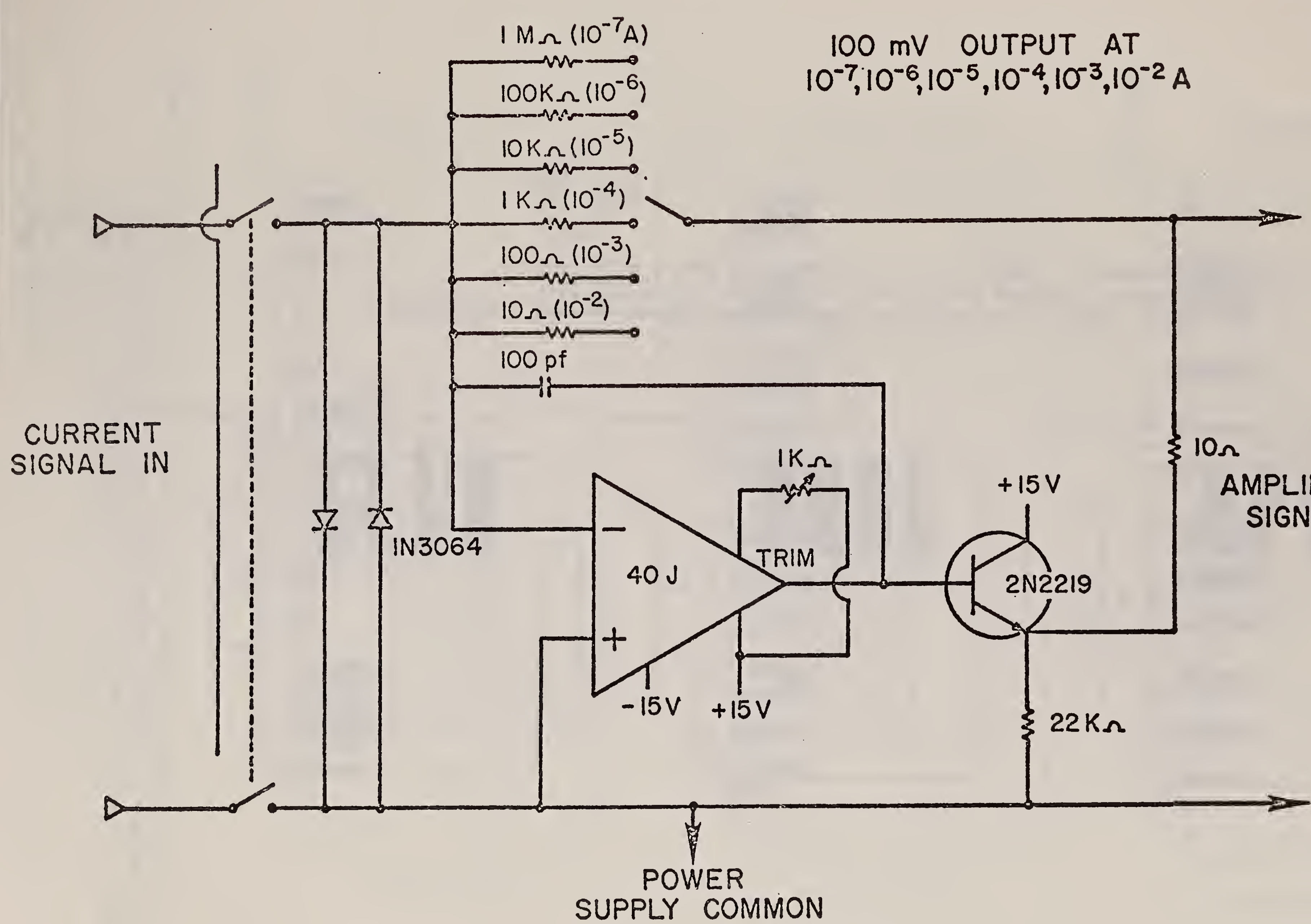

Figure 9. Solid state zero resistance amplifier (circuit suggested by R. J. Carpenter, Electronics Instrument Section, NBS).

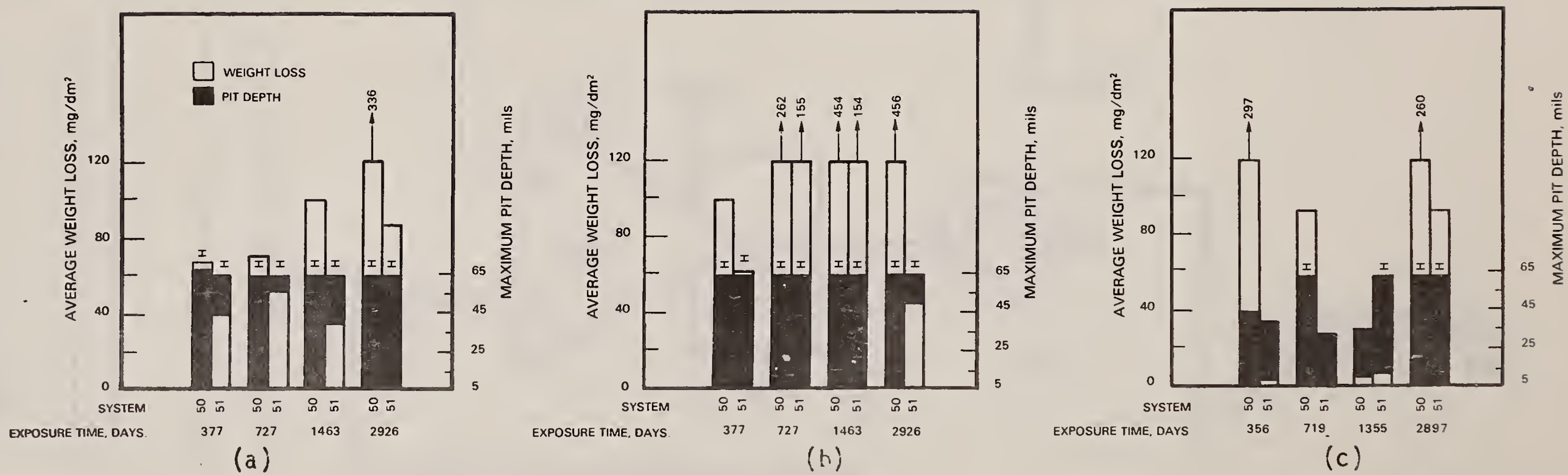

Figure 10. Average weight loss (mg/dm^2) and maximum pit depth (mils) for AISI 200 Series stainless steels after exposure in various soils. See Table 2 for descriptions of the systems. H-denotes perforation.
(a) Site C.
(b) Site E.
(c) Site G.

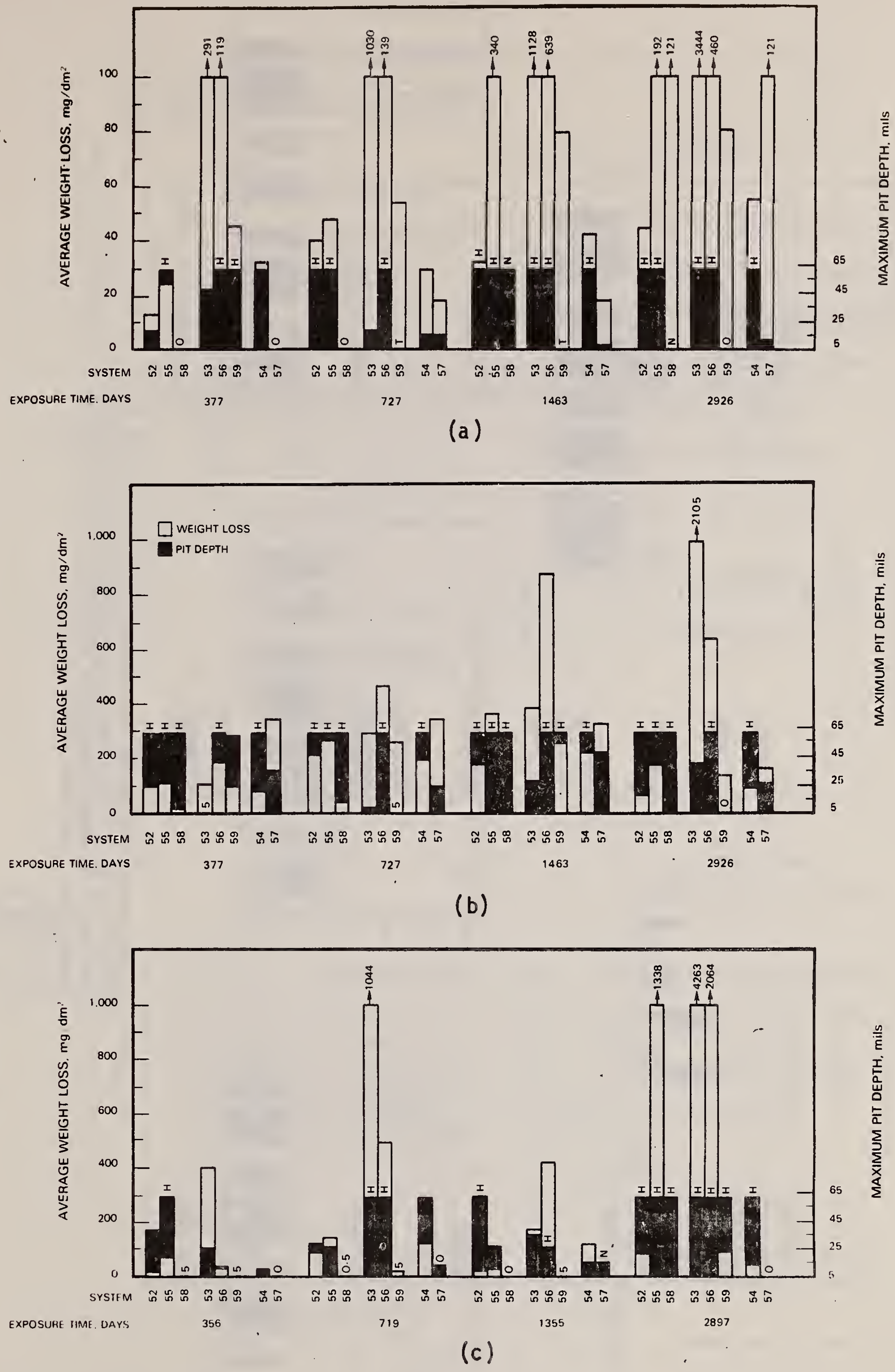

Figure 11. Average weight loss (mg/dm^2) and maximum pit depth (mils) for AISI 00 series stainless steels after exposure in various soils. See Table 2 for descriptions of the systems. O-none, N-<1 mg/dm^2, H-perforated and T-tunneling.
(a) Site C.
(b) Site E.
(c) Site G.

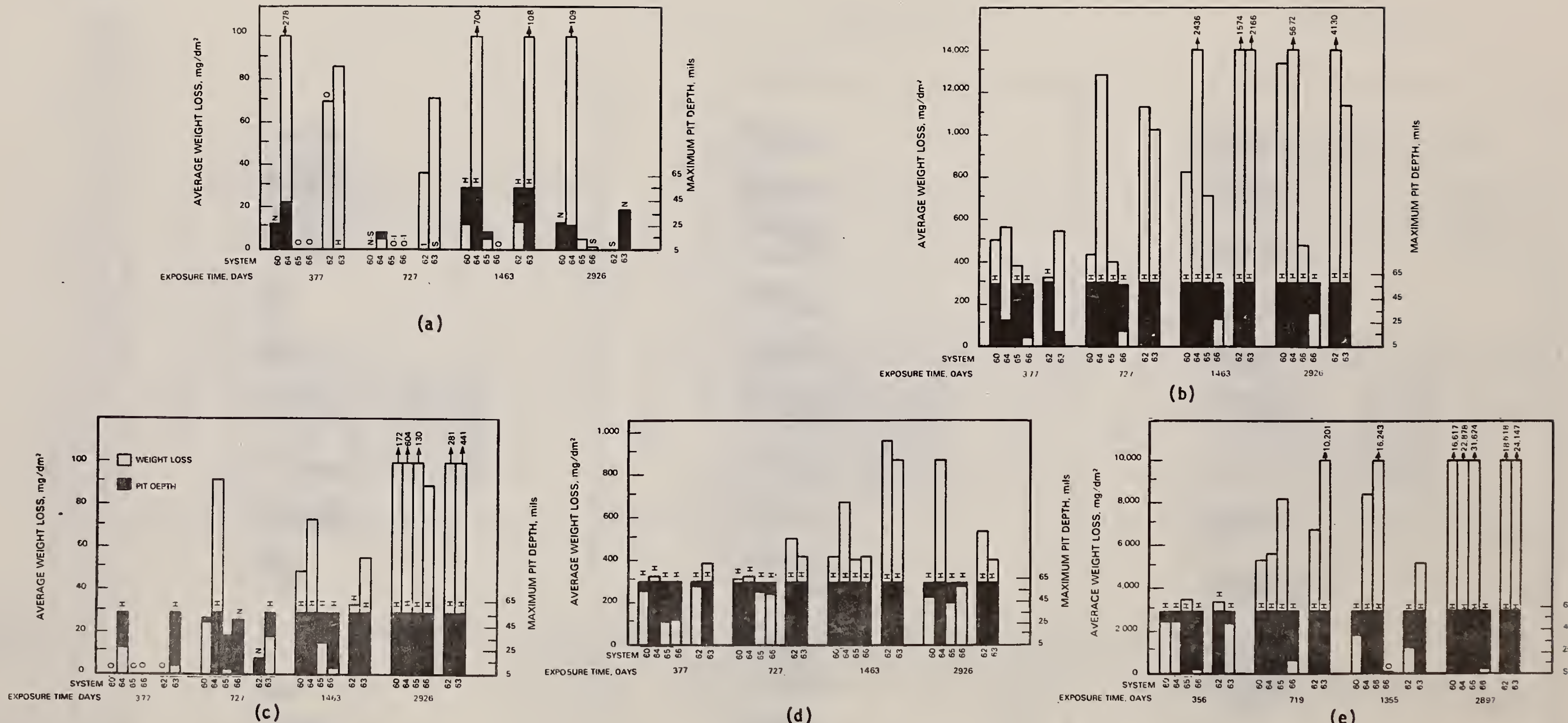

Figure 12. Average weight loss (mg/dm^2) and maximum pit depth (mils) for AISI 400 series stainless steels after exposure in various soils. See Table 2 for descriptions of the systems. O-none, N-<1 mg/dm^2, H-perforated, I-incipient pitting, S-<5 mils.

(a) Site A.
(b) Site C.
(c) Site D.
(d) Site E.
(e) Site G.

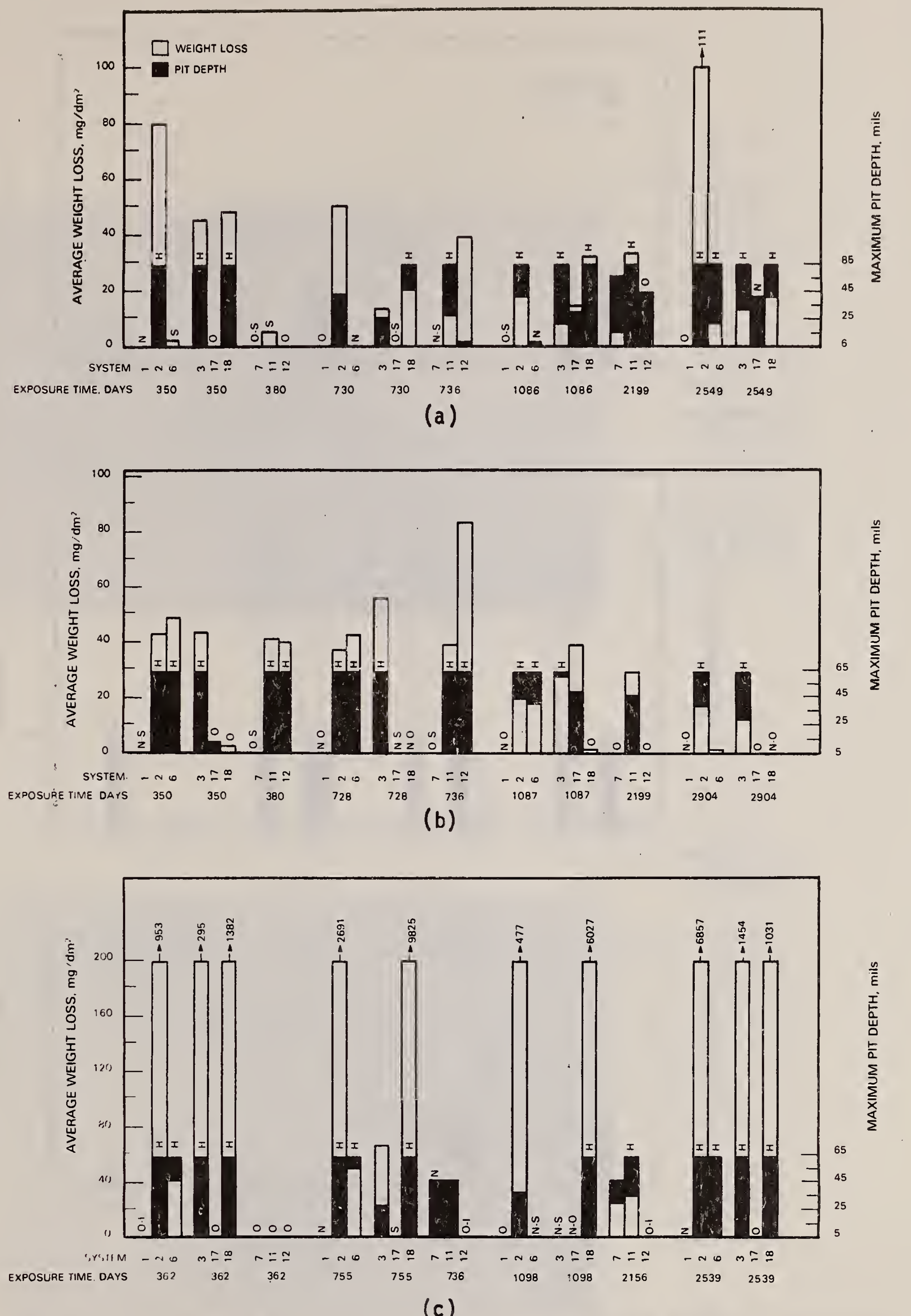

Figure 13. Average weight loss (mg/dm^2) and maximum pit depth (mils) for Fe-Cr alloy stainless steels after exposure in various soils. See Table 2 for descriptions of the systems. O-None, N-<1 mg/dm^2, H-perforated, I-incipient pitting and S-<5 mils.
(a) Site C.
(b) Site E.
(c) Site G.

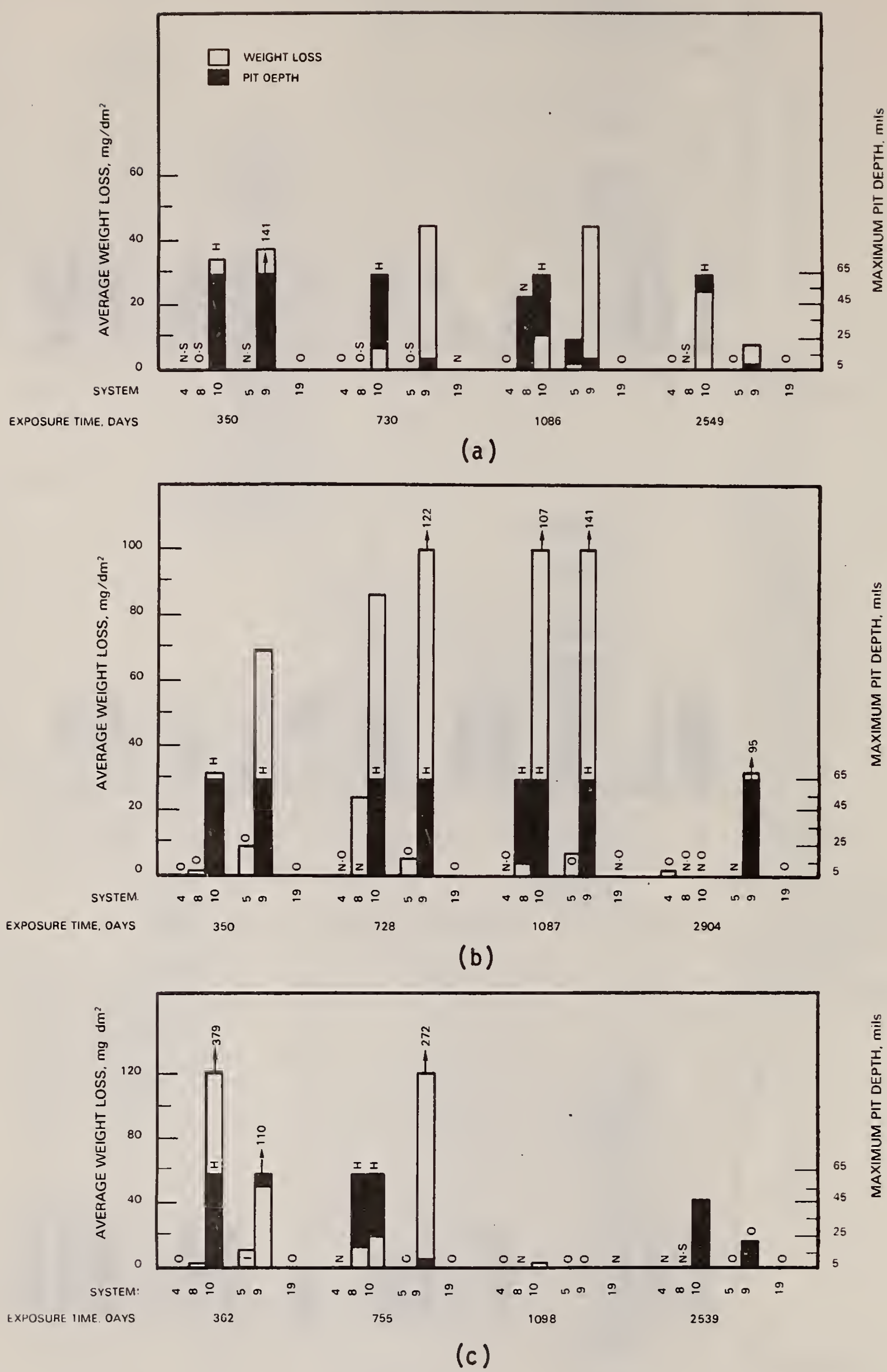

Figure 14. Average weight loss (mg/dm^2) and maximum pit depth (mils) for Fe-Cr-Ni alloy stainless steels after exposure in various soils. See Table 2 for descriptions of the systems. O-none, N-<1 mg/dm^2, H-perforated, I-incipient pitting, S-<5 mils.
(a) Site C.
(b) Site E.
(c) Site G.

Figure 15. Type 202 stainless steel buried for approximately 8 years at Site C. Arrows denote areas where tunneling corrosion was observed. X0.3.

Figure 16. Type 301 stainless steel buried for approximately 8 years at Site C. Tunneling corrosion was observed at edge areas (arrows). X0.3.

Figure 17. Type 301 stainless steel (sensitized) buried for approximately 8 years at Site C. Note etching of the surface and pitting corrosion where the specimen was perforated (arrow). Cracking was observed in the upper right quadrant (note missing portion of the specimen at this area). X0.3.

Figure 18. Type 301 stainless steel (sensitized) buried for approximately 8 years at Site G showing severe localized corrosion attack and cracking. X0.3.

Figure 19. Type 301 stainless steel with a cross-bead weld after exposure for approximately 8 years at Site C. With the exception of a small corrosion pit and tunneling corrosion observed at the weld (arrow), this specimen was relatively unaffected by corrosion. X0.3.

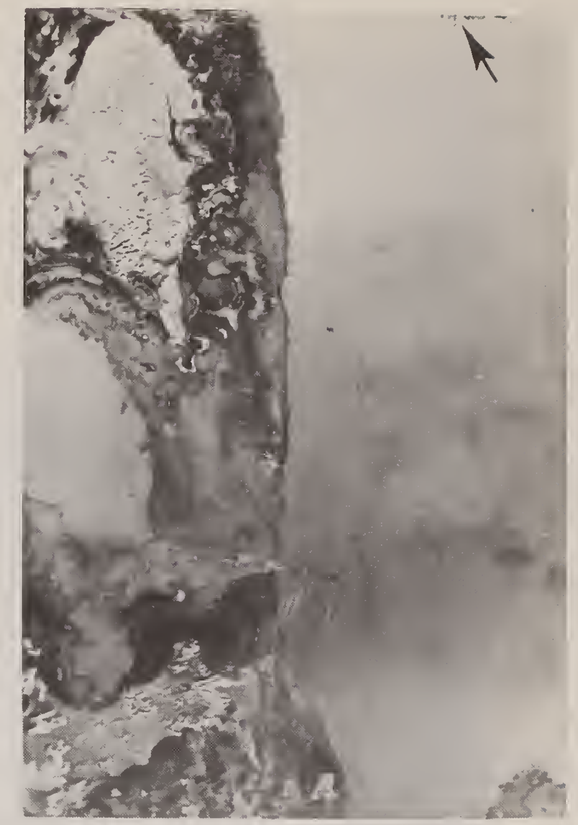

Figure 20. Type 304 stainless steel after exposure for approximately 8 years at Site G. Note sever etching (light areas on the left side) and tunneling corrosion at the top edge (arrow). The remainder of the surface was relatively unaffected by corrosion. X0.3.

Figure 21. Type 304 stainless steel (sensitized) after exposure for approximately 8 years at Site E. Areas exhibiting tunneling corrosion are noted at arrows. X0.3.

Figure 22. Type 304 stainless steel (sensitized) buried for approximately 8 years at Site E. Note tunneling corrosion which apparently originated at a corrosion pit on the surface of the specimen. X1.25

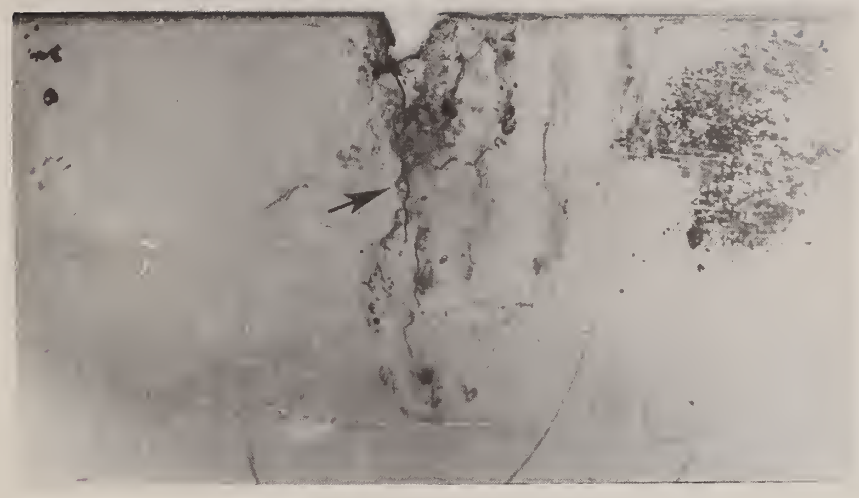

Figure 23. Type 304 stainless steel (sensitized) after exposure for approximately 8 years at Site E. Arrow denotes areas at end where cracking was observed. X0.6.

Figure 24. Type 409 stainless steel buried for approximately 8 years at years at Site C. Note severe corrosive attack on surface. Arrow denotes area where the specimen was perforated due to to corrosion. X0.3.

Figure 25. Type 409 stainless steel buried for approximately 8 years at Site G. Note severe localized corrosion and subsequent perforation of the material. X0.3.

Figure 26. Type 410 stainless steel after burial for approximately 8 years at Site E. Arrows denote areas which exhibited tunneling corrosion. X0.3.

Figure 27. Type 430 stainless steel after burial for approximately 8 years at Site G. This specimen was virtually destroyed due to corrosion. However, a small segment (lower right corner) was unaffected by corrosion. X0.3.

Figure 28. Type 430 stainless steel after exposure for approximately 8 years at Site D. Arrows denote areas where tunneling corrosion was observed. Filiform areas were etched. X0.3.

Figure 29. Type 409 stainless steel tube specimens havina a heliarc welded seam after exposure for approximately 8 years at Site G. Note severe localized corrosion at crevice areas (ends) and at other areas on the surfaces of the tubes. All were perforated due to corrosion. X0.3.

Figure 30. Type 409 stainless steel tube with a high frequency welded seam after exposure for approximately 8 years at Site C. Severe corrosion at crevice areas (areas at and adjacent to the capped ends) was observed. Other areas on the tube specimens exhibited severe general and localized pitting corrosion. All were perforated due to corrosion. X0.3.

Figure 31. Alloy 18 Cr (Ti) stainless steel after exposure for approximately 7 years at Site G. Note severe localized corrosion with subsequent perforation of the specimen at areas denoted by arrows. X0.3.

Figure 32. Alloy 18 Cr (Ti) stainless steel with a cross-bead weld after burial for approximately 7 years at Site G. This specimen exhibited severe localized corrosion, particularly in the lower right quadrant, at and adjacent to the weld. Arrow denotes area where the specimen was perforated due to corrosion. X0.3.

Figure 33. Alloy 18 Cr-8 Ni (N) stainless steel with a cross-bead weld after exposure for approximately 7 years at Site G. Pitting corrosion at area near the weld is shown at arrow. X0.3.

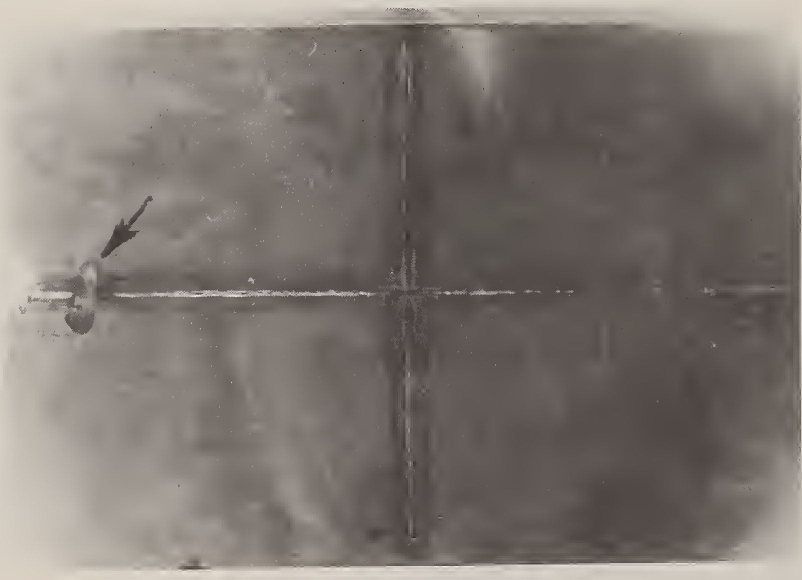

Figure 34. Alloy 18 Cr-8 Ni (N) stainless steel with a cross-bead weld after burial for 7 years at Site C. Localized corrosion is shown at the weld area designated by arrow. X0.3.

Figure 35. Alloy 18 Cr-2 Mo (Nb) stainless steel with a cross-bead weld after burial for approximately 7 years at Site C. Areas designated by arrows show pitting corrosion observed at the weld beads. X0.3.

Figure 36. Alloy 18 Cr (Ti) stainless steel tube with a heliarc weld seam after exposure for approximately 7 years at Site C. Note severe corrosion at and adjacent to crevice areas (top ends) on two specimens at the left. Both were perforated due to corrosion. X0.3.

Table 1. Properties of soils at test sites.

Site Iden	Soil	Location	Internal Drainage of Test Site	Resistivity[a] (ohm - cm)	pH	Composition of Water Extract (Parts per Million)								
						TDS[b]	Ca	Mg	Na + K as Na	CO_3	HCO_3	SO_4	Cl	NO_3
A	Sagemoor sandy loam	Toppenish, Wash.	Good	400	8.8	7,080	108	23	1,960	0.0	5,002	216	330	6
B	Hagerstown loam	Loch Raven, Md.	Good	12,600-34,760	5.3	(c)	-	-	-	-	-	-	-	-
C	Clay	Cape May, N.J.	Poor	400-1,150	4.3	14,640	540	754	2,242	0.0	0.0	6,768	3,529	118
D	Lakewood sand	Wildwood, N.J.	Good	13,800-57,500	5.7	(c)	-	-	-	-	-	-	-	-
E	Coastal sand	Wildwood, N.J.	Poor	1,320-49,500	7.1	11,020	302	329	3,230	0.0	55	1,133	5,765	31
G	Tidal marsh	Patuxent, Md.	Poor	400-15,500	6.0	11,580	140	165	2,392	0.0	0.0	1,709	3,259	37
						(Milligram equivalents per 100 grams of soil)								
A	-	-	-	-	-	-	0.54	0.19	8.50	0.0	8.20	0.45	0.93	0.01
B	-	-	-	-	-	(c)	-	-	-	-	-	-	-	-
C	-	-	-	-	-	-	2.70	6.18	9.51	0.0	0.0	14.0	9.94	0.19
D	-	-	-	-	-	(c)	-	-	-	-	-	-	-	-
E	-	-	-	-	-	-	1.51	2.70	13.9	0.0	0.09	2.36	16.2	0.05
G	-	-	-	-	-	-	0.70	1.35	10.2	0.0	0.0	3.56	9.18	0.06

(a) Resistivity determinations made at the test site by Wenner's 4-pin method [5] except for Site A where Shepard's cane [6] was used.

(b) TDS, total dissolved solids - residue dried at 105°C.

(c) Analysis not made for soils at Sites B and D because of the very low concentration of soluble salts in these soils.

Table 2. Stainless steel systems in underground corrosion tests

System	Burial Year	Stainless Steel	Spec. Config. & Size[a]	Treatment[b]	Passivation Procedure[c]	Stressed[d]	Spec. Coupled To
1	1971	26 Cr-1 Mo	Sheet (8"x12")	A	I	--	--
2	"	18 Cr (Ti)	" "	A	I	--	--
3	"	"	" "	XBW	I	--	--
4	"	20 Cr-24 Ni-6.5 Mo	" "	A	I	--	--
5	"	"	" "	S	I	--	--
6	"	18 Cr-2 Mo	" "	A	I	--	--
7	1972	18 Cr-2 Mo (Nb)	" "	A	I	--	--
8	1971	18 Cr-8 Ni(N)	" "	A	I	--	--
9	"	"	" "	XBW	I	--	--
10	"	26 Cr-6.5 Ni	" "	A	I	--	--
11	1972	18 Cr-2 Mo (Nb)	" "	XBW	I	--	--
12	"	"	Tube (2" ODx12")	HW	I	--	--
14	1971	Composite A	Sheet (8"x12"x0.12")	A	--	--	--
15	"	Composite B	" "	AA	--	--	--
16	"	Composite C	" "	A	--	--	--
17	"	26 Cr-1 Mo	Tube (2" ODx12")	HW	I	--	--
18	"	18 Cr (Ti)	(1 1/8" ODx12")	HW	I	--	--
19	"	20 Cr-24 Ni-6.5 Mo	(7/8" ODx12")	HW	I	--	--
20	"	26 Cr-1 Mo	Sheet (1"x12")	A	I	(UU)	--
21	"	"	" "	A	I	U	--
22	"	20 Cr-24 Ni-6.5 Mo	" "	A	I	(UU)	--
23	"	"	" "	A	I	U	--
24	"	"	" "	S	I	UU	--
25	"	18Cr-2Mo	" "	A	I	(UU)	--
26	"	"	" "	A	I	U	--
27	"	18 Cr-8 Ni(N)	" "	A	I	(UU)	--
28	"	"	" "	A	I	U	--
30	"	26 Cr-6.5 Ni	" "	A	I	U	--
33	"	26 Cr-1 Mo	" "	A	I	U	Zn
34	"	"	" "	A	I	U	Mg
35	"	"	" "	A	I	U	Fe
36	"	26 Cr-6.5 Ni	" "	A	I	U	Zn
37	"	"	" "	A	I	U	Mg
38	"	"	" "	A	I	U	Fe
42	"	"	" "	A	I	--	Cu
50	1970	201	Sheet (8"x12")	A	I	--	--
51	"	202	" "	A	I	--	--
52	"	301	" "	A	I	--	--
53	"	"	" "	S	I(f)	--	--
54	"	"	" "	XBW	I	--	--
55	"	304	" "	A	I	--	--
56	"	"	" "	S	I(f)	--	--
57	"	"	Tube (2" ODx12")	HW[e]	I	--	--
58	"	316	Sheet (8"x12")	A	I	--	--
59	"	"	" "	S	I	--	--
60	"	409	" "	A	III	--	--
61	"	"	" "	C	--	--	--
62	"	"	Tube (1-1/8" ODx12")	HW	III	--	--
63	"	"	Tube (7/8" ODx12")	HFW	III	--	--
64	"	410	Sheet (8"x12")	A	III	--	--
65	"	430	" "	A	II	--	--
66	"	434	" "	A	I	--	--
67	"	301	Sheet (1"x12")	HH	I	U	--
68	"	"	" "	HH	I	(UU)	--
69	"	"	" "	HH+S	I(f)	UU	--
70	"	"	" "	FH	I	U	--
71	"	"	" "	FH	I	(UU)	--
72	"	304	" "	A	I	U	--
73	"	"	" "	A	I	(UU)	--
74	"	"	" "	HH	I	U	--
75	"	"	" "	HH	I	(UU)	--
76	"	"	" "	S	I(f)	UU	--
77	"	316	" "	A	I	U	--
78	"	"	" "	A	I	(UU)	--
79	"	"	" "	S	I(f)	UU	--
80	"	434	" "	A	I	U	--
81	"	"	" "	A	I	(UU)	--
82	"	301	" "	HH	I	U	Zn
83	"	"	" "	HH	I	U	Mg
84	"	"	" "	HH	I	U	Fe
85	"	"	" "	FH	I	U	Zn
86	"	"	" "	FH	I	U	Mg
87	"	"	" "	FH	I	U	Fe
88	"	304	" "	A	I	U	Zn
89	"	"	" "	A	I	U	Mg
90	"	"	" "	A	I	U	Fe
91	"	"	" "	A	I	--	Cu
92	"	409	" "	A	III	--	Cu

(a) All sheet and tube specimens 0.064" thick.

Table 2 (Con't)

(b) Key: A - Annealed.
S - Sensitized (by heating at 1200°F for 2 hours, followed by air cooling and descaling in sodium hydroxide).
HW - Heliarc weld.
HFW - High frequency weld.
C - Coated (coal-tar epoxy).
HH - Half hard.
FH - Full hard
XBW - Cross bead weld (specified to be done in accordance with Welding Research Council recommendations. On half of these specimens, the welds were cleaned prior to exposure. The other half of the specimens were to be exposed "as welded".

(c) Passivation procedure:
I - 20 to 40% by volume of 67% nitric acid at 120-160°F for 20-30 minutes.
II - 20% by volume of 67% nitric acid plus 2-6% sodium dichromate at 110-140°F for 20-30 minutes.
III - 20 to 40% by volume of 67% nitric acid at 110-140°F for 20-30 minutes.

(d) Key: -- - Unstressed.
U - Single U-bend specimen.
UU - Double U-bend specimen, not spot welded.
(UU) - Double U-bend specimen, joined by a spot weld.

(e) Welded with a full finish per ASTM specification A249.

(f) Minimum specified concentration of acid, temperature and time for sensitized materials.

Table 3. Chemical analyses of non-ferrous constituents in stainless steels buried at various NBS underground test sites.

Stainless Steel	SYSTEMS	C	Mn	Si	S	P	Cr	Ni	Mo	N	Cu	Ti	OTHERS
		Weight %											
Type 201	50	0.066	6.90	0.47	0.009	0.034	16.76	5.10		0.078			
Type 202	51	0.10	8.05	0.41	0.004	0.003	17.50	5.13	0.15	0.15	0.12		
Type 301	52,53,54	0.092	1.1	0.49	0.006	0.015	16.1	7.1					
Type 301	67,68,69,82,83,84	0.10	1.02	0.34	0.016	0.030	17.43	7.14	0.22				Co-0.09
Type 301	70,71,85,86,87	0.13	0.86	0.54	0.013	0.020	16.98	7.23					
Type 304	55,56,72,73,76,88,89,90,91	0.048	1.46	0.50	0.012	0.030	18.2	9.80	0.17	0.042	0.19		
Type 304	57	0.06	0.82	0.68	0.015	0.024	18.45	9.11	0.40		0.25		
Type 304	74,75	0.051	1.0	0.64	0.009	0.022	17.6	9.8	0.15	0.16	0.11		Al<0.01,V-0.026
Type 316	58,59,77,78,79	0.049	1.62	0.53	0.009	0.020	17.48	13.53	2.28		0.11		
Type 409	60,61,92	0.058	0.47	0.57	0.005	0.014	10.75	0.61	0.12		0.37	0.60	Al-0.13
Type 409	62	0.05	0.51	0.44	0.013	0.024	11.22	0.67				0.65	
Type 409	63	0.05	0.41	0.44	0.018	0.022	11.20	0.34				0.55	
Type 410	64	0.14	0.55	0.14	0.014	0.016	12.53						
Type 430	65	0.060	0.46	0.50	0.010	0.017	16.67						
Type 434	66,80,81	0.076	0.42	0.43	0.011	0.017	18.2	0.32	0.76	0.046	0.05		Al-0.046,V-0.025
26Cr-1Mo	1,17,20,21,33,34,35	0.002	0.01	0.21	0.011	0.010	26.18	0.10	0.94	0.010			
18Cr(Ti)	2,3,18	0.046	0.32	0.40	0.013	0.023	18.22	0.49				0.55	
20Cr-24Ni-6.5Mo	4,5,19,22,23,24	0.038	1.73	0.81	0.004	0.013	20.41	23.61	6.50				
18Cr-2Mo	6,25,26	0.013	0.91	0.10	0.010	0.023	18.90	0.15	2.15	0.023	0.08		Nb-0.07,Pb-0.002 Sn-0.005,Al-0.01
18Cr-8Ni(N)	8,9,27,28	0.035	1.64	0.36	0.012	0.029	19.29	8.15	0.26	0.25	0.18		
26Cr-6.5Ni	10,30,36,37,38,42	0.015	0.49	0.40	0.020	0.022	26.5	6.2	0.04	0.021	0.08		Al<0.01,V-0.054
18Cr-2Mo (Nb)	7,11,12	0.03	0.91	0.78	0.016	0.02	18.54	0.28	1.97	0.031	0.13		Nb-0.47,Al-0.01 Pb-0.003
Composite Alloys[(a)]:													
A Type 430	14	0.06	0.16	0.31	0.008	0.015	16.86	0.28					
B Type 430	15	0.06	0.16	0.31	0.008	0.015	16.86	0.28					
C Type 304	16	0.02	1.26	0.48	0.018	0.02	17.3	10.2					
Carbon steel	14,15,16	0.042	0.32	0.009	0.012	0.007					0.017		Al-0.048

(a) A. Carbon Steel/430/Carbon Steel
B. Galv. Steel/430/Galv. Steel
C. Carbon Steel/304/Carbon Steel

Table 4. Mechanical properties[a] of stainless steels studied in this investigation

Alloy Designation	Treatment[b]	System	Tensile Strength, Ksi(d)	Yield Strength, Ksi(d)	Percent, Elongation in 2-in	Hardness
Type 201	--	50	103.5	53.0	52.5	R_B 92.5
Type 202	--	51	100.6	52.0	52.0	R_B 90.5
Type 301	--	52	120.1	42.1	64.0	R_B 85
Type 301	Sensitized	53	107.9	38.1	46.0	R_B 87
Type 301	Half-hard	67,68,82,83,84	162.0	116.0	25.0	R_C 34
Type 301	Half-hard + sensitized	69	147.0	97.5	26.0	R_C 28
Type 301	Full-hard	70,71,85,86,87	203.0	174.7	9.0	R_C 44
Type 301	Welded cross bead	54	See Type 301 (annealed)			
Type 304	--	55,72,73,88,89,90,91	86.9	46.4	52.0	R_B 85
Type 304	Sensitized	56,76	85.3	41.3	53.0	R_B 81.5
Type 304	Half-hard	74,75	144.7	129.3	14.0	R_C 33
Type 304	Heliarc weld	57	81.8	44.9	75.7	R_B 72
18Cr-8Ni(N)	--	8,9,27,28	103.0	60.0	45.0	R_B 91
Type 316	--	58,77,78	91.6	43.4	42.0	R_B 81
Type 316	Sensitized	59,79				
Type 409	--	60,92	70.6	46.6	31.0	R_B 77
Type 409	Heliarc weld	62	70.7	59.1	40.0	R_B 79
Type 409	Hi-Freq. weld	63	69.8	64.7	37.0	R_B 68
Type 410	--	64	74.5	52.8	29.5	R_B 84
Type 430	--	65	71.0	45.6	30.5	R_B 81
Type 434	--	66,80,81	79.8	56.3	26.0	R_B 86
26 Cr-1 Mo	--	1	71.5	54.0	26.0	R_B 88.5
26 Cr-1 Mo	--	17	79.5	48.1	31.0	R_B 78
26 Cr-1 Mo	--	20,21,33,34,35	67.0	48.6	26.5	R_B 79
18 Cr(Ti)	--	2,3,18	74.2	46.4	28.5	R_B 80
20 Cr-24 Ni-6.5 Mo	--	4,15,19,22,23,24	92.0	45.0	47.0	R_B 78.5
26 Cr-6.5 Ni	--	10,30,36,37,38,42	131.8	120.6	13.5	R_C 31
18 Cr-2 Mo	--	6,25,26	83.8	60.8	26.6	—
18 Cr-2 Mo (Nb)	--	7,11,12	81.0	61.8	36.0	R_B 86

(a) Properties are as furnished by supplier.
(b) All materials were in the annealed condition unless otherwise noted.
(c) Welded with a full finish per ASTM Specification A249.
(d) 1 Ksi = 6.8948 MPa.

Table 5. Summary of results[(a)] obtained from visual examination of stainless steel sheet specimens buried in the soils at the NBS soil corrosion test sites. Specimens of System Nos. 1 through 6, 8, 10, 14, 15, and 16 were buried for approximately 7 years. System No. 7 was buried for approximately 6 years while others were buried for approximately 8 years.

System	Stainless steel	Specimen Type and Treatment	Test Site (c)	Results of Visual Examination of Specimens (e) Exposed 1 year	Exposed 2 years	Exposed 4 years	Exposed 8 years
Exposed in 1970							
50	Type 201	Sheet, annealed	A	N	N	N	N
			B	N	RS	RS	N
			C	T,P,H	P(F,E),T,IP	H,P,T	H,P,T(AE,E,F)
			D	IP	P,IP	N	H,P,T(AE,E,F)
			E	H,P,T	H,T,P,IP,Et(sli)	H,T(E,F),P	H,P,T(AE,E,F),IF
			G	A,P,IP,Et(sli)	H(E),P,A(sev),IP	P+T(E,AE)	H,P,T(F,AE,E)ET
51	Type 202	Sheet, annealed	A	N	IP	DS	P(F)
			B	N	RS	DS+RS(sli)	N
			C	T,P,H	H,P(F,E),T,IP	H,P,T,RS	H,T,P(F,E,AE)
			D	IP	DS	DS	H,P,T(F,E,AE)
			E	H,T(E),P,IP	H,P,T,IP,IF	H,P,T,RS	H,T,P(AE,E,F),IF
			G	P,IP	P,IP	H,P,RS,DS,IP	H,T,P(AE,E,F)
52	Type 301	Sheet, annealed	A	N	IP	N	N
			B	IP	RS	DS(sli)	N
			C	T,P,IP	H,P(F,E),IP	H,P,T(E,AE)	H,P,T(AE,E)RS
			D	IP	IP	RS+DS(sli)	N
			E	H	H,P,T,IP	H,P+T	H,T,P(AE,E,F)RS,IF
			G	P,T(E),IP	T,P,A+Et(sev),IP	H,P,RS,IP	H,P,T(E,AE,F)
53	Type 301	Sheet, sensitized	A	IP,Et	Et(E),P,IP	P(sli),IP,RS,DS,Bl	P(Sli),Bl,RS
			B	IP(E)	P(sli),IP	RS,DS	P(Sli),Bl,RS
			C	P,Et	Et(sev),P(F,E),IP	H,P,A(sev-mod)	H,P(E,AE,F)Et,Ck
			D	IP(E)	P,Bl,IP	Bl,P,IP,Et,A(E)	P,Bl,(F,AE,E)RS,Ck
			E	A(E),P(E,AE),IP,Et	Et(sev),Bl,A(E),P,IP	P(AE,F),Bl,Ck,RS,IF	P(F,AE,E)RS,IF,Ck
			G	Et(mod-sev),P,IP	H,A+Et(sev),P,IP	P+DS,IP	H,P(F),A(sev),DS,Ck
55	Type 304	Sheet, annealed	A	N	IP	DS	N
			B	N	RS	N	N
			C	H,T,IP	T,P,IP	H,P+T(E,AE),Et	H,T,P(AE,F)
			D	IF	N	DS	P,T(E,AE)
			E	H,P,IP	H,T,P,IP	H,T+P"	H,T,P(E,AE,F)IF,RS
			G	H(E),P,IP,Et(sev)	A(sev),P,IP	P,Et,DS,RS	H,T,P(E,AE,F)Et,A(sev)
56	Type 304	Sheet, sensitized	A	Et[E(sli)],IP	P(sli),IP	Et(sli),IP	P,RS
			B	Et(sli),IP	N	Et(mod)	N
			C	H,T(E),P	H,P(E,AE),T,A(E),IP	H,P,A(sev),IP	H,T,P(E,AE,F),Ck
			D	IF	T,P(E,AE),IP,Bl	Et,P(AE),T(E,AE),Bl	H,T,P(E,AE,F)
			E	H,P,IP	H,T,P,IP	H,T,P,Et,RS	H,T,P(E,AE,F)IF,Ck
			G	H(E),P,IP	H,A,P,IP,Et(sev)	A(sev),P+Et(sli),IP,Et	H,T,P(F,AE,E)Et(sev),Ck
58	Type 316	Sheet, annealed	A	N	IP	RS(sli)	N
			B	N	N	DS(sli)	N
			C	Et,IP	IP	P(E),RS	P(E)RS
			D	N	N	N	N
			E	A+T(E),P(E,F)	H,T,P,IP	H,P(E,AE)	H,T,P(AE,E,F)
			G	IP	IP	N	H,T,P(AE,E)
59	Type 316	Sheet, sensitized	A	IP(E)	P(sli),IP	P(sli),IP,RS,Et	P(Sli)(F)
			B	N	DS	Et,RS	P(Sli)
			C	P(E,F),H(E)	A+P(E),T,Et(sli)	P,A(E),Et	P(E)Et,RS,A
			D	IP	N	Et,P,DS	N
			E	P(E)	P,A(E),Et(sli)	A(E),T(E,F),RS,IF	A(E)T,P(AE,E,F)IF,RS
			G	P(E)	P,IP,Et(sli)	IP,P,RS	H,T,P(E,AE),A(E)IF
60	Type 409	Sheet, annealed	A	IP	N	H,P(E,AE,F),DS	P(AE,E,F)RS
			B	N	P(sli)	DS,RS	P(F)
			C	P,H(E),Et(sev)	H,P,Et(sev),T,IP	H,P(E,AE,F),A,RS,IP	H,P(E,AE,F)A(sev)Et,IF
			D	IF,RS	P,T	H,P(E,AE,F),T,Et	H,T,P(F,AE,E)
			E	H,T(E,F),P	H,T(AE,F),P,IP,Et(sli)	H,T(E,AE,F),RS,IF	H,T,P(E,AE,F)IF,RS
			G	H,Et(sev),P,IP	H,P,A(sev),Et,IP	H,P(E,AE,F),A(sev)	H,P,(F,AE,E)IF,A(sev)

Table 5 (Cont'd)

System	Stainless steel	Specimen Type and Treatment	Test Site (c)	Results of Visual Examination of Specimens (e) Exposed 1 year	Exposed 2 years	Exposed 3 years	Exposed 7 years
8	18 Cr-8 Ni(N)	Sheet, annealed	A	IP	N	N	RS(Sli)
			B	N	RS	DS,IF	N
			C	IP	P,IP,RS	P(E),RS,IF	P(E)RS,IF
			D	N	Et(sli)	DS	N
			E(d)	P(E)	P(E)	H,P(E,AE),RS,IF	RS(AE,E)
			G	P(E,F),IP	H,P,T(E,AE),Et,IP	A(mod),Et(sli),IP	A(Sli)(F)RS(E)
10	26 Cr-6.5 Ni	Sheet, annealed	A	P(sli),IP	P[sli(AE)]	DS	P(Sli)(F,AE)
			B	N	RS	DS	N
			C	H,T,P,IP	H,T(E),P,IP	H,P(E,AE,F),Et(sli)	H,T,P(AE,E,F)IF
			D	N	IP	N	H,P(F)
			E(d)	H,P,IP	H,P,T(E,AE,F),IP	H,P(E,AE,F),IP	N
			G	H,P,A+Et(sev),IP	H,P,T(E,AE),IP	P,IP,DS,RS	P(E,F)
14	Composite A	Sheet, hot rolled and pickled	A	Et(sev),P	P,Et[(sev)AE,F]	P(E,AE,F),Et	P(E,AE,F),A,(sev)Et
			B	Et(sev),P,IP	P,Et[(sev),AE,F],A(E)	P(E,AE,F),Et	P(E,AE,F),A,(sev)Et
			C	Et(sev),P	P,Et(AE,F),A(E)	P(E,AE,F),Et	P,(E,AE,F),A,(sev)Et
			D	Et(sev),P	P,Et(AE,F)	RS,P(E,AE,F),Et	P(E,AE,F)A,(sev)Et
			E(d)	Et[E+F(sev)]	P,Et(AE,F)	RS,P(E,AE,F),Et	P(E,AE,F)A,(sev)Et
			G	Et(sev),Bl,P(AE)	P,Et(AE,F),A(E)	P(E,AE,F),Et	P(E,AE,F)A,(sev)Et
15	Composite B	Sheet, hot-dip zinc coated (4.5 oz/sq. ft.-Zn)	A	N	N,c	N	N
			B	N	N	N	A(Sli)(E,AE)
			C	N	N	N	A(Sli)(F,E,AE)
			D	N	N	N	N
			E(d)	A[F(sli)]	N	A[F(sli)]	N(E,AE,F)
			G	P(F),Fl(E,AE)	P[F(sli)]	A[F(sli)]	A(Mod),P,Et
16	Composite C	Sheet, hot rolled and pickled	A	Et(sev),P(AE,F)	P,Et(AE,F)	P(E,AE,F),Et	P(E,AE,F)A(sev)Et
			B	Et(sev),P	P,Et(AE,F),A(E)	P(E,AE,F),Et	P(E,AE,F)A(sev)Et
			C	Et(sev),P	P,Et(AE,F)	P(E,AE,F),Et,RS	P(E,AE,F)A(sev)Et
			D	Et(sev),P	P,Et(AE,F)	RS,P(E,AE,F)Et	P(E,AE,F)A(sev)Et
			E(d)	Et(sev),P	P,Et(AE,F)	RS,P(E,AE,F)Et	P(E,AE,F)A(sev)Et
			G	Et(sev),P	P,Et(AE,F)	P(E,AE,F),Et	P(E,AE,F)A(sev)Et
Exposed in 1972				Exposed 1 year	Exposed 2 years		Exposed 6 years
7	18 Cr-2 Mo(Nb)	Sheet, annealed	A	N	P,DS		N
			B	N	DS		N
			C	N	P(E,AE),RS,IF		P(E,AE,F)
			D	N	N		RS,DS
			E	P,IP	P(AE,F),RS		IF
			G	N	P(E,F)		H,T,P(AE,E,F)

(a) Results given for each system at each of the six soil test sites are a summary tabulation for four individual specimens.

(b) Specimen dimensions and treatment for each system are given in Table 2.

(c) Properties of the soils for each of the test sites are given in Table 1.

(d) Specimens removed from site "E" in 1979 after 8 years exposure.

(e) Abbreviations used:

- A- Metal attack
- AE- Adjacent to edge
- Bl- Blisters
- BS- Black stain
- c- Coating chipped
- Ck- Specimen cracked
- DS- Dark stain
- E- Edge
- Et- Etched
- F- Face
- Fl- Coating flaked
- H- Perforation
- IF- Iridescent film
- IP- Incipient pitting
- mod- Moderate
- N- No apparent attack
- P- Pitting
- RS- Rust stain
- s- Scored area
- sev- Severe
- sli- Slight
- T- Tunneling
- U- Undercutting

Table 5 (Cont'd.)

System	Stainless steel	Specimen Type and Treatment	Test Site (c)	Results of Visual Examination of Specimens (e)			
				Exposed 1 year	Exposed 2 years	Exposed 4 years	Exposed 8 years
61	Type 409	Sheet, painted	A	N	N	N	N
			B	N	N	N	N
			C	N	N	N	N
			D	N	N	N	N
			E	N	N	RS(c)	RS(E),Bl
			G	N	N	N	N
61	Type 409	Sheet, painted and scored	A	RS(s)	N	RS(s)	N
			B	RS(s)	RS(s)	N	N
			C	RS(s,c)	RS[s(sli)],U	RS(s)	RS(s),Bl,U(s)
			D	c,RS(s)	RS[s(sli)]	Bl+U(s)	RS(s)
			E	c,RS(s)	P+RS(s),U,Bl	RS(s)	RS(s)U(s)
			G	RS(s)	P+RS(s),U,Bl	RS(s)	A(s)Bl(s)U(s),RS(S)
64	Type 410	Sheet, annealed	A	P+IP(E,F)	T,P,A(E)	H,P(E,AE,F),DS,IP	P,T(F,AE,E)RS
			B	IP	N	P,IP,RS	P(F),RS(E)
			C	H,P,IP	H,P,Et(sev),A,IP	H,P(E,AE,F),Et+A(sli)	H,P(E,AE,F),A(sev)
			D	H,P,T,IP	H,T,P,A(E),Et(sev),IP	H,T(E,AE,F),P(E,F),A(E)	H,T,P(F,E,AE)
			E	H(E)T	H,T,P,IP	H,T(E,AE,F),P,RS,DS	H,T,P(E,AE,F)RS
			G	Et(sev),H,P,IP	H,A+Et(sev),P,IP	H,P(E,AE,F),A(sev)	H,P(F,E,AE),A(sev),IF,RS
65	Type 430	Sheet, annealed	A	Et(sli),IP	IP	P,T,IP	N
			B	N	N	IF	N
			C	H(E)	H,P,T,Et	H,P(E,AE,F),Et(sli),A(sev)	H,T,P(F,E,AE)Et,DS
			D	IF	T(F)	H,T(E,AE,F),P	H,P,T(F,E,AE)
			E	H,T,IP	H,T,P,IP	H,P+T(E,AE,F),IP,RS	H,T,P(E,AE,F)
			G	H,Et(sev),P,IP	H,P,A+Et(sev),IP	H,P(E,AE,F),A(sev),IP	H,P(F,AE,E),A(sev)RS,DS
66	Type 434	Sheet, annealed	A	N	IP	N	N
			B	IP	N	N	N
			C	H(E)	H,P,T,IP	H,P(E,AE,F),T(E,AE),Et,IP	H,T,P(F,E,AE)
			D	N	P(F),IP(E)	H,T(AE),P(AE,F)	H,P,T(F,AE,E)
			E	H,P,IP	H,T,P,IP	H,P,T(E,AE,F),RS	H,T,P(E,AE,F)IF,RS
			G	H(E),P,IP	H,P,A+Et(sev),IP	P(E,AE),Et(sli),RS	H,P,T(E,AE,F)
Exposed in 1971				Exposed 1 year	Exposed 2 years	Exposed 3 years	Exposed 7 years
1	26 Cr-1 Mo	Sheet, annealed	A	IP	N	DS	N
			B	N	RS	DS	N
			C	IP(E)	IP,RS	P,RS,IP,IF	RS(sev),DS
			D	IP	Et(sli)	RS	N
			E(d)	IP	N	IF,RS	N
			G	Et(sli),IP	N	N	N
2	18 Cr(Ti)	Sheet, annealed	A	P(sli),IP	N	Et(sli),P,RS	P(Sli)AE
			B	N	Et(sli),RS	DS	N
			C	H,P,Et,IP	Et,P(E,F),IP,RS	H,P(E,F),Et(sli),IP	H,P(F,AE),A,RS
			D	P(AE),T,IP	N	RS	H,T,P(F,AE)
			E(d)	H,P,T	H,P(E,AE,F),T	H,P(E,AE,F),IP	H,T,P(E,AE,F)
			G	H,P,A+Et(sev),IP	H,P(E,AE,F),Et,IP	P,A(sev),IP,RS	H,P(E,AE,F)Et,A(sev)
4	20 Cr-24 Ni-6.5 Mo	Sheet, annealed	A	IP	N	DS	N
			B	N	Et(sli),RS	N	N
			C	IP(E)	N	N	N
			D	N	Et(sli),RS	RS	N
			E(d)	N	N	N	N
			G	N	N	RS	N
5	20 Cr-24 Ni-6.5 Mo	Sheet, sensitized	A	IP	N	DS	N
			B	N	N	DS	N
			C	IP	Et(sli),IP,RS	Et(sli),P(E),RS	RS,DS
			D	IP	Et(sli)	IF,DS	N
			E(d)	A(E)	Et(sli)	DS	N
			G	P(E),Et(sli),IP	Et(sli)	Et(sli),DS	N
6	18 Cr-2 Mo	Sheet, annealed	A	IP	N	DS	N
			B	IP	N	DS,IF	N
			C	T,P(E,F),IP	RS	P(AE),RS,DS	H,T,P(AE,E,F)RS
			D	N	Et(sli)	RS,IF	P,T(F)
			E(d)	H,P,IP	H,P(E,AE,F),RS	H,P(E,AE,F)	N
			G	H,T,A,P,IP	H,P(E,AE,F),Et	P(E),RS,DS	H,P(E,F,AE)

Table 6. Summary of results[a] obtained from visual examination of welded stainless steel sheet and tube specimens buried in the soils at six NBS soil corrosion test sites for up to 8 years.

System	Stainless Steel	Material and Treatment	Test Site [c]	Body or Face	Cap	End or Edge	Weld[e]	Body or Face	Cap	End or Edge	Weld[e]	Body or Face	Cap	End or Edge	Weld[e]	Body or Face	Cap	End or Edge	Weld[e]
Exposed in 1970				Exposure Time, 1 Year				Exposure Time, 2 Years				Exposure Time, 4 Years				Exposure Time, 8 years			
54	Type 301	Sheet with	A	N	N/A	N	N	IP	N/A	P(AE)	P(AW)	N	N/A	N	N	DS	N/A	N	N
		cross-bead	B	N	N/A	N	N	IP	N/A	N	RS(W,AW)	DS,IF	N/A	N	N	N	N/A	N	IF(W,AW)
		weld	C	N	N/A	P	P(AW)	P	N/A	P	P(W,AW)	H,P	N/A	P+T(E,AE)	P(W,AW)	P,T	N/A	T,H(AE,E)	P,T,H(AW)IF
			D	IP	N/A	N	N	N	N/A	N	P(AW)	RS	N/A	N	P+RS(W)	P,T	N/A	P,T(AE,E)	P,T(AW)
			E	H	N/A	N	N	H,T,P,IP	N/A	P	P(AW)	H,P,T,RS	N/A	P+T(E,AE)	RS(W)	P,T	N/A	H,P,T(AE)	H,P,T(AW,W)
			G	P	N/A	P	P(W,AW)	P,Et(sev),IP	N/A	P	P+A(W,AW)	A(sev),P	N/A	A(sev)+P	A(sev),P(W,AW)	P,A(ser)	N/A	H,P(E,AE)	P(W,AW)
57	Type 304	Tube with	A	Et(sli)	N	N	N	Et	N	N	N	P,Et(sli)	P(AC)	N	P(AW)	P	RS	N	N
		heliarc weld-	B	Et(sli)	N	N	N	Et(sli)	Et(UC)	N	N	Et(sli),RS	N	N	N	Et,RS	RS(AC,UC)	N	N
		ed seam (2-in	C	Et(sli)	N	N	N	P	P(UC,AC),A(UC)	N	P(W,AW)	P	P(AC),Et(UC)	N	N	P	P,Et(AC,UC)	N	RS(AW,W)
		OD)	D	Et(sli)	N	N	N	Et(sli)	N	N	N	P,RS	RS(UC)	N	N	Et	Et(UC)	N	Et(W,AW)
			E	Et(mod to sev)	N	N	N	Et(sev),P,IP	P(AC,UC)	N	N	P	P+Et(AC,UC)	N	N	P,RS	P,Et,A(AC,UC)	P	P(W,AW)
			G	Et(mod),P,IP	N	N	N	P,Et(sli),IP	P(AC,UC)	N	P(W)	P	N	N	P(AW)	Et,RS,IF	P,Et(AC,UC)	P	N
62	Type 409	Tube with	A	P,IP	P+IP(UC)	N	P+IP(W)	Et(sli),IP	N	N	IP(AW)	H,P,T,Et	P+T(AC)	N	N	P,Et	RS,DS(UC)	N	RS,DS(W,AW)
		heliarc weld-	B	N	N	N	N	P,IP	N	N	N	Et,IF	N	N	N	DS,Et	DS(UC,AC)	N	N
		ed seam	C	H	N	N	N	H,P,Et,IP	H+P(AC,UC)	N	P(W)	H,P,Et,IP	P(AC,UC)	N	P(W,AW)	H,P	H,P(UC,AC)	N	HP(W,AW)Et
		(1-1/8-in OD)	D	N	N	N	N	P,Et(sli),IP	N	N	N	H,P	P(AC)	N	N	H,P,T,Et	T,P(UC,AC)	N	P(W,AW)
			E	H,P	N	N	N	H,P,Et(sli),IP	H+P(AC,UC)	N	P(W)	H,P,T,IP	P+T(AC,UC)	N	N	H,P,T	H,P(UC,AC)Et	N	H,P(W,AW)
			G	H,Et+A(sev),P	N	N	N	H,P,A(sev),Et,IP	H+P(AC,UC)	N	H+P(W,AW)	H,P,IP	P(AC,UC)	N	P(W,AW)	H,A(sev)	H,A(sev)	N	H,A(sev)
63	Type 409	Tube with	A	Et,P	IP(AC)	N	IP(W)	IP	N	P	IP(AW)	H,P,T	P(AC)	N	P(AW)	P	N	N	N
		high frequency	B	N	N	N	N	P,IP	N	N	EP(W,AW)	N	N	N	N	N	N	N	N
		welded-seam	C	P	N	N	N	H,P,Et,IP	H(AC)	N	H(W),P(W,AW)	H,P,Et	P(AC,UC)	N	P(W,AW)	H,P,T	H,P(VC,AC)	-	H,P(W,AW)
		(7/8-in OD)	D	N	N	N	H,P(AW)	H,P,Et(sli),IP	N	N	H+P(W,AW)	H	P(AC)	N	P(W,AW)	H,P,T	H,P,T(AC)	-	H,P,T(W,AW)
			E	H,P,IP	N	N	N	H,T,P,IP	H+P(AC,UC)	N	H+P(W,AW)	H,P,IP	P(AC,UC)	N	P(W,AW)	H,P,T	H,P,T(AC,UC)	-	H,P(W)
			G	H,A(sev),P	P(AC)	N	N	H,P,A(sev),Et	H+P(AC)	N	H+P(W,AW)	H,P,IP	P(AC)	N	P(W,AW)	H,A(sev)	H,A(sev)	-	H,A(sev)
Exposed in 1971				Exposure Time, 1 Year				Exposure Time, 2 Years				Exposure Time, 3 Years				Exposure Time, 7 years			
3	18 Cr(Ti)	Sheet with	A	IP,Et	N/A	N	N	P	N/A	N	N	P,RS,DS	N/A	N	N	N	N/A	N	N
		cross-bead	B	N	N/A	N	N	N	N/A	N	N	DS	N/A	N	N	N	N/A	N	N
		weld	C	P,T,IP	N/A	P,T	P(W,AW)	P,Et(sli),IP	N/A	P	P(W)	H,P,Et,IP	N/A	P(E,AE)	P(W;AW)	P,T	N/A	H,P,T(AE,E)	H,P(W)
			D	P	N/A	N	P(W,AW)	N	N/A	N	N	DS	N/A	N	N	P,T	N/A	N	P
			E(f)	H,P,IP	N/A	H,P	P(W,AW)	H,P,Et,IP	N/A	P(AE,E)	P(W)	H,P,DS,IF	N/A	P(E,AE)	N	H,P(F)	N/A	H,P(E)	H,P(W,AW)
			G	H,P,IP	N/A	H,P	P(W,AW)	P,Et,T	N/A	P(AE,E)	N	RS	N/A	P(E)	P(W)	H,P,Et	N/A	H,P,Et(AE,E)	H,P,Et(W,AW)
9	18 Cr-8 Ni(N)	Sheet with	A	IP	N/A	N	Et(W),IP(AW)	N	N/A	N	N	N	N/A	N	N	RS	N/A	DS	N
		cross-bead	B	RS	N/A	N	Et(W)	RS	N/A	N	RS(W)	DS	N/A	N	N	N	N/A	IF(AE)	N
		weld	C	A,P	N/A	N	Et+P(W),IP(AW)	Et,IP	N/A	Et(AE)	P(W,AW),Et(AW)	H,Et(sev)	N/A	N	P(W,AW)	H,P	N/A	H,P	H,P
			D	N	N/A	N	Et(W),IP(AW)	Et(sli)	N/A	N	N	RS	N/A	N	N	N	N/A	N	P
			E(f)	P,T,Et	N/A	N	P(W,AW),H(AW)	Et(sli)	N/A	N	P(W,AW)	H,RS	N/A	A	P(W,AW)	RS	N/A	N	P
			G	P,Et,IP	N/A	P	P+Et(W),IP(AW).	P	N/A	P(AE,E)	Et(W,AW)	Et(sli),RS	N/A	N	P(W,AW)	IF	N/A	N	N
17	26 Cr-1 Mo	Tube with	A	N	N	N	N	N	N	N	N	DS	N	P(E)	N	IF	IF(AC)	N	N
		heliarc weld-	B	N	N	N	N	N	N	N	N	Et(sli),DS	N	N	N	N	N	N	N
		ed seam	C	N	N	N	N	N	P(AC,UC),RS(UC)	N	N	RS,IP	P+Et[(sev)UC]	N	N	Et	P,Et(UC)IF	N	N
		(8-in OD)	D	N	N	N	N	N	N	N	N	N	N	N	N	Et	Et(AC)	N	N
			E(f)	N	P(UC)	N	N	N	P+Et(UC)	N	N	P,IF	P+Et[(sev)UC]	N	N	N	IF(AC)	N	N
			G	P	RS(AC)	N	N	N	P(UC)	N	N	P	N	N	N	N	N	N	N

Table 6 (Con't).

System	Stainless Steel	Material and Treatment	Test Site (c)	Body or Face	Cap	End or Edge	Weld[e]	Body or Face	Cap	End or Edge	Weld[e]	Body or Face	Cap	End or Edge	Weld[e]	Body or Face	Cap	End or Edge	Weld[e]
18	18 Cr(Ti)	Tube with heliarc welded seam (1-1/8-in DD)	A	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
			B	N	N	N	N	N	N	N	N	Et(sli)	N	N	N	N	N	N	N
			C	P,IP,Et	H+P(AC)	N	P(W,AW)	P	H+P(AC)	N	P(W,AW)	H,P	P(AC)	N	P(W,AW)	H,P	H,P(AC,UC)	N	H,P(W)
			D	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
			E(f)	P,IP	H(AC)	N	N	N	P(UC)	N	N	N	N	N	N	N	N	N	N
			G	H,P,Et,IP	N	N	H+P(W,AW)	H,P,Et	H,P+Et(AC)	N	N	H,P,IP	P(AC)	N	P(W,AW)	H,P,Et	Et(AC)	N	H,P,(W,AW)
19	20 Cr-24 Ni-6.5 Mo	Tube with heliarc welded seam	A	N	N	N	N	N	N	N	N	N	N	N	N	IF	IF	N	IF(AW)
			B	N	N	N	N	RS	N	N	N	N	N	N	N	Et,RS	N	N	N
			C	RS	N	N	N	RS	N	N	N	N	N	N	N	Et,RS	RS,Et(AC,UC)	N	N
			D	RS	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
			E(f)	N	N	N	N	N	N	N	N	N	N	N	N	RS	IF	N	N
			G	N	N	N	N	N	RS(AC)	N	N	N	N	N	N	N	N	N	N
Exposed in 1972				Exposure Time, 1 year				Exposure Time, 2 years								Exposure Time, 6 years			
11	18 Cr-2 Mo(Nb)	Sheet with cross-bead weld	A	N	N/A	N	N	DS	N/A	N	N					N	N/A	N	P(W)RS
			B	N	N/A	N	N	N	N/A	N	N					N	N/A	N	N
			C	Et(sli)	N/A	N	P(W),Et(W,AW)	H,P,Et(sev)	N/A	P(E)	P(W,AW)					P,T	N/A	N	H,P,T,(AW,W)
			D	N	N/A	N	N	RS,IF	N/A	N	RS(W,AW)					N	N/A	N	P(W,AW)
			E	P	N/A	N	P(W,AW)	H,P,IF	N/A	P(E)	P(W,AW)					N	N/A	H,P(E,AE)	H,P(W)
			G	N	N/A	N	N	P,RS	N/A	N	P(W)					N	N/A	T,H(AE)	H,T(W,AW)
12	18 Cr-2 Mo(Nb)	Tube with heliarc welded seam	A	N	N	N	N	P	N	N	P(AW)					N	N	N	N
			B	N	N	N	N	N	N	N	N					N	N	N	P(W)
			C	N	N	N	N	P,IP	N	N	N					P	N	N	P(AW)
			D	N	N	N	N	N	N	N	N					N	N	N	P(W,AW)
			E	N	P(UC)	N	N	H,P	P(AC,UC)	N	P(AW)					N	N	N	N
			G	N	N	N	N	RS,DS	IP(AC,UC)	N	N					N	N	N	N

(a) Results given for each system exposed at the six soil test sites are a summary tabulation for 4 individual specimens.

(b) Specimen dimensions and treatment for each system are given in Table II.

(c) Properties of the soils are given in Table I.

(d) Abbreviations used:

A-metal attack	mod-moderate	UC-undercap
AC-adjacent to cap	N-no apparent attack	W-weld
AE-adjacent to edge	N/A-not applicable	
AW-adjacent to weld	P-pitting	
E-edge	RS-rust stain	
Et-etched	sev-severe	
H-perforation	sli-slight	
IP-incipient pitting	T-tunneling	

(e) W or AW do not necessarily signify that more severe attack occurred in the weld than in the parent metal.

(f) Specimens at site "E" removed in 1979 after 8 years exposure.'

Table 7. Average Weight Loss (mg/dm^2) and Pit Depth (mils) for Stainless Steel Sheet and Tube Specimens Buried in Sagemoor Sandy Loam (Site A) for up to Eight Years

System*	Material	Treatment (a)	Exposure, Time, Days	Average[b] Weight Loss, mg	Average[b] Weight Loss, mg/dm^2	Pit Depth, mils[d] Maximum	Pit Depth, mils[d] Average of 5 Deepest[e]
Exposed in 1970							
50	Type 201	A	413	--	--	--	--
			791	--	--	--	--
			1442	--	--	--	--
			2989	1	<1	--	--
51	Type 202	A	413	--	--	--	--
			791	--	--	IP	--
			1442	--	--	--	--
			2989	<1	<1	<5	--
52	Type 301	A	413	--	--	--	--
			791	--	--	<5	--
			1442	--	--	--	--
			2989	--	--	--	--
53	Type 301	S	413	50	4	IP	--
			791	180	14	<5	--
			1442	1247	99	<5	--
			2989	74	6	<5	--
54	Type 301	XBW	413	--	--	--	--
			791	--	--	<5	--
			1442	--	--	--	--
			2989	--	--	--	--
55	Type 304	A	413	--	--	--	--
			791	--	--	--	--
			1442	--	--	--	--
			2989	96	8	--	--
56	Type 304	S	413	256	20	--	--
			791	227	18	<5	--
			1442	614	49	--	--
			2989	858	68	12	--
57	Type 304	HW	413	--	--	--	--
			791	--	--	--	--
			1442	--	--	18	--
			2989	70	17	<5	<5

Table 7 (Con't.)

System*	Material	Treatment (a)	Exposure, Time, Days	Average[(b)] Weight Loss mg	Average[(b)] Weight Loss mg/dm^2	Pit Depth, mils[(d)] Maximum	Pit Depth, mils[(d)] Average of 5 Deepest[(e)]
58	Type 316	A	413	--	--	--	--
			791	--	--	--	--
			1442	--	--	--	--
			2989	--	--	--	--
59	Type 316	S	413	--	--	IP	--
			791	58	5	<5	--
			1442	384	31	7	--
			2989	145	12	6	<5
60	Type 409	A	413	3	<1	29	--
			791	1	<1	<5	--
			1442	150	12	H	H
			2989	12	<1	31	3
62	Type 409	HW	413	176	70	--	--
			791	91	36	IP	--
			1442	32	13	H	--
			2989	--	--	<5	--
63	Type 409	HFW	413	167	86	IP	--
			791	139	71	<5	--
			1442	210	108	H	H
			2989	<1	<1	19	--
64	Type 410	A	413	3495	278	48	--
			791	68	5	20	7
			1442	8843	704	H	H
			2989	1354	109	28	8
65	Type 430	A	413	--	--	--	--
			791	--	--	IP	--
			1442	66	5	22	--
			2989	66	5	--	--
66	Type 434	A	413	--	--	--	--
			791	--	--	IP	--
			1442	--	--	--	--
			2989	13	1	--	--

Table 7 (Con't.)

System*	Material	Treatment (a)	Exposure, Time, Days	Average(b) Weight Loss mg	Average(b) Weight Loss mg/dm²	Pit Depth, mils(d) Maximum	Pit Depth, mils(d) Average of 5 Deepest(e)
Exposed in 1971							
1	26Cr-1Mo	A	496	<1	<1	IP	--
			860	--	--	--	--
			1147	--	--	--	--
			2574	<1	<1	--	--
2	18Cr(Ti)	A	496	1	<1	IP	--
			860	3	<1	--	--
			1147	1	<1	<5	--
			2574	--	--	<5	--
3	18Cr(Ti)	XBW	496	--	--	<5	--
			860	4	<1	<5	--
			1147	4	<1	--	--
			2574	--	--	--	--
4	20Cr-24Ni-6.5Mo	A	496	--	--	IP	--
			860	<1	<1	--	--
			1147	<1	<1	--	--
			2574	--	--	--	--
5	20Cr-24Ni-6.5Mo	S	496	--	--	IP	--
			860	--	--	--	--
			1147	--	--	--	--
			2574	--	--	--	--
6	18Cr-2Mo	A	496	--	--	IP	--
			860	1	<1	--	--
			1147	<1	<1	--	--
			2574	--	--	--	--
8	18Cr-8Ni(N)	A	496	--	--	IP	--
			860	--	--	--	--
			1147			--	--
			2574	--	--	--	--
9	18Cr-8Ni(N)	XBW	496	--	--	IP	--
			860	--	--	--	--
			1147	2	<1	--	--
			2574	--	--	--	--
10	26Cr-6.5Ni	A	496	--	--	<5	--
			860	--	--	<5	--
			1147	3	<1	--	--
			2574	--	--	<5	--

Table 7 (Con't.)

System*	Material	Treatment (a)	Exposure, Time, Days	Average[b] Weight Loss mg	Average[b] Weight Loss mg/dm^2	Pit Depth, mils[d] Maximum	Pit Depth, mils[d] Average of 5 Deepest[e]
14	Composite A[c]	--	496	80800	6357	N/A	
			860	116350	9153	N/A	
			1147	165175	12995	N/A	
			2574	178675	14057	N/A	
15	Composite B[c]	HDZ	496	1150	90	N/A	
			860	21975	1729	N/A	
			1147	27875	2193	N/A	
			2574	28425	2236	N/A	
16	Composite C[c]	--	496	83275	6551	N/A	
			860	112175	8825	N/A	
			1147	149075	11728	N/A	
			2574	185850	14621	N/A	
17	26Cr-1Mo	HW	496	--	--	<5	--
			860	--	--	--	--
			1147	<1	<1	16	--
			2574	--	--	--	--
18	18Cr(Ti)	HW	496	--	--	--	--
			860	--	--	--	--
			1174	4	2	--	--
			2574	5	2	--	--
19	20Cr-24Ni-6.5Mo	HW	496	--	--	--	--
			860	--	--	--	--
			1147	--	--	--	--
			2574	2	1	--	--
Exposed in 1972							
7	18Cr-2Mo (Nb)	A	364	--	--	--	--
			651	--	--	<5	--
			2178	5	<1	--	--
11	18Cr-2Mo (Nb)	XBW	364	--	--	--	--
			651	--	--	--	--
			2178	2	<1	<5	--
12	18Cr-2Mo (Nb)	HW	364	--	--	--	--
			651	--	--	<5	--
			2178	--	--	≲5	--

Table 7 (Con't)

*Systems 12, 17, 18, 19, 57, 62 and 63 were tube specimens fabricated from sheet material, welded at the seams and then plugged and capped at each end to minimize internal corrosion. Specimens of all other systems were flat sheet material.

(a) Abbreviations used:

A-annealed
S-sensitized
XBW-cross-bead weld
HW-heliarc weld
HFW-high frequency weld
HDZ-hot-dip zinc coated (galvanized, 4.5 oz/ft^2) after bonding. See footnote (c).

(b) Average for four specimens. -- indicates negligible or none.

(c) All composites were metallurgically bonded.
Composite A-Carbon steel/Type 430/Carbon steel.
Composite B-Carbon steel/Type 430/Carbon steel.
Composite C-Carbon steel/Type 304/Carbon steel.

(d) 1 mil=0.025 mm. IP-incipient pitting. H-perforated. N/A- not applicable. W-weld.

(e) Average of five deepest pits on each of four individual specimens unless noted otherwise.

(f) Average of ten deepest pits on each of four individual specimens.

Table 8. Average Weight Loss (mg/dm^2) and Pit Depth (mils) for Stainless Steel Sheet and Tube Specimens Buried in Hagerstown Loam (Site B) for up to Eight Years.

System*	Material	Treatment (a)	Exposure, Time, Days	Average[b] Weight Loss mg	Average[b] Weight Loss mg/dm^2	Pit Depth, mils[d] Maximum	Pit Depth, mils[d] Average of 5 Deepest[e]
Exposed in 1970							
50	Type 201	A	371	--	--	--	--
			736	--	--	--	--
			1513	--	--	--	--
			2988	--	--	--	--
51	Type 202	A	371	--	--	--	--
			736	--	--	--	--
			1513	--	--	--	--
			2988	--	--	--	--
52	Type 301	A	371	--	--	--	--
			736	--	--	--	--
			1516	--	--	--	--
			2988	--	--	--	--
53	Type 301	S	371	10	<1	IP	--
			736	22	2	--	--
			1513	204	16	--	--
			2988	56	4	<5	--
54	Type 301	XBW	371	--	--	--	--
			736	--	--	--	--
			1513	--	--	--	--
			2988	--	--	--	--
55	Type 304	A	371	--	--	--	--
			736	--	--	--	--
			1513	--	--	--	--
			2988	--	--	--	--
56	Type 304	S	371	785	62	--	--
			736	660	53	--	--
			1513	707	56	--	--
			2988	102	8	--	--
57	Type 304	HW	371	--	--	--	--
			736	--	--	--	--
			1513	--	--	--	--
			2988	--	--	--	--

Table 8 (Con't.)

System*	Material	Treatment (a)	Exposure, Time, Days	Average(b) Weight Loss mg	Average(b) Weight Loss mg/dm2	Pit Depth, mils(d) Maximum	Pit Depth, mils(d) Average of 5 Deepest(e)
58	Type 316	A	371	--	--	--	--
			736	--	--	--	--
			1513	--	--	--	--
			2988	--	--	--	--
59	Type 316	S	371	--	--	--	--
			738	25	2	--	--
			1513	261	21	--	--
			2988	138	11	<5	--
60	Type 409	A	371	--	--	--	--
			736	<1	<1	--	--
			1513	<1	<1	--	--
			2988	6	<1	14	--
62	Type 409	HW	371	--	--	--	--
			736	--	--	IP	--
			1513	--	--	--	--
			2988	--	--	--	--
63	Type 409	HFW	371	--	--	--	--
			736	--	--	IP	--
			1513	--	--	--	--
			2988	--	--	--	--
64	Type 410	A	371	1458	116	--	--
			736	1207	96	--	--
			1513	72	6	--	--
			2988	48	4	<5	--
65	Type 430	A	371	1	<1	--	--
			736	<1	<1	--	--
			1513	--	--	--	--
			2988	--	--	--	--
66	Type 434	A	371	--	--	--	--
			736	--	--	--	--
			1513	--	--	--	--
			2988	--	--	--	--

Table 8 (Con't.)

System*	Material	Treatment (a)	Exposure, Time, Days	Average[b] Weight Loss mg	Average[b] Weight Loss mg/dm²	Pit Depth, mils[d] Maximum	Pit Depth, mils[d] Average of 5 Deepest[e]
Exposed in 1971							
1	26Cr-1Mo	A	394	<1	<1	--	--
			777	--	--	--	--
			1170	1	<1	--	--
			2617	--	--	--	--
2	18Cr-Ti	A	394	3	<1	--	--
			777	--	--	--	--
			1170	--	--	--	--
			2617	2	<1	--	--
3	18Cr(Ti)	XBW	394	--	--	--	--
			777	--	--	--	--
			1170	2	<1	--	--
			2617	--	--	--	--
4	20Cr-24Ni-6.5Mo	A	394	--	--	--	--
			777	2	<1	--	--
			1170	<1	<1	--	--
			2617	4	<1	--	--
5	20Cr-24Ni-6.5Mo	S	394	--	--	--	--
			777	--	--	--	--
			1170	--	--	--	--
			2617	--	--	--	--
6	18Cr-2Mo	A	394	1	<1	--	--
			777	--	--	--	--
			1170	6	<1	--	--
			2617	2	<1	--	--
8	18Cr-8Ni(N)	A	394	--	--	--	--
			777	2	<1	--	--
			1170	--	--	--	--
			2617	--	--	--	--
9	18Cr-8Ni(N)	XBW	394	--	--	--	--
			777	--	--	--	--
			1170	--	--	--	--
			2617	--	--	--	--
10	26Cr-6.5Ni	A	394	--	--	--	--
			777	--	--	--	--
			1170	--	--	--	--
			2617	2	<1	--	--

Table 8 (Con't.)

System*	Material	Treatment (a)	Exposure, Time, Days	Average[b] Weight Loss mg	Average[b] Weight Loss mg/dm^2	Pit Depth, mils[d] Maximum	Pit Depth, mils[d] Average of 5 Deepest[e]
14	Composite A[c]	--	394	65925	5186	N/A	
			777	87425	6878	N/A	
			1170	100400	7899	N/A	
			2617	150675	11854	N/A	
15	Composite B[c]	HDZ	394	--	--	N/A	
			777	5875	462	N/A	
			1170	4275	336	N/A	
			2617	21125	1662	N/A	
16	Composite C[c]	--	394	77833	6123	N/A	
			777	107350	8445	N/A	
			1170	110900	8724	N/A	
			2617	161250	12685	N/A	
17	26Cr-1Mo	HW	397	--	--	--	--
			777	--	--	--	--
			1170	--	--	--	--
			2617	--	--	--	--
18	18Cr-Ti	HW	394	1	<1	--	--
			777	--	--	--	--
			1170	2	<1	--	--
			2617	3	1	--	--
19	20Cr-24Ni-6.5Mo	HW	394	--	--	--	--
			777	--	--	--	--
			1170	--	--	--	--
			2617	<1	<1	--	--
Exposed in 1972							
7	18Cr-2Mo (Nb)	A	395	--	--	--	--
			801	--	--	--	--
			2232	--	--	--	--
11	18Cr-2Mo (Nb)	XBW	395	--	--	--	--
			801	--	--	--	--
			2232	--	--	--	--
12	18Cr-2Mo (Nb)	HW	395	--	--	--	--
			801	--	--	--	--
			2232	--	--	7	--

Table 8 (Con't)

*Systems 12, 17, 18, 19, 57, 62 and 63 were tube specimens fabricated from sheet material, welded at the seams and then plugged and capped at each end to minimize internal corrosion. Specimens of all other systems were flat sheet material.

(a) Abbreviations used:

A-annealed
S-sensitized
XBW-cross-bead weld
HW-heliarc weld
HFW-high frequency weld
HDZ-hot-dip zinc coated (galvanized, 4.5 oz/ft^2) after bonding. See footnote (c).

(b) Average for four specimens. -- indicates negligible or none.

(c) All composites were metallurgically bonded.
Composite A-Carbon steel/Type 430/Carbon steel.
Composite B-Carbon steel/Type 430/Carbon steel.
Composite C-Carbon steel/Type 304/Carbon steel.

(d) 1 mil=0.025 mm. IP-incipient pitting. H-perforated. N/A- not applicable. W-weld.

(e) Average of five deepest pits on each of four individual specimens unless noted otherwise.

(f) Average of ten deepest pits on each of four individual specimens.

Table 9. Average Weight Loss (mg/dm^2) and Pit Depth (mils) for Stainless Steel Sheet and Tube Specimens Buried in Clay (Site C) for up to Eight Years.

System*	Material	Treatment (a)	Exposure, Time, Days	Average[b] Weight Loss mg	Average[b] Weight Loss mg/dm^2	Pit Depth, mils[d] Maximum	Pit Depth, mils[d] Average of 5 Deepest[e]
Exposed in 1970							
50	Type 201	A	377	767	61	H	--
			727	872	69	H	--
			1463	1242	99	H	H
			2926	4222	336	H	--
51	Type 202	A	377	504	40	H	--
			727	680	54	H	H
			1463	435	35	H	H
			2926	1073	85	H	H
52	Type 301	A	377	169	13	20	--
			727	505	40	H	H
			1463	406	32	H	H
			2926	549	44	H	H
53	Type 301	S	377	3651	291	48	15
			727	12930	1030	19	14
			1463	14163	1128	H	--
			2926	43237	3444	H	H
54	Type 301	XBW	377	368	29	63	--
			727	379	30	16	6
			1463	524	42	H	H
			2926	694	55	H	--
55	Type 304	A	377	300	24	H	--
			727	609	48	H	--
			1463	4268	340	H	H
			2926	2410	192	H	H
56	Type 304	S	377	1491	119	H	--
			727	1745	139	H	--
			1463	8022	639	H	H
			2926	5778	460	H	H

Table 9 (Con't.)

System*	Material	Treatment (a)	Exposure, Time, Days	Average[b] Weight Loss mg	Average[b] Weight Loss mg/dm^2	Pit Depth, mils[d] Maximum	Pit Depth, mils[d] Average of 5 Deepest[e]
57	Type 304	HW	377	--	--	--	--
			727	74	18	16	5
			1463	74	18	7	6
			2926	494	121	11	6
58	Type 316	A	377	--	--	--	--
			727	--	--	--	--
			1463	6	<1	63	--
			2926	5	<1	--	--
59	Type 316	S	377	568	45	H	--
			727	707	56	T	--
			1463	988	79	120(T)	--
			2926	1000	80	--	--
60	Type 409	A	377	6329	504	H	--
			727	5462	435	H	--
			1453	10349	824	H	H
			2926	16821	1340	H	H
62	Type 409	HW	377	822	328	H	--
			727	2842	1133	H	H[f]
			1463	3947	1574	H	H
			2926	10357	4130	H	H
63	Type 409	HFW	377	1245	638	18	--
			727	2166	1110	H	H
			1463	4407	2259	H	H
			2926	2389	1224	H	H
64	Type 410	A	377	7053	562	30	--
			727	15999	1274	H	--
			1463	30574	2436	H	H
			2926	71198	5672	H	H
65	Type 430	A	377	4741	378	H	--
			727	5088	405	H	H
			1463	8978	715	H	H
			2926	6007	478	H	H
66	Type 434	A	377	513	41	H	--
			727	927	74	H	H[f]
			1463	1619	129	H	H
			2926	2015	160	H	H

Table 9 (Con't.)

System*	Material	Treatment (a)	Exposure, Time, Days	Average[b] Weight Loss		Pit Depth, mils[d]	
				mg	mg/dm^2	Maximum	Average of 5 Deepest[e]
Exposed in 1971							
1	26Cr-1Mo	A	350	9	<1	IP	--
			730	--	--	IP	--
			1086	--	--	<5	--
			2549	--	--	--	--
2	18Cr(Ti)	A	350	1008	80	H	--
			730	628	50	42	--
			1086	227	18	H	--
			2549	1399	111	H	18
3	18Cr(Ti)	XBW	350	569	45	H	--
			730	163	13	24	--
			1086	101	8	H	--
			2549	160	13	H	H
4	20Cr-24Ni-6.5Mo	A	350	2	<1	IP	--
			730	--	--	--	--
			1086	--	--	--	--
			2549	--	--	--	--
5	20Cr-24Ni-6.5Mo	S	350	11	<1	IP	--
			730	--	--	IP	--
			1086	14	1	22	--
			2549	--	--	--	--
6	18Cr-2Mo	A	350	26	2	<5	--
			730	6	<1	--	--
			1086	1	<1	7	--
			2549	103	8	H	--
8	18Cr-8Ni(N)	A	350	--	--	IP	--
			730	--	--	<5	--
			1086	5	<1	50	--
			2549	12	<1	<5	--
9	18Cr-8Ni(N)	XBW	350	462	37	141	--
			730	552	44	10	--
			1086	554	44	H	--
			2549	90	7	H	H
10	26Cr-6.5Ni	A	350	423	34	H	--
			730	80	6	H	H
			1086	132	11	H	H
			2549	284	23	H	H

Table 9 (Con't.)

System*	Material	Treatment (a)	Exposure, Time, Days	Average[b] Weight Loss mg	Average[b] Weight Loss mg/dm^2	Pit Depth, mils[d] Maximum	Pit Depth, mils[d] Average of 5 Deepest[e]
14	Composite A[c]	--	350	38500	3029	N/A	
			730	60975	4797	N/A	
			1086	133000	10463	N/A	
			2549	320325	25201	N/A	
15	Composite B[c]	HDZ	350	43025	3385	N/A	
			730	57950	4559	N/A	
			1086	80600	6341	N/A	
			2549	77450	6093	N/A	
16	Composite[c]	--	350	40500	3186	N/A	
			730	59175	4655	N/A	
			1086	126100	9921	N/A	
			2549	379850	29883	N/A	
17	26Cr-1Mo	HW	350	--	--	--	--
			730	--	--	<5	--
			1086	58	14	35	7
			2549	3	<1	41	6
18	18Cr(Ti)	HW	350	120	48	H	--
			730	50	20	H	H
			1086	81	32	H	H
			2549	46	18	H	H
19	20Cr-24Ni 6.5Mo	HW	350	--	--	--	--
			730	<1	<1	--	--
			1086	--	--	--	--
			2549	--	--	--	--
Exposed in 1972							
7	18Cr-2Mo (Nb)	A	380	--	--	<5	--
			736	6	<1	<5	--
			2199	59	5	55	--
11	18Cr-2Mo (Nb)	XBW	380	60	5	<5	--
			736	136	11	H(T)	--
			2199	408	33	H	30
12	18Cr-2Mo (Nb)	HW	380	--	--	--	--
			736	160	39	7	--
			2199	--	--	43	7

Table 9 (Con't)

*Systems 12, 17, 18, 19, 57, 62 and 63 were tube specimens fabricated from sheet material, welded at the seams and then plugged and capped at each end to minimize internal corrosion. Specimens of all other systems were flat sheet material.

(a) Abbreviations used:

A-annealed
S-sensitized
XBW-cross-bead weld
HW-heliarc weld
HFW-high frequency weld
HDZ-hot-dip zinc coated (galvanized, 4.5 oz/ft^2) after bonding. See footnote (c).

(b) Average for four specimens. -- indicates negligible or none.

(c) All composites were metallurgically bonded.
Composite A-Carbon steel/Type 430/Carbon steel.
Composite B-Carbon steel/Type 430/Carbon steel.
Composite C-Carbon steel/Type 304/Carbon steel.

(d) 1 mil=0.025 mm. IP-incipient pitting. H-perforated. N/A- not applicable. W-weld.

(e) Average of five deepest pits on each of four individual specimens unless noted otherwise.

(f) Average of ten deepest pits on each of four individual specimens.

Table 10. Average Weight Loss (mg/dm^2) and Pit Depth (mils) for Stainless Steel Sheet and Tube Specimens Buried in Lakewood Sand (Site D) for up to Eight Years.

System*	Material	Treatment (a)	Exposure, Time, Days	Average(b) Weight Loss mg	Average(b) Weight Loss mg/dm^2	Pit Depth, mils(d) Maximum	Pit Depth, mils(d) Average of 5 Deepest(c)
Exposed in 1970							
50	Type 201	A	377	--	--	IP	--
			727	--	--	40	--
			1463	--	--	--	--
			2926	364	29	H	16
51	Type 202	A	377	--	--	--	--
			727	--	--	--	--
			1463	9	<1	--	8
			2926	100	8	H	--
52	Type 301	A	377	--	--	IP	--
			727	--	--	IP	--
			1463	--	--	--	--
			2926	--	--	--	--
53	Type 301	S	377	714	57	--	--
			727	1100	88	--	--
			1463	1499	119	30	7
			2926	4815	384	58	31
54	Type 301	XBW	377	--	--	--	--
			727	--	--	IP	--
			1463	--	--	<5	--
			2926	31	2	40	8
55	Type 304	A	377	11	<1	IP	--
			727	--	--	--	--
			1463	--	--	--	--
			2926	211	17	H	H
56	Type 304	S	377	268	21	--	--
			727	711	57	H	--
			1463	1243	99	57	--
			2926	7944	633	H	H
57	Type 304	HW	377	--	--	--	--
			727	--	--	--	--
			1463	--	--	8	--
			2926	181	44	--	--

Table 10 (Con't.)

System*	Material	Treatment (a)	Exposure, Time, Days	Average[b] Weight Loss mg	Average[b] Weight Loss mg/dm²	Pit Depth, mils[d] Maximum	Pit Depth, mils[d] Average of 5 Deepest[e]
58	Type 316	A	377	--	--	--	--
			727	--	--	--	--
			1463	--	--	--	--
			2926	--	--	--	--
59	Type 316	S	377	99	8	--	--
			727	144	11	--	--
			1463	179	14	<5	--
			2926	132	10	--	--
60	Type 409	A	377	--	--	--	--
			727	258	20	54	--
			1463	620	49	H	H
			2926	2166	172	H	H
62	Type 409	HW	377	--	--	--	--
			727	--	<1	21	--
			1463	83	33	H	-H
			2926	705	281	H	H
63	Type 409	HFW	377	7	4	H	--
			727	34	18	H	--
			1463	108	55	H	H
			2926	860	441	H	H
64	Type 410	A	377	146	12	H	--
			727	1157	92	H	--
			1463	920	73	H	H
			2926	7578	604	H	H
65	Type 430	A	377	0	0	--	--
			727	22	2	18	--
			1463	186	15	H	H
			2926	1638	130	H	H
66	Type 434	A	377	--	--	--	--
			727	<1	<1	56	--
			1463	56	4	H	H
			2926	1123	89	H	H

Table 10 (Con't.)

System*	Material	Treatment (a)	Exposure, Time, Days	Average(b) Weight Loss mg	Average(b) Weight Loss mg/dm²	Pit Depth, mils(d) Maximum	Pit Depth, mils(d) Average of 5 Deepest(e)
Exposed in 1971							
1	26Cr-1Mo	A	350	<1	<1	IP	--
			727	<1	<1	--	--
			1086	3	<1	--	--
			2549	3	<1	--	--
2	18Cr(Ti)	A	350	8	<1	23	--
			727	--	--	--	--
			1086	--	--	--	--
			2549	109	9	H	14
3	18Cr(Ti)	XBW	350	3	<1	26	14
			727	<1	<1	--	--
			1086	--	--	--	--
			2549	28	2	61	8
4	20Cr-24Ni-6.5Mo	A	350	2	<1	--	--
			727	1	<1	--	--
			1086	<1	<1	--	--
			2549	21	2	--	--
5	20Cr-24Ni-6.5Mo	S	350	--	--	IP	--
			727	--	--	--	--
			1086	--	--	--	--
			2549	--	--	--	--
6	18Cr-2Mo	A	350	<1	<1	--	--
			727	1	<1	--	--
			1086	<1	<1	--	--
			2549	40	3	23	--
8	18Cr-8Ni(N)	A	350	--	--	IP	--
			727	--	--	--	--
			1086	--	--	--	--
			2549	--	--	--	--
9	18Cr-8Ni(N)	XBW	350	--	--	--	--
			727	--	--	IP	--
			1086	--	--	--	--
			2549	132	10	30	19
10	26Cr-6.5Ni	A	350	--	--	--	--
			727	--	--	--	--
			1086	--	--	--	--
			2549	121	10	H	--

Table 10 (Con't.)

System*	Material	Treatment (a)	Exposure, Time, Days	Average[b] Weight Loss mg	Average[b] Weight Loss mg/dm^2	Pit Depth, mils[d] Maximum	Pit Depth, mils[d] Average of 5 Deepest[e]
14	Composite A[c]	--	350	26300	2069	N/A	
			727	32075	2523	N/A	
			1086	45100	3548	N/A	
			2549	130175	10241	N/A	
15	Composite B[c]	HDZ	350	--	--	N/A	
			727	--	--	N/A	
			1086	1200	94	N/A	
			2549	26575	2091	N/A	
16	Composite C[c]	--	350	26250	2065	N/A	
			727	38900	3060	N/A	
			1086	48000	3776	N/A	
			2549	130100	10235	N/A	
17	26Cr-1Mo	HW	350	--	--	--	--
			727	--	--	--	--
			1086	--	--	--	--
			2549	--	--	--	--
18	18Cr(Ti)	HW	350	--	--	--	--
			727	<1	<1	--	--
			1086	3	1	--	--
			2549	1	<1	--	--
19	20Cr-24Ni 6.5Mo	HW	350	--	--	--	--
			727	--	--	--	--
			1086	2	1	--	--
			2549	--	--	--	--
Exposed in 1972							
7	18Cr-2Mo (Nb)	A	380	--	--	--	--
			736	--	--	--	--
			2199	--	--	--	--
11	18Cr-2Mo (Nb)	XBW	380	4	<1	--	--
			736	15	1	--	--
			2199	110	9	41	--
12	18Cr-2Mo (Nb)	HW	380	--	--	--	--
			736	--	--	--	--
			2199	--	--	10	--

Table 11. Average Weight Loss (mg/dm²) and Pit Depth (mils) for Stainless Steel Sheet and Tube Specimens Buried in Coastal Sand (Site E) for up to Eight Years.

System*	Material	Treatment (a)	Exposure, Time, Days	Average[b] Weight Loss mg	Average[b] Weight Loss mg/dm^2	Pit Depth, mils[d] Maximum	Pit Depth, mils[d] Average of 5 Deepest[e]
Exposed in 1970							
50	Type 201	A	377	1272	101	H	--
			727	3294	262	H	--[f]
			1463	5705	454	H	H
			2926	5721	456	H	H
51	Type 202	A	377	774	62	H	--[f]
			727	1943	155	H	H
			1463	1939	154	H	H
			2926	585	47	H	H
52	Type 301	A	377	1315	105	H	--[f]
			727	2713	216	H	H
			1463	2320	185	H	H
			2926	898	72	H	H
53	Type 301	S	377	1375	110	<5	--
			727	3723	296	8	--
			1463	4873	388	28	14
			2926	26427	2105	40	24
54	Type 301	XBW	377	1052	84	H	--[f]
			727	2542	202	H	H
			1463	2828	225	H	H
			2926	1110	88	H	H
55	Type 304	A	377	1399	111	H	--
			727	3386	270	H	--
			1463	4564	364	H	H
			2926	2273	181	H	--
56	Type 304	S	377	2391	190	H	--
			727	5883	469	H	H
			1463	11088	883	H	H
			2926	8078	644	H	H
57	Type 304	HW	377	623	152	38	--
			727	1414	345	26	--
			1463	1352	330	53	21
			2926	696	170	30	23

Table 11 (Con't.)

System*	Material	Treatment (a)	Exposure, Time, Days	Average[b] Weight Loss mg	Average[b] Weight Loss mg/dm^2	Pit Depth, mils[d] Maximum	Pit Depth, mils[d] Average of 5 Deepest[e]
58	Type 316	A	377	156	12	H	--
			727	515	41	H	--
			1463	83	7	H	--
			2926	80	6	H	--
59	Type 316	S	377	1322	105	62	--
			727	3274	261	<5	--
			1463	3306	263	H	--
			2926	1760	140	--	--
60	Type 409	A	377	3303	263	H	H(f)
			727	3947	314	H	H
			1463	5235	417	H	H
			2926	2868	228	H	H
62	Type 409	HW	377	742	296	H	H
			727	1260	502	H	H
			1463	2417	964	H	H
			2926	1348	537	H	H
63	Type 409	HFW	377	753	386	H	H
			727	1023	524	H	H
			1463	1702	872	H	H
			2926	790	405	H	H
64	Type 410	A	377	3990	318	H	H
			727	4012	320	H	H(f)
			1463	8477	675	H	H
			2926	10912	869	H	H
65	Type 430	A	377	1434	114	H	H(f)
			727	3160	252	H	H
			1463	5084	403	H	H
			2926	2627	209	H	H
66	Type 434	A	377	1575	125	H	H(f)
			727	3085	246	H	H
			1463	5174	412	H	H
			2926	3564	284	H	H
Exposed in 1971							
1	26Cr-1Mo	A	350	4	<1	IP	--
			728	<1	<1	--	--
			1087	<1	<1	--	--
			2904	8	<1	--	--

Table 11 (Con't.)

System*	Material	Treatment (a)	Exposure, Time, Days	Average[b] Weight Loss mg	Average[b] Weight Loss mg/dm^2	Pit Depth, mils[d] Maximum	Pit Depth, mils[d] Average of 5 Deepest[(]
2	18Cr(Ti)	A	350	542	43	H	H[f]
			728	464	37	H	H
			1087	250	20	H	H
			2904	218	17	H.	H
3	18Cr(Ti)	XBW	350	538	43	H	--
			728	688	55	H	H
			1087	350	28	H	H
			2904	156	12	H	H
4	20Cr-24Ni-6.5Mo	A	350	--	--	--	--
			728	1	<1	--	--
			1087	2	<1	--	--
			2904	15	1	--	--
5	20Cr-24Ni-6.5Mo	S	350	110	9	--	--
			728	65	5	--	--
			1087	90	7	--	--
			2904	6	<1	--	--
6	18Cr-2Mo	A	350	610	49	H	--
			728	534	42	H	H
			1087	224	18	H	H
			2904	13	1	--	--
8	18Cr-8Ni(N)	A	350	17	1	--	--
			728	12	<1	24	--
			1087	56	4	H	--
			2904	<1	<1	--	--
9	18Cr-8Ni(N)	XBW	350	867	69	H	--
			728	1536	122	H	--
			1087	1776	141	H	--
			2904	394	31	95(W)	--
10	26Cr-6.5Ni	A	350	389	31	H	--
			728	1082	86	H	H
			1087	1343	107	H	H
			2904	2	<1	--	--
14	Composite A[c]	--	350	23500	1849	N/A	
			728	27125	2134	N/A	
			1087	39100	3076	N/A	
			2904	221950	17461	N/A	
15	Composite B[c]	HDZ	350	1325	104	N/A	
			728	1350	106	N/A	
			1087	12575	989	N/A	
			2904	4475	352	N/A	

Table 11 (Con't.)

System*	Material	Treatment (a)	Exposure, Time, Days	Average[b] Weight Loss mg	Average[b] Weight Loss mg/dm^2	Pit Depth, mils[d] Maximum	Pit Depth, mils[d] Average of 5 Deepest[e]
16	Composite C[c]	--	350	19775	1556	N/A	
			728	17750	1396	N/A	
			1087	38450	3025	N/A	
			2904	247700	19487	N/A	
17	26Cr-1Mo	HW	350	--	--	13	--
			728	4	<1	5	--
			1087	160	39	50	16
			2904	--	--	--	--
18	18Cr(Ti)	HW	350	4	2	--	--
			728	<1	<1	--	--
			1087	3	1	--	--
			2904	<1	<1	--	--
19	20Cr-24Ni-6.5Mo	HW	350	--	--	--	--
			728	--	--	--	--
			1087	1	<1	--	--
			2094	--	--	--	--
Exposed in 1972							
7	18Cr-2Mo (Nb)	A	380	--	--	<5	--
			736	--	--	<5	--
			2199	--	--	--	--
11	18Cr-2Mo (Nb)	XBW	380	515	41	H	--
			736	486	39	H	--
			2199	283	22	H	H
12	18Cr-2Mo (Nb)	HW	380	162	40	H	H
			736	340	83	H	--
			2199	--	--	--	--

Table 11 (Con't)

*Systems 12, 17, 18, 19, 57, 62 and 63 were tube specimens fabricated from sheet material, welded at the seams and then plugged and capped at each end to minimize internal corrosion. Specimens of all other systems were flat sheet material.

(a) Abbreviations used:

A-annealed
S-sensitized
XBW-cross-bead weld
HW-heliarc weld
HFW-high frequency weld
HDZ-hot-dip-zinc coated (galvanized, 4.5 oz/ft^2) after bonding. See footnote (c).

(b) Average for four specimens. -- indicates negligible or none.

(c) All composites were metallurgically bonded.
Composite A-Carbon steel/Type 430/Carbon steel.
Composite B-Carbon steel/Type 430/Carbon steel.
Composite C-Carbon steel/Type 304/Carbon steel.

(d) 1 mil=0.025 mm. IP-incipient pitting. H-perforated. N/A- not applicable. W=weld.

(e) Average of five deepest pits on each of four individual specimens unless noted otherwise.

(f) Average of ten deepest pits on each of four individual specimens.

Table 12. Average Weight Loss (mg/dm^2) and Pit Depth (mils) for Stainless Steel Sheet and Tube Specimens Buried in Tidal Marsh (Site G) for up to Eight Years.

System*	Material	Treatment (a)	Exposure, Time, Days	Average(b) Weight Loss mg	Average(b) Weight Loss mg/dm^2	Pit Depth, mils(d) Maximum	Pit Depth, mils(d) Average of 5 Deepest(e)
Exposed in 1970							
50	Type 201	A	356	3728	297	45	--
			719	1179	94	H	--
			1355	78	6	35	--
			2897	3260	260	H	H
51	Type 202	A	356	55	4	40	--
			719	14	1	33	7
			1355	86	7	H	H
			2897	1173	93	H	H
52	Type 301	A	356	146	12	40	--
			719	1105	88	30	--
			1355	218	17	H	H
			2897	1046	83	H	H
53	Type 301	S	356	4995	398	25	--
			719	13103	1044	H	--
			1355	2185	174	36	13
			2897	53517	4263	H	29
54	Type 301	XBW	356	33	3	13	--
			719	1565	125	62	9
			1355	1400	112	12	--
			2897	536	43	H	H
55	Type 304	A	365	904	72	H	--
			719	1803	144	36	11
			1355	304	24	37	6
			2897	16803	1338	H	H
56	Type 304	S	356	293	23	20	--
			719	6162	491	H	--
			1355	5146	410	26	8
			2897	25905	2064	H	H
57	Type 304	HW	356	--	--	--	--
			719	--	--	10	3
			1355	2	<1	11	5
			2897	--	--	--	--

Table 12 (Con't.)

System*	Material	Treatment (a)	Exposure, Time, Days	Average(b) Weight Loss mg	Average(b) Weight Loss mg/dm^2	Pit Depth, mils(d) Maximum	Pit Depth, mils(d) Average of 5 Deepest(e)
58	Type 316	A	356	--	--	< 5	--
			719	--	--	< 5	--
			1355	--	--	--	--
			2897	86	7	H	--
59	Type 316	S	356	--	--	< 5	--
			719	64	5	< 5	--
			1355	--	--	< 5	--
			2897	1136	90	H	--
60	Type 409	A	356	31401	2501	H	H(f)
			719	66322	5283	H	H(f)
			1355	23206	1849	H	H(f)
			2897	208593	16617	H	H
62	Type 409	HW	356	8438	3364	H	H(f)
			719	17045	6796	H	H(f)
			1355	4218	1682	H	H
			2897	46694	18618	H	H
63	Type 409	HFW	356	4681	2399	H	H(f)
			719	19902	10201	H	--
			1355	10214	5236	H	H
			2897	47111	24147	H	H
64	Type 410	A	356	31982	2548	H	H(f)
			719	70709	5633	H	H(f)
			1355	105184	8379	H	H
			2897	287184	22878	H	H
65	Type 430	A	356	44270	3527	H	H(f)
			719	103628	8255	H	H(f)
			1355	191351	15243	H	H
			2897	399493	31824	H	H
66	Type 434	A	356	74	6	H	--
			719	7299	581	H	--
			1355	--	--	6	--
			2897	1754	140	H	H
Exposed in 1971							
1	26Cr-1Mo	A	362	--	--	IP	--
			755	3	<1	--	--
			1098	--	--	--	--
			2539	3	<1	--	--

Table 12 (Con't.)

System*	Material	Treatment (a)	Exposure, Time, Days	Average(b) Weight Loss mg	Average(b) Weight Loss mg/dm^2	Pit Depth, mils(d) Maximum	Pit Depth, mils(d) Average of 5 Deepest(e)
2	18Cr(Ti)	A	362	11962	953	H	--
			755	33777	2691	H	H
			1098	5984	477	37	13
			2539	86077	6857	H	H
3	18Cr(Ti)	XBW	362	3699	295	H	--
			755	820	65	28	--
			1098	3	<1	<5	--
			2539	18255	1454	H	H
4	20Cr-24Ni-6.5Mo	A	362	--	--	--	--
			755	<1	<1	--	--
			1098	--	--	--	--
			2539	6	<1	--	--
5	20Cr-24Ni-6.5Mo	S	362	134	11	IP	--
			755	--	--	--	--
			1098	--	--	--	--
			2539	--	--	--	--
6	18Cr-2Mo	A	362	528	42	H	--
			755	630	50	H	H
			1098	<1	<1	<5	--
			2539	42	3	H	--
8	18Cr-8Ni(N)	A	362	50	4	5	--
			755	159	13	H	H
			1098	2	<1	--	--
			2539	1	<1	<5	--
9	18Cr-8Ni(N)	XBW	362	646	51	110	--
			755	3409	272	11	--
			1098	--	--	--	--
			2539	--	--	16	--
10	26Cr-6.5Ni	A	362	4752	379	H	--
			755	248	20	H	H
			1098	14	1	7	6
			2539	18	1	47	--
14	Composite A(c)	--	362	112575	8857	N/A	
			755	380200	29911	N/A	
			1098	398800	31374	N/A	
			2539	654375	51481	N/A	
15	Composite B(c)	HDZ	362	44025	3464	N/A	
			755	66250	5212	N/A	
			1098	49300	3879	N/A	
			2539	139750	10994	N/A	

Table 12 (Con't.)

System*	Material	Treatment (a)	Exposure, Time, Days	Average[b] Weight Loss mg	Average[b] Weight Loss mg/dm^2	Pit Depth, mils[d] Maximum	Pit Depth, mils[d] Average of 5 Deepest[e]
16	Composite[c]	--	362	104900	8253	N/A	
			755	256400	20172	N/A	
			1098	358000	28165	N/A	
			2539	704350	55413	N/A	
17	26Cr-1Mo	HW	362	--	--	--	--
			755	57	14	<5	--
			1098	4	<1	<5	--
			2539	--	--	--	--
18	18Cr(Ti)	HW	362	3466	1382	H	--
			755	24641	9825	H	H
			1098	15115	6027	H	H
			2539	2585	1031	H	H
19	20Cr-24Ni 6.5Mo	HW	362	--	--	--	--
			755	--	--	--	--
			1098	<1	<1	--	--
			2539	--	--	--	--
Exposed in 1972							
7	18Cr-2Mo (Nb)	A	362	--	--	--	--
			736	4	<1	45	--
			2156	305	24	H	H
11	18Cr-2Mo (Nb)	XBW	362	--	--	--	--
			736	--	--	45	--
			2156	361	29	H	H
12	18Cr-2Mo (Nb)	HW	362	--	--	--	--
			736	--	--	IP	--
			2156	--	--	--	--

Table 12 (Con't)

*Systems 12, 17, 18, 19, 57, 62 and 63 were tube specimens fabricated from sheet material, welded at the seams and then plugged and capped at each end to minimize internal corrosion. Specimens of all other systems were flat sheet material.

(a) Abbreviations used:

A-annealed
S-sensitized
XBW-cross-bead weld
HW-heliarc weld
HFW-high frequency weld
HDZ-hot-dip zinc coated (galvanized, 4.5 oz/ft^2) after bonding. See footnote (c).

(b) Average for four specimens. -- indicates negligible or none.

(c) All composites were metallurgically bonded.
Composite A-Carbon steel/Type 430/Carbon steel.
Composite B-Carbon steel/Type 430/Carbon steel.
Composite C-Carbon steel/Type 304/Carbon steel.

(d) 1 mil=0.025 mm. IP-incipient pitting. H-perforated. N/A- not applicable. W=weld.

(e) Average of five deepest pits on each of four individual specimens unless noted otherwise.

(f) Average of ten deepest pits on each of four individual specimens.

Table 13. Summary of Results Obtained from Non-Galvanically Coupled Stressed 1-in x 12-in Stainless Steel Specimens After Exposure for up to 8 years at the six NBS Soil Corrosion Test Sites

Number of Specimens Failed

System	Stainless Steel Exposed in 1970	Treatment (a)	Stressed Specimen(b)	Exposure Time Years	Site A	Site B	Site C	Site D	Site E	Site G
67	Type 301	HH	U	1	0	0	0	0	0	0
				2	0	0	1(c)	0	0	0
				4	0	0	0	0	0	0
				8	0	0	0	0	0	0
68	Type 301	HH	(UU)	1	0	0	0	0	0	0
				2	0	0	0	0	0	0
				4	0	0	0	0	0	0
				8	0	0	0-NR*	0	0	0
69	Type 301	HH&S	UU	1	1(d)	1(d)	2(d)	2	2	1
				2	1	0	2	2	2	1
				4	2	1	2	2	2	2
				8	0	1	2	2	2	2
70	Type 301	FH	U	1	0	0	0	0	0	0
				2	0	0	0	0	0	0
				4	0	0	0	0	0	0
				8	0	0	0	0	0	0
71	Type 301	FH	(UU)	1	0	0	0	0	0	0
				2	0	0	0	0	0	1(d)
				4	0	0	0	0	0	0
				8	0	0	0	0	0	0
72	Type 304	—	U	1	0	0	0	0	0	0
				2	0	0	0	0	0	0
				4	0	0-NR*	0	0	0	0
				8	0	0	0	0	0-NR*	0

Table 13 (cont'd.)

System	Stainless Steel Exposed in 1970	Treatment (a)	Stressed Specimen(b)	Exposure Time Years	Site A	Site B	Site C	Site D	Site E	Site G
73	Type 304	—	(UU)	1	0	0	0	0	0	0
				2	0	0	0	0	0	0
				4	0	0	0	0	0	0
				8	0	0	0	0	0	0-NR*
74	Type 304	HH	U	1	0	0	0	0	0	0
				2	0	0	0	0	0	0
				4	0	0	0	0	0	0
				8	0	0	0-NR*	0	0	0-NR*
75	Type 304	HH	(UU)	1	0	0	0	0	0	0
				2	0	0	0	0	0	0
				4	0	0	0	0	0	0
				8	0	0	0	0	0	0
76	Type 304	S	UU	1	0	0	0	0	1	0
				2	0	0	1-1(d)	0	0	0
				4	0	0-NR*	0	0	0	0
				8	0	0	0	0	0	0
77	Type 316	—	U	1	0	0	0	0	0	0
				2	0	0	0	0	0	0
				4	0	0	0	0	0	0
				8	0	0	0	0	0	0
78	Type 316	—	(UU)	1	0	0	0	0	0	0
				2	0	0	0	0	0	0
				4	0	0-NR*	0	0	0	0
				8	0	0	0	0-NR*	0	0
79	Type 316	S	UU	1	0	0	0	0	0	0
				2	0	0	0	0	0	0
				4	0	0	0	0	0	0
				8	0	0	0	0	0	0
80	Type 434	—	U	1	0	0	0	0	0	0
				2	0	0	0	0	0	0
				4	0	0-NR*	0	0	0-NR*	0
81	Type 434	—	(UU)	1	0	0	0	0	0	0
				2	0	0	0	0	0	0
				4	0	0	0-NR*	0	0	0
				8	0	0	0	0	0	0

Table 13 (cont'd.)

System	Stainless Steel Exposed in 1971	Treatment (a)	Stressed Specimen(b)	Exposure Time Years	Site A	Site B	Site C	Site D	Site E	Site G
20	26Cr-1Mo	—	(UU)	1	0	0	0	0	0	0
				2	0	0	0	0	0	0
				3	0	0	0	0	0	0
				7(e)	0	0	0	0	0	0
21	26Cr-1Mo	—	U	1	0	0	0	0	0	0
				2	0	0	0	0	0	0
				3	0	0	0	0	0	0
				7(e)	0	0	0	0	0	0
22	20Cr-24Ni-6.5Mo	—	(UU)	1	0	0	0	0	0	0
				2	0	0	0	0	0	0
				3	0	0	0	0	0	0
				7(e)	0	0	0	0	0	0
23	20Cr-24Ni-6.5Mo	—	U	1	0	0	0	0	0	0
				2	0	0	0	0	0	0
				3	0	0	0	0	0	0
				7(e)	0	0	0	0	0	0
24	20Cr-24Ni-6.5Mo	—	UU	1	0	0	0	0	0	0
				2	0	0	0	0	0	0
				3	0	0	0	0	0	0
				7(e)	0	0	0	0	0	0
25	18Cr-2Mo	—	(UU)	1	0	0	0	0	0	0
				2	0	0	0	0	0	0
				3	0	0	0	0	0	0
				7(e)	0	0	0	0	0	0
26	18Cr-2Mo	—	U	1	0	0	0	0	0	0
				2	0	0	0	0	0	0
				3	0	0	0	0	0	0
				7(e)	0	0	0	0	0	0
27	18Cr-8Ni(N)	—	(UU)	1	0	0	0	0	0	0
				2	0	0	0	0	0	0
				3	0	0	0	0	0	0
				7(e)	0	0	0	0	0	0

Table 13 (cont'd.)

System	Stainless Steel Exposed in 1971 (e)	Treatment (a)	Stressed Specimen(b)	Exposure Time Years	Site A	Site B	Site C	Site D	Site E	Site G
28	18Cr-8Ni(N)	—	U	1	0	0	0	0	0	0
				2	0	0	0	0	0	0
				3	0	0	0	0	0-NR*	0
				7(e)	0	0	0	0	0	0
30	26Cr-6.5Ni	—	U	1	0	0	0	0	0	0
				2	0	0	0	0	0	0
				3	0	0	0	0	0	0
				7(e)	0	0	0	0	0	0

*Specimen not retrieved

(a) All specimens in the annealed condition unless noted otherwise

HH-half hard
FH-full hard
S-sensitized

(b) U-single U-bend specimen
UU-double U-bend specimen
(UU)-double U-bend specimen, joined by a spot weld

(c) Micro crack on face, specimen considered failed

(d) Micro crack on edge, specimen considered failed

(e) For specimens buried at Site E, exposure time was 8 years.

Table 14. Average[a] couple current vs. failure.

System	Specimen	Coupled to	Site A Washington		Site B Loch Raven		Site C Cape May		Site D Wildwood (Dry Sand)		Site E Wildwood (Wet Sand)		Site G Patuxent	
			$\mu A/cm^2$	Failures	$\mu A/cm^2$	Failures	$\mu A/cm^2$	Failures	$\mu A/cm^2$	Failures	$\mu A/cm^2$	Failures	$\mu A/cm^2$	Failures
82	301 HH[b]	Zn	2.58	0	1.43	2	20	2	0.94	2	1.14	2	10.3	2
83	"	Mg	17.2	1	4.81	2	122	2	3.95	2	34.7	2	237	2
84	"	Fe	0.06	0	0.48	0	1.45	2	0.17	0	0.48	0	4.08	0
85	301 FH[b]	Zn	4.17	0	1.51	2	20.5	2	1.23	2	0.98	2	14.7	2
86	"	Mg	20.5	2	8.66	2	120	2	3.79	2	34.7	2	249	2
87	"	Fe	0.05	0	0.56	0	1.29	2	0.23	0	0.59	0	4.65	1
88	304[b]	Zn	2.57	0	1.86	0	26.3	0	0.96	0	0.71	0	11.5	0
89	"	Mg	25.3	0	6.38	0	117	0	5.25	0	30.2	0	258	0
90	"	Fe	0.09	0	0.45	0	0.99	0	0.06	0	0.59	0	8.27	0
33	26Cr-1Mo[c]	Zn	7.75	0	1.49	0	33.8	0	1.39	0	2.47	0	18.5	0
34	"	Mg	22.7	0	3.57	0	133	0	3.77	0	24.0	0	353	0
35	"	Fe	4.73	0	0.54	0	0.87	0	0.25	0	2.4	0	-0.21	0
36	26Cr-6.5Ni[c]	Zn	7.30	0	1.72	0	27.8	0	1.31	0	5.01	0	13.1	0
37	"	Mg	47.4	0	4.0	0	138	0	4.53	0	28.4	0	375	0
38	"	Fe	0.37	0	0.98	0	1.57	0	0.35	0	0.94	0	6.52	0

[a]Average of two specimens - 16 readings.

[b]Four year exposure.

[c]Three year exposure.

Table 16. Average[a] Galvanic Current[b]/Average[a] Potential[c] For Stainless Steels Connected To Copper.

System	Material	Site A Toppenish, Washington μA (V)	Site B Loch Raven, Maryland μA (V)	Site C Cape May, New Jersey μA (V)	Site D Wildwood, New Jersey (Dry Sand) μA (V)	Site E Wildwood, New Jersey (Wet Sand) μA (V)	Site G Lexington Park, Maryland μA (V)
42[d]	Alloy 26 Cr-6.5 Ni	+0.92 (-0.078)	-2.27 (+0.001)	+7.91 (-0.114)	-7.45 (-0.111)	-80.42 (-0.001)	-2.85 (-0.427)
91[e]	AISI Type 304	+1.81 (-0.030)	-10.57 (+0.006)	-7114 (-0.132)	+7.36 (-0.188)	-9.78 (-0.124)	+13.02 (-0.443)
92[e]	AISI Type 409	-3.08 (-0.041)	-9.21 (+0.002)	+13.74 (-0.281)	+6.68 (-0.164)	+5.65 (-0.116)	-6.16 (-0.462)

(a) Average of a minimum of 14 readings on each of two specimens per system at each site. The surface area of each electrode was 154.8 cm^2.
(b) Negative current indicates that the stainless steel was cathodic to copper.
(c) Potential vs $Cu-CuSO_4$.
(d) Exposure time - 9 years.
(e) Exposure time - 10 years.

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16. ABSTRACT (A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)

In order to obtain more definitive information regarding the corrosion and stress corrosion of stainless steels in soil environments, NBS in cooperation with the Committee of Stainless Steel Producers, AISI, initiated in 1970 a soil burial program in representative soil environments. Test materials included coated and uncoated sheet specimens in the annealed and sensitized condition, uncoated welded tubing specimens and galvanically coupled and uncoupled stressed and unstressed specimens. To date approximately 10,000 specimens have been buried at six soil test sites. This report contains the results obtained for specimens buried for up to approximately eight years.

17. KEY WORDS (six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)

Coatings; corrosion behavior; field-tests; galvanic couples; soil environment, stainless steels; stress-corrosion behavior

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