Anchor Corrosion
Reference & Examples

Introduction

Corrosion is a naturally occurring process whereby the surface of a metallic structure is oxidized or reduced to a corrosion product such as "rust" (typically iron oxide). The metallic surface is attacked through the migration of ions and loses its original strength by the thinning of the member. When corrosion eventually destroys a sufficient amount of the structure's strength, a failure will occur. The failure may be as simple as a blemish on an auto body to a catastrophic failure of a bridge. The purpose of this bulletin is to answer typical corrosion questions in the case of anchors buried in soil. It is by no means a definitive study, it is some typical cases to give the reader a better understanding of subsurface corrosion. A corrosion engineer should be consulted for site specific solution when there is a significant probability of corrosion.

Much of this work is taken from the NBS circulator 579, April 1, 1957 (O.P.)* by Melvin Romanoff. The tables have been reconstructed in a more usable format and included in the Appendices. The reader is encouraged to obtain his own copy and make his own tables.

In our experience, the vast majority of square shaft and pipe shaft anchors have a calculated service life well in excess of the design life (generally 50 or 100 years) of the structure. In highly corrosive soils and areas of stray currents (e.g., transmission pipelines and DC railroads) additional measures must be taken to protect the anchor. A typical anode selection calculation is included in Appendix B.

Background

Mechanical, physical, and chemical properties must be considered in the use of metals. Mechanical and physical properties are more clearly defined, and usually expressed, in terms of constants. The chemical properties of a metal are dependent on environmental conditions. The corrosion control industry has grown considerably, in the past 20 years, because metals or alloys are still largely selected for their mechanical and physical qualities alone.

Electrochemistry is the study of metals as they relate to their environment. Corrosion can be defined as the deterioration of a metal due to its interaction with that environment. The exact mechanism of the corrosion process taking place at the metal-environment interface is highly complex. However, the study of electrochemistry teaches us that several conditions must be present before the corrosion mechanism takes place. These are:

1. Two points (or areas) on a metallic structure must differ in electrical potential (anode and cathode).

2. The anode and cathode must be electrically connected.

3. The electrically connected anode and cathode must be immersed in a common electrolyte (soil, water or solution).

When these conditions exist, oxidation of the metal (anode) and reduction of a species in solution (oxidizing agent at the cathode) occur with consequent electron transfer through the metal from the anode to the cathode. Metal at the anode will be consumed, while metal at the cathode is protected from corrosion damage. The amount of metal lost is directly proportional to the DC current flow. For mild steel, the metal loss has been determined to be approximately 20 pounds per amp year. (Typical currents encountered are of the magnitude of 10-5 to 10-3 amps.

The amount of corrosion current that eventually flows is a function of the anode to the cathode area relationship, circuit resistance, and the electrical potential between the anode and cathode.

* Available from National Association of Corrosion Engineers, 1440 South Creek Drive, Houston, TX 77084.

Depending on its physical and metallurgical nature, and on the prevailing environmental conditions, corrosion can affect a metal in several different ways. Some of these types are listed below:

Type	Characteristics
Uniform or near uniform	Corrosion takes place at all areas of the metal at the same, or similar, rate.
Localized	Some areas of the metal corrode at different rates than other areas due to heterogeneties in the metal or environment. This type of attack can approach pitting.
Pitting	Very highly localized attack at specific areas, resulting in small pits that may penetrate to perforation.

Considerations need to be applied as to the types and rates of corrosion anticipated, and the function of the metal in question. Certain forms of corrosion can be tolerated, but uniform corrosion will be our concern here.

Soil Environments

Soils constitute the most complex environment known to metallic corrosion. Corrosion of metals in soil can vary from fairly rapid dissolution to negligible effects. Moisture in soils will probably have the most profound affect when considering corrosivity than any other variable. No corrosion will occur in environments that are completely dry. Water is required in soils for ionization of the oxidation process and ionization of soil electrolytes. Flowing water is a more severe enviromnent than stagnant water.
See Figure 1 for a typical moisture content-soil resistivity curve, in this case, a clay.

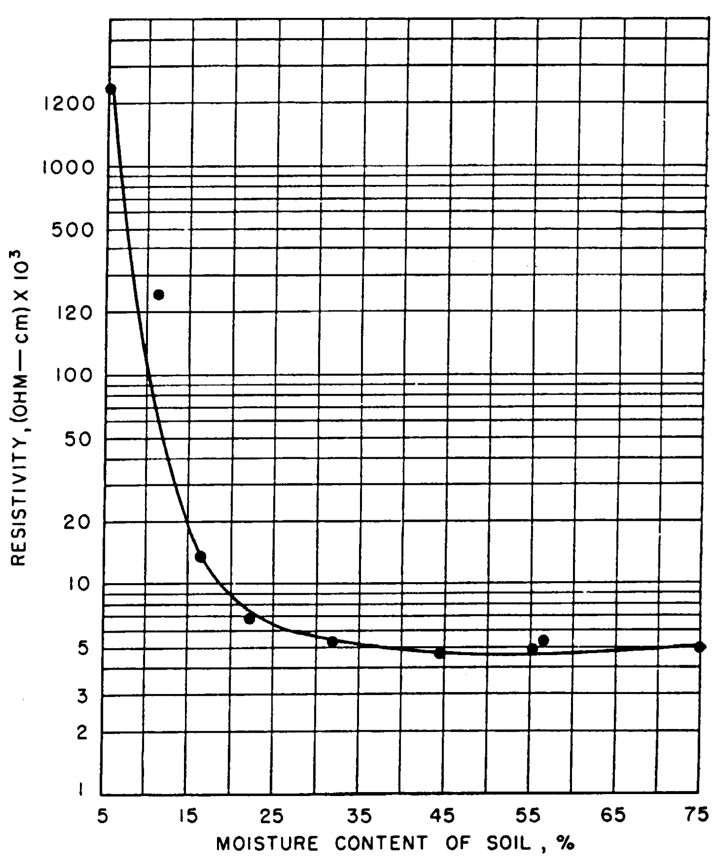


Figure 1. Resistivity versus Moisture Content (Romanoff, 1957)

 Hubbell Power Systems, Inc. Centralia, MO 65240 USA

Most all soils are heterogeneous. This results in different environments interacting on different parts of the metal surface, and produces differences in electrical potential. Differences in oxygen, acidity, and salt content also give rise to corrosion cells.

Soil resistivities (conductivity) are extremely important as they can be corrosion rate controlling. Lower resistivities (high conductivity) can generate high corrosion rates. Metals that are buried will generally be anodic in a low resistivity soil, and cathodic at an adjacent high resistivity soil. Soil heterogeneity in conjunction with specific resistivity, is the most important aspect of soil corrosion. The following table may serve as a guide in predicting the corrosivity of a soil with respect to resistivities alone:

Classification	Soil Resistivity (Ohm-cm)	Anticipated Corrosivity
Low Resistance	0 - 2,000	Severe
Medium	2,000 - 10,000	Moderate
High	10,000 - 30,000	Mild
Very High	Above 30,000	Unlikely

Soils are generally classified according to their particle size. The general classifications are broken down into sand, silt, and clay. Included with the mineral particles are organic matter, moisture, gases and living organisms. Soil pore space will contain either water or gases. Fine textured soils, such as clays, are more tightly packed and have less pore capacity, thus they are less permeable. Sand on the other hand, has a greater pore space and, hence, is more permeable.

An example of helix life based on uniform corrosion rates is given in Appendix A. This example calculation should only be used to estimate the service life of an unprotected anchor (i.e., without cathodic protection in a homogenious soil).

As noted earlier, corrosion rate is a function of soil water content. Table 1 in Appendix A gives pH and conductivity based on laboratory tests of saturated soil samples. Table 2 of Appendix B is a tabulation of typical soil resistivities as measured in the field. Temperature, pressure, soil texture and composition also affect corrosion rate. Depth of the soil sample is affected by all four of these factors. Table 4 is a detailed description of soil profile at each of the test sites given.

The writer feels that resistivity, as measured by the 4-pin method, at the specific site is the best measurement in that it "integrates" the resistivity of the entire soil profile. Such a measurement is superior to estimates based on values taken from the appended tables.

Corrosion Control

One of the methods to control corrosion damage is to electrically isolate the metallic surface from the electrolyte. Coatings are used in this regard to retard the flow of corrosion current into the soil. If it were possible to apply, and keep a 100% watertight seal over a buried structure, corrosion problems would be solved. However, complete isolation is not practical and usually not possible due to holidays or pin holes in the coating. Damage during anchor installation is also inevitable.

Galvanized coatings protect the underlying structure in two ways. Initially, they provide a protective layer between the metal and the environment. Secondly, this type of coating will provide cathodic protection (galvanic action) to exposed surfaces. This sacrificial action will result in depletion of the zinc coating in more aggressive environments.

Asphaltic coatings or paints only provide physical protection from the environment. At coating holidays, a small-anode to large-cathode area relationship probably will exist. Corrosion activity would be expected to be highly localized where the metal is exposed, or the anode area.

For very aggressive environments, a good procedure to minimize or eliminate corrosion activity is to apply cathodic protection in conjunction with coatings. Cathodic protection is a method of eliminating corrosion damage to a structure by the application of DC current. The effect of this current is to force the metallic surface to become cathodic (i.e., collecting current). If this current is of sufficient magnitude, all metallic surfaces will become cathodic to the external anode.

Both sacrificial (galvanic) and impressed current (rectifier and ground bed) cathodic protection systems are used to provide this current. If the current source is derived from a sacrificial metal (magnesium and zinc are the two most common galvanic anodes used in soils), the effectiveness will depend on the soil properties in which it is placed. More available current is generated from a sacrificial anode in low resistant soils than high resistant soils. It is also desirable to place impressed current anode beds in lower resistant soils. However, since the available driving potential is greater (rectifier control), the soil resistivity is less significant.

Current requirements needed to protect a structure from corrosion vary, due to physical and environmental factors. These requirements could range from 0.01 ma/ft^2 of metal surface for a well-applied, high-dielectric-strength plastic coating to 150 ma/ft^2 for bare steel immersed in a turbulent, high-velocity, salt-water environment. In soil, 1 ma/ft^2 is typically used as the required current to protect steel.

An anode selection problem is given in Appendix B.

Appendix A

Table A1: Corrosion of Buried Steel Samples

Table A2: Corrosion of Galvanized Pipe

Table A3: Loss in Weight of Zinc Plate

Sample Calculation on Expected Helix Life

Table A1: Corrosion of Buried Steel
(abstracted from NBS Cir. 579 Tables 6, 8 and 13)

No. Soil NBS Test Site	Location	Resistivity Ohm-cm	pH	Drainage	Duration of Exposure Years	Loss in Wt. oz./ft.^{2}
1 ALLIS SILT LOAM	CLEVELAND,OH.	1215	7.0	POOR	1.0	1.1
					3.6	3.9
					5.5	4.7
					7.7	6.6
					9.6	8.8
					11.6	9.3
2 BELL CLAY	DALLAS,TX.	684	7.3	POOR	2.1	2.4
					4.0	3.0
					5.9	3.4
					7.9	3.6
					12.0	5.9
					17.6	8.1
3 CECIL CLAY LOAM	ATLANTA,GA.	17,790	4.8	GOOD	2.0	2.0
					4.1	3.5
					6.0	3.5
					8.0	3.9
					10.1	4.1
					12.1	5.1
4 CHESTER LOAM	JENKINSTOWN,PA	6,670	5.6	FAIR	1.1	1.4
					4.0	3.5
					6.1	4.6
					8.0	5.3
					12.0	6.2
5 DUBLIN CLAY ADOBE	OAKLAND, CA.	1,315	7.0	POOR	1.9	1.4
					4.1	2.4
					6.2	4.8
					8.1	5.2
					12.1	5.4
					17.5	8.3
6 EVERETT GRANUALLY SANDY LOAM	SEATTLE, WA.	43,100	5.9	GOOD	1.9	0.2
					4.1	0.8
					6.2	0.7
					8.1	0.8
					12.1	0.9
					17.5	1.5

Table A1: Corrosion of Buried Steel
(abstracted from NBS Cir. 579 Tables 6, 8 and 13)

No. Soil NBS Test Site	Location	Resistivity Ohm-cm	pH	Drainage	Duration of Exposure Years	Loss in Wt. oz./ft.²
7 MADDOX SILT LOAM	CINCINNATI,OH.	2,120	4.4	FAIR	1.0	0.6
					3.5	2.4
					7.7	3.7
					11.5	1.3
					16.9	6.4
8 FARGO CLAY LOAM	FARGO,N.D.	330	7.6	POOR	1.1	0.8
					3.8	2.0
					5.8	2.6
					7.7	3.2
					9.9	4.6
					11.8	6.5
9 GENESSEE SILT LOAM	SIDNEY,OH.	2,820	6.8	POOR	1.0	0.9
					3.5	2.0
					5.5	2.8
					7.7	3.0
					11.5	5.0
					16.9	5.4
10 GLOUESTER SANDY LOAM	MIDDLEBORO,MA.	7,460	6.6	FAIR	1.3	1.3
					4.0	1.2
					6.1	3.4
					7.9	4.5
					12.0	4.4
11 HAGERSTOWN LOAM	LOCH RAVEN,MD.	11,000	5.3	GOOD	1.4	0.5
					4.0	1.2
					6.0	1.3
					7.8	1.5
					10.0	2.0
					11.9	1.9
12 HANFORD FINE SANDY LOAM	LOS ANGELES,CA.	3,190	7.1	FAIR	1.9	0.3
					4.4	2.0
					6.2	3.0
					8.0	1.0*
					12.1	3.9*
					17.5	5.6*
13 HANFORD VERY FINE SANDY LOAM	BAKERSFIELD,CA.	290	9.5	FAIR	1.9	3.4
					4.2	3.3
					5.9	7.4

Table A1: Corrosion of Buried Steel
(abstracted from NBS Cir. 579 Tables 6, 8 and 13)

No. Soil NBS Test Site	Location	Resistivity Ohm-cm	pH	Drainage	Duration of Exposure Years	Loss in Wt. oz./ft.^{2}
14 HEMPSTEAD SILT LOAM	ST. PAUL, MN.	3,520	6.2	FAIR	1.4	0.5
					3.8	2.4
					5.8	3.1
					7.7	2.2
					9.9	5.3
					11.8	4.5
15 HOUSTON BLACK CLAY	SAN ANTONIO,TX.	489	7.5	POOR	2.0	2.1
					4.0	3.2
					5.9	5.4
					8.0	5.5
					12.0	7.8
					17.6	10.4
16 KALMIA FINE SANDY LOAM	MOBILE, AL.	8,290	4.4	FAIR	2.0	2.1
					4.0	3.0
					6.0	4.3
					7.9	4.5
					10.0	6.2
					12.0	7.3
17 KEYPORT LOAM	ALEXANDRIA. VA.	5,980	4.5	POOR	1.2	1.4
					3.8	3.2
					5.9	5.2
					7.7	6.6
					11.8	9.0
					17.0	8.2
18 KNOX SILT LOAM	OMAHA, NE.	1,140	7.3	GOOD	1.2	0.6
					3.8	1.6
					5.8	2.6
					7.7	2.0
					9.8	3.3
					11.7	2.6
19 LINDLEY SILT LOAM	DES MOINES, IA.	1,970	4.6	GOOD	1.1	0.7
					3.7	2.2
					5.7	2.3
					7.6	2.8
					9.7	2.9
					11.6	3.1

Table A1: Corrosion of Buried Steel
(abstracted from NBS Cir. 579 Tables 6, 8 and 13)

No. Soil NBS Test Site	Location	Resistivity Ohm-cm	pH	Drainage	Duration of Exposure Years	Loss in Wt. oz./ft.[2]
20 MAHONING SILT LOAM	CLEVELAND, OH.	2,890	7.5	POOR	1.0	1.0
					3.6	2.3
					5.5	2.1
					7.7	2.5
					9.6	4.1
					11.6	6.0
21 MARSHALL SILT LOAM	KANSAS CITY, MO.	2,370	6.2	FAIR	1.5	2.1
					4.0	2.4
					6.0	4.7
22 MEMPHIS SILT LOAM	MEMPHIS, TN.	5,150	4.9	GOOD	1.7	1.9
					3.7	3.7
					5.6	5.4
					7.6	5.8
					9.6	6.1
					11.6	7.4
23 MEREED SILT LOAM	BUTTONWILLOW, CA.	278	9.4	FAIR	1.9	7.8
					4.3	1.05
					6.2	15.7
					8.0	18.6
					10.2	18.9
					12.1	20.4
24 MERRIMAE GRAVELLY SANDY LOAM	NORWOOD, MA.	11,400	4.5	GOOD	1.3	0.3
					4.0	0.4
					6.1	0.8
					7.9	0.8
					12.0	1.4
					17.2	1.4
25 MIAMI CLAY LOAM	MILWAUKEE, WI.	1,780	7.2	FAIR	1.0	0.4
					3.7	1.4
					5.7	1.9
					7.6	2.0
					11.7	2.9
					17.0	3.1
26 MIAMI SILT LOAM	SPRINGFIELD, OH.	2,980	7.3	GOOD	1.0	0.8
					3.5	1.8
					5.5	1.5

Table A1: Corrosion of Buried Steel
(abstracted from NBS Cir. 579 Tables 6, 8 and 13)

No. Soil NBS Test Site	Location	Resistivity Ohm-cm	pH	Drainage	Duration of Exposure Years	Loss in Wt. oz./ft.[2]
					7.7	1.6
					11.5	3.5
					16.9	4.1
27 MILLER CLAY	BUNKIE, LA.	570	3.7	POOR	2.0	0.5
					4.0	3.6
					6.0	3.0
					8.0	5.4
					12.0	7.6
					17.6	9.3
28 MONTEZUMA CLAY ADOBE	SAN DIEGO, CA.	408	6.8	POOR	4.6	?
					5.0	10.0
					7.7	15.1
					9.0	16.8
29 MUCK	NEW ORLEANS, LA.	1,270	4.2	VERY POOR	2.0	1.4
					1.4	6.8
					6.0	9.9
					8.0	11.0
					10.0	14.0
					12.0	19.4
30 MUSEATINE SILT LOAM	DAVENPORT, LA.	1,300	7.0	POOR	1.4	0.9
					3.6	1.2
					5.7	2.0
					8.2	4.2
					11.6	5.3
					17.0	5.4
31 NORFOLK FINE SAND	JACKSONVILLE, FL.	20,500	4.7	GOOD	2.0	1.5
					4.1	2.2
					6.0	1.9
					8.0	2.8
					12.0	2.7
					17.7	4.4
32 ONTARIO LOAM	ROCHESTER, N.Y.	5,700	7.3	GOOD	1.0	0.4
					3.7	1.4
					5.8	1.8
					7.6	2.3
					9.6	2.5
					11.7	3.7

Table A1: Corrosion of Buried Steel
(abstracted from NBS Cir. 579 Tables 6, 8 and 13)

No. Soil NBS Test Site	Location	Resistivity Ohm-cm	pH	Drainage	Duration of Exposure Years	Loss in Wt. oz./ft.^{2}
33 PEAT	MILWAUKEE, WI.	800	6.8	VERY POOR	1.0	0.5
					3.7	3.5
					5.8	5.6
					7.6	8.8
					9.7	9.8
					11.7	14.2
34 PENN SILT LOAM	NORRISTOWN, PA.	4,900	6.7	FAIR	1.4	1.1
					4.0	1.9
					6.1	2.7
					8.0	3.5
					9.9	4.1
					12.0	3.2
35 RAMONA LOAM	LOS ANGELES, CA.	2,060	7.3	GOOD	1.9	0.7
					4.1	1.4
					6.2	1.0
					8.0	1.7
					12.1	1.1
					17.5	0.9
36 RUSTON SANDY LOAM	MERIDIAN, MS.	11,200	4.5	GOOD	2.0	1.1
					4.1	2.1
					6.0	1.8
					8.0	2.4
					12.0	2.9
					17.7	3.7
37 ST. JOHN'S FINE SAND	JACKSONVILLE, FL.	11,200	3.8	POOR	2.0	2.4
					4.1	4.2
					6.0	4.6
					8.0	5.2
					10.1	7.7
					12.0	6.8
38 SASSAFRAS GRAVELLY SANDY LOAM	CAMDEN, N.J.	38,600	4.5	GOOD	1.4	0.2
					4.0	0.6
					6.1	0.8
					8.0	1.8
					12.0	2.6
					17.2	2.6

Table A1: Corrosion of Buried Steel
(abstracted from NBS Cir. 579 Tables 6, 8 and 13)

No. Soil NBS Test Site	Location	Resistivity Ohm-cm	pH	Drainage	Duration of Exposure Years	Loss in Wt. oz./ft.^{2}
39 SASSAFRAS SILT LOAM	WILMINGTON, DE	7.440	5.6	FAIR	1.4	1.3
					4.0	2.7
					6.1	2.7
					8.0	3.6
					9.9	4.5
					12.0	5.2
40 SHARKEY CLAY	NEW ORLEANS, LA.	970	6.0	POOR	2.0	2.0
					4.1	3.7
					6.0	5.3
					8.0	5.5
					10.0	6.0
					12.0	6.7
41 SUMMIT SILT LOAM	KANSAS CITY, MO.	1,320	5.3	FAIR	1.5	1.0
					4.0	3.0
					6.0	4.2
					7.9	4.7
					12.0	5.3
					17.4	7.0
42 SUSQUEHANNA CLAY	MERIDAN, MS.	13,700	4.7	FAIR	2.0	3.1
					4.1	5.9
					6.0	7.3
					8.0	93.
					10.1	12.5
					12.0	17.1
43 TIDAL MARSH	ELIZABETH, N.J.	60	3.1	VERY POOR	1.3	2.8
					4.1	4.8
					6.2	7.1
					8.0	11.4
					9.9	17.0
					12.0	17.6
44 WABASH SILT LOAM	OMAHA, NE.	1,000	8.8	GOOD	4.1	0.5
					3.6	1.8
					5.7	2.4
					7.6	2.0
					11.6	3.5
45 UNIDENTIFIED ALKALI	CASPER, WY	263	7.4	POOR	1.2	1.3

Table A1: Corrosion of Buried Steel
(abstracted from NBS Cir. 579 Tables 6, 8 and 13)

No. Soil NBS Test Site	Location	Resistivity Ohm-cm	pH	Drainage	Duration of Exposure Years	Loss in Wt. oz./ft.[2]
SOIL					3.8	3.3
					5.8	3.1
					7.7	3.8
					9.8	12.1
					11.7	9.3
46 UNIDENTIFIED SANDY LOAM	DENVER, CO.	1,500	7.0	GOOD	1.5	0.9
					4.0	2.6
					5.1	3.0
					8.0	5.7
					10.2	4.1
					12.0	4.4
47 UNIDENTIFIED SILT LOAM	SALT LAKE CITY,UT	1,770	7.6	POOR	1.5	0.4
					4.1	1.3
					6.1	1.2
					8.0	1.8
					12.1	2.8
					17.1	8.1
48 ACADIA CLAY	SPINDLETON,TX	190	6.2	POOR	2.0	7.4
					5.4	12.7
					7.5	11.5
					14.3	21.0
49 CERIL CLAY LOAM	ATLANTA, GA.	8,500	4.9	GOOD	2.0	2.7
					5.5	3.0
					7.6	4.2
					9.5	4.1
					14.3	4.4
50 HAGERSTOWN LOAM	LOCK ROESLN	5,210	5.8	GOOD	1.9	2.4
					5.2	2.2
					7.1	3.2
					9.1	3.8
					14.2	3.1
51 LAKE CHARLES CLAY	LEAGUE CTY,TX.	234	8.8	POOR	2.0	4.0
					5.4	13.9
					7.5	21.0
					9.4	28.8
					14.4	35.2

Table A1: Corrosion of Buried Steel
(abstracted from NBS Cir. 579 Tables 6, 8 and 13)

No. Soil NBS Test Site	Location	Resistivity Ohm-cm	pH	Drainage	Duration of Exposure Years	Loss in Wt. oz./ft.^{2}
52 MUCK	NEW ORLEANS,LA.	712	4.2	VERY POOR	2.0	3.2
					5.5	11.2
					7.6	14.1
					9.5	16.2
					14.4	25.5
53 CARLISLE MUCK	KALAMOZOO,MI.	1,660	5.6	VERY POOR	5.1	2.1
					7.2	3.0
					9.1	4.7
					14.2	3.9
54 PEAT	PLYMOUTH,OH.	218	2.6	POOR	1.9	6.2
					5.2	11.0
					7.3	7.6
					9.2	16.7
					14.3	28.8

Table A2: Corrosion of Galvanized Pipe Buried in 1924 (abstracted from NBS Cir. 579, Table 65)

Soil		Duration of test	Loss in weight (oz/ft²)	
No.	Type		Pipe A (2.82)[a]	Bare[b]
		Years		
1	Allis silt loam	10.66	2.92	10.20
2	Bell clay	9.92	.35	-------
3	Cecil clay loam	10.09	.41	3.96
4	Chester loam	10.62	1.94	-------
5	Dublin clay adobe	10.17	1.82	-------
6	Everett gravelly sandy loam	10.16	.12	-------
7	Maddox silt loam	10.48	2.62	-------
8	Fargo clay loam	10.63	.78	5.55
9	Genesee silt loam	9.48	1.10	-------
10	Gloucester sandy loam	10.62	1.29	-------
11	Hagerstown loam	10.55	.90	1.79
12	Hanford fine sandy loam	10.17	-------	-------
13	Hanford very fine sandy loam	10.16	.87	-------
14	Hempstead silt loam	10.64	.26	5.00
15	Houston black clay	10.06	.35	-------
16	Kalmia fine sandy loam	10.04	.99	6.44
17	Keyport loam	10.57	3.64	-------
19	Lindley silt loam	10.51	.68	3.30
20	Mahoning silt loam	10.67	1.22	5.01
22	Memphis silt loam	9.93	1.19	7.16
23	Merced silt loam	10.16	9.60	25.66
24	Merrimac gravelly sandy loam	10.63	.26	-------
25	Miami clay loam	10.65	.36	-------
26	Miami silt loam	10.48	.71	-------
27	Miller clay	10.08	.92	-------
28	Montezuma clay adobe	9.60	1.96	16.32
29	Muck	10.08	5.98	14.79
30	Muscatine silt loam	10.51	.47	-------
31	Norfolk fine sand	10.04	.16	-------
32	Ontario loam	10.71	.60	3.04
33	Peat	10.65	1.83	11.96
35	Ramona loam	10.16	.30	-------
36	Ruston sandy loam	10.05	.23	-------
37	St. John's fine sand	10.04	2.03	8.54
38	Sassafras gravelly sandy loam	10.62	.21	-------
40	Sharkey clay	10.08	.93	7.48
41	Summit silt loam	10.52	.54	-------
42	Susquehanna clay	10.05	.71	10.64
43	Tidal marsh	10.73	1.38	12.72
44	Wabash silt loam	10.52	-------	-------
45	Unidentified alkali soil	10.55	1.84	13.53
46	Unidentified sandy loam	10.54	.17	4.38
47	Unidentified silt loam	10.60	1.06	-------

[a] The weight of coating given here is in ounces per square foot of exposed area. It is the average obtained from at least 10 measurements of thickness by the stripping method.

[b] In the column headed "Bare" are presented the average weight losses of rolled iron and steel specimens buried a similar length of time, i.e., approximately 10 years. These were not available for all soils.

Table A3: Loss in Weight of Zinc Plate (abstracted from NBS Cir. 579, Table 66)

Size	Type	Years of Exposure	Conductivity Ω Cm	Loss in Weight oz/ft.^{2}
51	Acadia Clay	2.0	190	2.0
53	Cecil Clay Loam	12.7	17,790	2.2
55	Hagerstown Loam	12.6	886	1.2
56	Lake Charles Clay	12.7	406	9.0
58	Muck	12.7	712	7.5
59	Carlisle Muck	12.7	1660	4.6
60	Rifle Peat	4.0	218	10.4
61	Sharkey Clay	12.7	943	2.0
62	Susquehanna Clay	12.7	6920	1.7
63	Tidal Marsh	12.6	84	4.1
64	Docas Clay	12.8	62	2.0
65	Chino Silt Loam	12.7	148	1.8
66	Mohave Fine Gravelly Loam	12.7	232	5.5
67	Cinders	4.0	455	12.2

Sample Calculation on Expected Helix Life

Assume ⅛" allowable thickness loss for helix. Determine life of helical pier in soil having resistivity of 400, 1000 & 3000 Ω-cm.

Allowable Steel Loss:

$$\frac{0.125\ in^3 * 0.2836\ lb/in^3 * 16\ oz/lb}{in.} * \frac{144\ in^2}{ft^2} = 81.66\ oz/ft^2$$

Site† No.	Resistivity Ohm-cm	Years Exposed	Loss in Wt. oz/ft^2	Loss per Yr. oz/ft^2
28	408	9	16.8	1.87
44	1000	11.6	3.5	0.30
26	2980	16.9	4.1	0.25

Total zinc coat loss:

ASTM A153 Coating B = 1.8 oz/ft^2

56	406	11.1	6.6	0.59
61	943	11.2	2.1	0.19
--	~3000	Not Available	Not Available	Not Available

Years required for ⅛" steel loss and all zinc (Y_T)

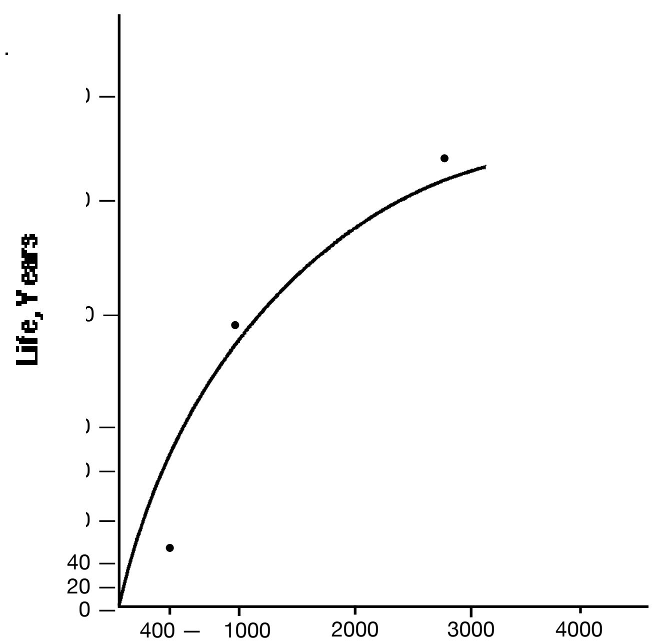
$$Y_T = \frac{81.66\ oz/ft^2}{Loss/yr.\ Steel} + \frac{1.8\ oz/ft^2}{Loss/yr.\ Zinc}$$

Resistivity	Years for Steel	Years for Zinc	Y_T
408	43	3	46
1000	272	9.5	281.5
2980	326	Use 9.5	335.5

See attached plot.

†Site Nos. Refer to data from Table A1 & A2.

Example Resistivity vs. Helix Life



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Appendix B

Sample Calculation Anode Section

Table B1 Typical Resistivities

Table B2: Typical Anode Data

Table B3: Descriptions of Soil

Example Design
Anode Selection

SS150 ANCHOR EXAMPLE

SURFACE AREA DATA
ROD: 1½ x 1½ x 7' = 3.5 Sq. Ft.
Helix Area: 8 dia. = 1.1 Sq. Ft.
10 dia. = 1.5 Sq. Ft.
12 dia. = 1.8 Sq. Ft.

SAMPLE CALCS:

On one wall: Assume 5 each 8 x 1½ Sq. Ft.
SS150 Anchors in 2500 ohm cm Soil

A = 5 x (1.1 + 3.5) = 23 ft² Total

Ireq'd = 1.0 ma (*)/ft² x 23 sq. ft. = 23 ma

FROM ANODE CHART TABLE

Using 2500 ohm cm Soil
17# Anode = 26 yr.
9# Anode = 13 yr.

OR:

USEFUL LIFE OF ANODE @ 60% Consump.

.6 x 17 = 10.2 lb.

PROTECTS FOR:

$$\text{Est. Life} = \frac{10.2\#}{17.5\#/\text{Amp-Yr.}} \qquad \frac{1}{.023\ \text{Amp}} \qquad = 25.3\ \text{Yr.}$$

(*) 1.0 ma/Sq. Ft. is usual current req't assumed for buried steel. With low resist. (2000 ohm cm)

Table B-1 Typical Field Resistivities

MATERIAL	OHM-CENTIMETERS
Graphite	0.03
Salt Water	20.
Laom	1500.
Silt-Loam (25% moisture)	2500.
Gravel-sand-loam (wet)	10000.
Peat	800.
Clay-Silt (25% moisture)	600.
Adobe clay (25% moisture)	400.
Tidal clay-loam	250.
Coal coke breeze (moist)	50.
Sand & Clay (25% moisture)	1000.
Shale (wet)	2000.
Shale (dry)	1000000.
Sandstone (wet)	7000.
Sandstone (dry)	5000000.
Limestone (25% moisture)	15000.
Limestone (dry)	100000.
Coal	10000.
Glacial Till	50000.
Dry Clay	60000.
Conglomerate	200000.
Slate (wet)	64000.
Slate (dry)	650000.
Granite	over 75 million
Petroleum	over 100 million

Table B-2 Typical Anode Data

Magnesium Anode Design Data - 9# & 17# Package
(H - 1 Alloy - ASTM Alloy AZ-63)

SOIL RESISTIVITY (OHM-CM)	ANODE RES. (OHMS)	DRIVING POT. (MV) 1	OUTPUT (MA)	LIFE (YEARS)		
				17# (2)	17# (2)	9# (2)
1000	7.5	425	57	11	**11**	6
1500	11	438	40	16	**16**	9
2000	15	450	30	21	**21**	11
2500	19	463	24	26	**26**	13
3000	23	475	21	30	**30**	16
4000	30	500	17	37	**37**	20
5000	38	525	14	45	**45**	24
6000	45	550	12	52	**52**	27
7000	54	575	11	57	**57**	30
8000	60	600	10	63	**63**	34
10,000	80	625	8	75	**75**	39
20,000	165	650	4	150	**150**	80

NOTES:

1. Against cathode polarized to -0.900 volts vs. Cu-$CuSO_4$ and adjusted for decrease in anode potential resulting from current output.
2. Estimated for useful effective life at 60% of anode weight. Typical consumption rate (17.5#/amp-year).
3. All figures are approximate estimates.

Table B3: Descriptions of Soils at the Test Sites (from NBS Circular 579,1957)

Prepared by M. Romanoff. The profiles have been described by S. Ewing, I. A. Denison, G. N. Scott, and by the following soil surveyors from the Bureau of Plant Industry of the United States Department of Agriculture: A. E. Taylor, M. H. Lapham, R. Wildermuth, W. J. Geib, H. H. Bennett, H. G. Lewis, F. A. Hayes, W. T. Carter, R. C. Roberts, Mark M. Baldwin, R. S. Smith.

When the profile at the test site was not described the typical profile of the soil type was taken from soil-survey reports.

Site No.	Soil type	Location	Description of soil profile (Depths are in inches)	Internal drainage	Topography	Depth of specimens
						Inches
1	Allis silt loam	Cleveland, Ohio	0–8 grayish yellow or yellowish gray silt loam mottled with yellow and yellowish brown. 8–23 mottled yellow and gray silty clay loam which contains fragments of shale. 23–30 bluish gray silty clay loam with bands of yellow indicating the bedding planes of the shale. 30–70 silty clay or silty clay loam layer of shale which has a bluish gray color and is streaked along bedding planes with yellow. 70–76 reddish brown shale streaked with gray. 76–90 compact bluish gray shale with yellowish brown and reddish brown streaks. 90–100 the streaks become less conspicuous. This shale runs high in aluminum sulfate, which, with water, breaks down into aluminum hydroxide and sulfuric acid.	Poor	Undulating to gently rolling.	95
2	Bell clay	Dallas, Tex.	0–10 black to dark brown silty clay. 10–740 black clay. No definitely residual matter was discovered within 40 inches. Small rounded quartzite gravel and lime concentrations disseminated through the subsoil.	do	Level	Below 40
3	Cecil clay loam	Atlanta, Ga.	0–8 grayish brown, rather compact, very fine sandy loam. A few fragments of granite and quartz found on the surface. 8–10 transition layer into 10–32 compact brittle red clay containing very few mica flakes and practically no sand and stones. 32–48 micaceous, more friable, and not as compact as above horizon, red clay loam or clay. 48–52 layer of sandy clay with yellowish mottlings. 52–70 red micaceous clay as in 32–48. 70–74 red very fine sandy loam with yellowish mottlings. 74—96 moderately friable, red very fine sandy loam, full of mica crystals, and having a few brownish and yellowish mottlings due to partially decomposed rock. 96–108 very friable fine sandy loam, mottled yellow, red, and brown.	Little excessive	Moderate slope.	30
4	Chester loam	Jenkintown, Pa.	0–10 grayish brown mellow loam gradually getting lighter in color with increasing depth. The top 6 inches of the trench is a mixture of road material and soil. No vegetation. 10–34 mellow, only slightly darker in color and heavier in texture with increasing depth. 34–96 micaceous rather loose friable silt loam containing considerable fine sand. At 36 inches there is a layer of partially decomposed granite. Soil in this site is considerably wetter than the average condition of this soil, as the trench gets all the rain water that falls on the adjacent highway.	Good	Gently rolling	36
5	Dublin clay adobe	Oakland, Calif.	0–10 dark dull gray or drab clay of adobe structure, sticky when wet, contains numerous plant and grass roots and an appreciable amount of fine gritty material and gravel fragments. 10–36 slightly more compact brownish gray or drab friable clay which is sticky when wet. Somewhat mottled with brown and dull slaty gray or black streaks. It contains spherical shotlike iron concretions of black or bluish black color, ranging in size from a pinhead to small buckshot. 36–48 soil grades into a yellowish brown silty clay material. This horizon is mildly calcareous and is the upper limit of lime accumulation. 48–60 yellowish brown compact clay containing many light grayish fragments of lime carbonate nodules localized in thin seams or layers, the material being partially cemented.	Poor	Smooth and level.	30
6	Everett gravelly sandy loam.	Seattle, Wash.	0–8 brown to light brown sandy loam darkened by presence of organic matter. 8–24 light brown sandy loam. Both this and the above horizon contain little gravel, and considerable coarse sand. Both horizons are loose and friable and contain numerous grass roots. 24–30 grayish brown gravelly sandy loam. Slightly compact. Below 30 inches hard cemented gravel and sand, with very little lime of a grayish brown color.	Excessive	Moderately rolling.	36

Table B3
National Bureau of Standards test sites — Continued

Site No.	Soil type	Location	Description of soil profile (Depths are in inches)	Internal drainage	Topography	Depth of speci-mens
						Inches
7	Maddox silt loam	Cincinnati, Ohio	0–5 brownish yellow friable silty clay loam. 5–15 brownish yellow smooth, plastic, heavy, moderately tight clay mottled light gray. The mottles are of moderate extent and development and occur in small irregular veins. The soil material fractures into irregularly shaped lumps, ranging in size from ½ to 1½ inches in diameter. 15–22 brownish yellow or yellow sticky, plastic, slowly pervious, moderately compact heavier clay containing a moderate amount of light gray mottles. It has a fragmental structure forming hard, irregular aggregates from ½ to 1½ inches in diameter. 22–30 varicolored bluish gray and olive-green tight, smooth, plastic, very heavy clay or silty clay having occasional staining of rust-yellow. This layer has been developed from the weathering of underlying shale rock materials.	Fair	Smooth ridge top.	22
8	Fargo clay loam	Fargo, N. Dak.	0–24 black noncalcareous clay loam. Rather friable. Breaks with concoidal fracture into pea-size pieces. 24–42 calcareous transition layer with tongues of both horizons extending into the layer. 42–88 grayish brown heavy clay loam. Light gray when dry—highly calcareous. Below 88 parent material of old lake laid deposits. Grayish brown color containing rusty brown streaks and mottlings. Few hard concretions that are largely lime.	Poor	Level	66
9	Genesee silt loam	Sidney, Ohio	0–10 brownish gray silt loam, slightly streaked with reddish brown. 10–16 gray loam streaked reddish brown and mottled yellowish brown and brownish yellow. 16–22 transition to fine sandy loam mottled reddish brown. At 22 bed of gray gravel.	do		22
10	Gloucester sandy loam	Middleboro, Mass.	Surface—light brown sandy loam. Subsoil—light grayish brown fine sandy loam containing some gravel.	Fair		36
11	Hagerstown loam	Loch Raven, Md.	0–12 dark brown or brown friable loam. 12–33 reddish brown or red clay loam. Moderately compact. Contains fragments of stone, chert. 33+ moderately friable rusty brown heavy silt loam with a reddish cast. This extends to the underlying rock, which is rather clear, crystalline, and hard (not limestone). In one place in the trench the rock is at a depth of about 4 feet.	Good	Slight slope	36
12	Hanford fine sandy loam	Los Angeles, Calif.	The entire profile is a grayish brown friable, loose, micaceous fine sandy loam containing thin layers of material as heavy as loam and as tight as sand. Noncalcareous at surface, and only faintly calcareous at 6 feet. This soil differs from soil 13 in that it does not contain soluble carbonates in appreciable amount.	do	Practically level.	24
13a	Hanford very fine sandy loam.	Bakersfield, Calif.	0–56 light grayish brown smooth, friable, micaceous very fine sandy loam. 56–62 light grayish brown very fine sand. 62–66 same as 0–56. 68–72 same as 56–62. The soil is high in alkali in the carbonate form, and formerly called black alkali.	Fair	Almost level	30
13b	do	do	0–6 grayish brown very slightly compacted loam. 6–84 light grayish brown friable loose micaceous very fine sandy loam. Numerous roots in first 3 feet. Few light colored specks at 3 feet. A special set of specimens are buried at the site. The profile is similar to site 13a, but differs by being low in alkali content.	Good	Very gently undulating.	
14	Hempstead silt loam	St. Paul, Minn.	0–15 dark brown (almost black) silt loam. 15–24 transition layer consisting of tongues and streaks of the two adjoining horizons extending into each other. 24–42 brown silt loam with yellowish cast, slightly compact. 42+ grayish brown sand containing some gravel. Entire profile is noncalcareous.	Fair	do	44
15	Houston black clay	San Antonio, Tex.	0–36 black clay with no appreciable change. Highly calcareous. Small fragments of lime are found throughout the section.	Poor		36

Table B3
National Bureau of Standards test sites — Continued

Site No.	Soil type	Location	Description of soil profile (Depths are in inches)	Internal drainage	Topography	Depth of speci-mens
						Inches
16	Kalmia fine sandy loam	Mobile, Ala.	0–8 grayish brown fine sandy loam, which appears to have been disturbed. 8–42 yellowish brown very fine sandy loam. Texture gradually gets finer and compactness increases with depth. Some reddish mottlings and a few iron concentrations about ¼ inch in diameter, which are most numerous at about 3 feet and disappear at 6 feet. 42–48 brownish yellow or yellow silt loam mottled with red. 48–96 mottled red, gray, and yellow material containing thin layers of clay and fine sand but with the average texture of silt loam. Below 72 inches the color is light yellowish brown with light gray mottlings.	Fair	Gentle slope.	30
17	Keyport loam	Alexandria, Va.	0–6 grayish brown loam or silt loam without structure. Moderately loose and friable. 6–14 transition layer, slightly compact clay loam. 14–48 light yellowish brown rather compact clay loam with concoidal fracture exposing shiny surfaces. Slightly mottled with gray. Texture gets a little lighter with increasing depth. 48–74 brown fine sandy loam with slight reddish cast. 74–76 light gray clayey sand. 76–96 brown sand almost saturated with water. 96+gravel. Entire profile is noncalcareous	do	do	36
18	Knox silt loam	Omaha, Neb.	0–8 dark brown silt loam full of brickbats, plaster, rotten wood, etc. The surface soil partly removed and mixed with foreign matter. 8–72 light brown very uniform smooth friable silt loam that gets a little lighter in color with depth. Moderately moist. Contains a few brown spots due to rotten roots at 8 to 24 inches. Very faintly calcareous at 48 inches and below.	Good	Practically level.	48
19	Lindley silt loam	Des Moines, Iowa	0–4 dark brown silt loam, friable and full of organic matter. 4–18 slightly compact heavy silt loam, yellowish brown. 18–34 transition layer into. 24–50 rather compact more yellowish brown clay containing a few dark-colored specks. 50–76 grayish brown clay loam with bright yellow mottlings and a few white specks. Less compact than above. 76–84 gritty material of variable texture and color, containing light colored cherty material. 84 large boulder or gravel	Good	Moderate slope.	36
20	Mahoning silt loam	Cleveland, Ohio	0–4 brownish gray heavy silt loam or light silty clay loam. 4–8 pinkish red clay, mottled brownish yellow, yellow, yellowish brown, and gray. 8–24 mottled drabbish gray-yellow, brownish yellow, and yellowish brown clay. 24–46 drabbish gray clay, mottled with brownish yellow, and pinkish red. 46–50+ mottled gray, brownish yellow, and yellowish brown, calcareous clay.	Poor	Gently undulating.	48
21	Marshall silt loam	Kansas City, Mo.	0–28 brown or chocolate brown friable, uniform silt loam 28–36 transition layer 36–84 light brown silt loam very uniform and smooth. Noncalcareous to 6 feet. 84+light brown noncalcareous clay slightly mottled with grayish brown.	Good	Moderately rolling.	60
22	Memphis silt loam	Memphis, Tenn.	0–4 light brown silt loam containing thin discontinuous layers of darker color probably due to the turning under of organic matter when the soil was cultivated. 4–96 light brown slightly compact silt loam with some grayish mottlings but no hard lime concretions. Very uniform in color and texture.	do	Very gently undulating.	33
23	Merced silt loam	Buttonwillow, Calif.	0–14 dark brown (almost black) silt loam. ¼-inch crust, 3-inch mulch, which is underlaid by slightly compact very lightly moist material with no definite structure. 14–72 light gray loam, moderately compact and moist with somewhat lighter texture and a more open structure below 48 inches, where thin layers of sandy loam occur. Friable and loose. Thin layers of grayish brown sand occur at 60 inches. Location has all indications of a soil high in alkali. Highly calcareous up to surface.	Fair	Level	30
24	Merrimac gravelly sandy loam.	Norwood, Mass.	0–4 brown loam containing considerable sand and coarse sand. 4–33+grayish coarse sand or fine gravel.	Good		33

Table B3
National Bureau of Standards test sites — Continued

Site No.	Soil type	Location	Description of soil profile (Depths are in inches)	Internal drainage	Topography	Depth of specimens
						Inches
25	Miami clay loam	Milwaukee, Wis.	0–6 grayish brown silt loam. 6–30 yellowish brown, stiff, heavy clay loam to clay, containing a small amount of gritty material. 30–48 slightly calcareous browinsh yellow heavy clay loam, somewhat lighter than the above and also contains some gritty material.	Fair		36
26	Miami silt loam (mottled phase).	Springfield, Ohio	0–2 grayish brown silt loam. 2–7 brownish gray to yellowish-gray silt loam. 7–10 gray silt loam mottled faintly with yellow. 10–16 mottled yellow and gray silt loam. 16–24 brown clay loam to clay mottled brownish yellow and yellowish brown. 24–36 reddish brown stiff clay. 36–48 yellowish brown gravelly friable clay, somewhat calcareous in the lower part of the layer.	Good		36–48
27	Miller clay	Bunkie, La.	Dull red heavy calcareous clay extending down below the depth at which the specimens are buried. Soil map shows Miller clay at this location and a sample of the soil was identified as typical Miller clay.	Very poor	Level	30
28	Montezuma clay adobe	San Diego, Calif.	0–8 filled material—brickbats, gravel, etc. 8–46 gray or light grayish-brown adobe containing some gritty material and gravel in the first foot. Noncalcareous. 46–50 light gray sandy clay, somewhat sticky. 50–60 grayish brown or yellowish brown gravelly sand. 60+ gravel.	Poor	Level to gently rolling.	40
29	Muck	New Orleans, La.	Surface—to varying depths consists of dark colored material of variable texture, most of which is fill. Subsoil—black, semifluid mass of well-decomposed mulch which rests upon an almost solid mat of old cypress stumps and roots that are in an excellent state of preservation. Substratum—stiff, putty-like gray clay. The land was originally a cypress swamp.	Very poor		24
30	Muscatine silt loam	Davenport, Iowa	0–6 dark brown silt loam (grayish brown when dry). 6–7 gray or grayish brown silt loam with yellow mottlings that are evenly distributed and containing a few brown specks. Noncalcareous throughout.	Poor	Level	36
31	Norfolk fine sand	Jacksonville, Fla.	0–4 grayish brown fine sand containing organic matter. 4–15 gradual transition into very slightly compact, very pale yellow sand. Deepest in color and more compact at 15 inches. 15+compactness gradually decreases and the color gets a little lighter. Slight yellow mottlings at 60 inches. The same sand probably extends to 20 or 30 feet. This soil was called Norfolk sand in previous corrosion reports.	Good	Almost level	24
32	Ontario loam	Rochester, N. Y.	0–8 brown to grayish brown (when dry) mellow and friable, fine sandy loam to fine sand. 8–18 slightly more compact, though crumbly loam to fine sandy loam, light brown to yellowish brown in color. 18–33 grayish brown to brownish gray compact loam in place, though friable when bored out. 33+partially weathered till material. Parent material from which the soil is derived is largely limestone, with some sandstone, shale, and igneous rocks. Gravel and small stones are abundant in lower portions. The soil is calcareous at from 15 to 24 inches.	Good	Gently sloping to undulating.	48
33	Peat	Milwaukee, Wis.	A black well-decomposed peat 30 to 36 inches deep, where it rests on a drab or bluish plastic clay loam. The lower part of the section was saturated with water. The peat merges into clyde loam, the line of separation being rather indefinite. A sample of this soil lost 42 percent on ignition.	Very poor		24
34	Penn silt loam	Norristown, Pa.	0–8 brown or dark brown silt loam 8–24 reddish brown silt loam containing considerable sand. 24–38 slightly lighter in color than above layer. 38–56 Indian red or reddish-brown silt loam. 56+ shale	Fair	Gentle slope	36
35	Ramona loam	Los Angeles, Calif.	0–22 light brown moderately compact loam with slight reddish tint and a slight admixture of organic matter to 2 inches of surface. Very dry. 22–54 slightly moist, hard, gritty, compact, brittle, reddish brown clay loam containing numerous white specks. 54–72 light reddish brown or light-brown gritty silt loam. White specks present but not as compact as horizon above. Entire profile is noncalcareous.	Good	Moderately rolling.	36

Table B3
National Bureau of Standards test sites — Continued

Site No.	Soil type	Location	Description of soil profile (Depths are in inches)	Internal drainage	Topography	Depth of specimens
						Inches
36	Ruston sandy loam	Meridian, Miss.	0–8 light brown, loose, friable sandy loam. 8–30 brownish red or rusty brown heavy fine sandy loam. Rather compact and hard. 30–60 reddish brown, rather compact, heavy fine sandy loam. 60–96 mottled red and yellow compact heavy fine sandy loam. No gravel or stones present in the profile.	Good	Gently rolling.	36
37	St. John's fine sand	Jacksonville, Fla.	0–2 dark gray or grayish brown fine sand. The organic matter imparts the dark color. 2–10 the material merges into a rather compact yellowish layer having a distinct lower boundary. The organic matter decreases with depth and the yellow color becomes brighter. The yellow sand contains a few very hard round black iron concretions about ¼ inch in diameter that are surrounded by reddish brown sand. 10–28 light gray slightly compact fine sand which becomes lighter with increasing depth and is almost white at 28 inches. 28–36 dark brown hard compact iron cemented hardpan with the characteristic coffee ground color. 36–60 pale yellow fine sand saturated with water.	Poor	Practically level.	30
38	Sassafras gravelly sandy loam.	Camden, N. J.	0–8 grayish brown gravelly sandy loam which gradually changes into a light yellowish brown or yellowish gray. 8–28 light gray or yellowish brown gravelly sandy loam which is darker than the horizon below. 28–96 light gray gravelly sandy loam with faint yellow cast. Entire profile is loose and open and is noncalcareous. The amount of gravel is rather small for a gravelly type soil. The size of the gravel varies up to 8 inches in diameter and is all smooth and waterworn.	Good	Moderate uniform slope.	30
39	Sassafras silt loam	Wilmington, Del.	This soil has been so disturbed that an accurate description of the profile is impossible. 0–12 grayish brown moderately friable silt loam. 12–30+ slightly yellowish-brown silt loam which extends below the specimens. The trench bottom shows considerable gravel and a little gravel exists throughout the profile.	Fair	Practically level.	30
40	Sharkey clay	New Orleans, La.	0–8 dark brown or brown clay loam containing organic matter and full of grass roots. Rather compact. 8–30 stiff, plastic gray clay mottled with rusty colored material. No definite hard iron concretions. 30–60 gray silt loam mottled with rusty brown. The rusty colored spots get lighter in color with depth and practically disappeared at 60 inches.	Poor	Gently undulating to level.	30
41	Summit silt loam	Kansas City, Mo.	0–22 very uniform and smooth brown silt loam. 22–36 light brown smooth silt loam. 36–108 light brown uniform silt loam faintly mottled with grayish brown. Noncalcareous to 9 feet at which depth the soil is underlain by shale.	Fair	Gentle slope	36
42	Susquehanna clay	Meridian, Miss.	Top soil corroded away. 0–6 rather compact but friable light reddish brown clay. 6–45 mottled red, yellow, and gray very hard compact clay that has a cubical structure. 45–56 mottled red, yellow and gray heavy silt loam. 56–84 same as 6–45.	Fair	Steep slope	30
43	Tidal marsh	Elizabeth, N. J.	Entire soil profile, and especially the surface foot, contains a large percentage of undecayed organic matter and has a black color when wet. Upon drying the color changes to grayish brown. The soil contains hydrogen sulfide and a considerable amount of soluble salts, but no lime. The surface portion of the soil lost 20.7 percent on ignition.	Very poor	Level	36
44	Wabash silt loam	Omaha, Neb.	Except for the addition of grass roots to the top 8 to 12 inches, the entire profile consists of a uniform dark brown silt loam (black when wet) or silty clay loam, to a depth of at least 8 feet. Noncalcareous throughout.	Good	Practically level.	30
45	Unidentified alkali soil	Casper, Wyo.	0–6 light gray to light grayish brown sand to heavy silt loam. Little organic matter. 6–20 brown to grayish brown heavy compact, gritty clay. Plastic and waxy when wet, but becomes hard and tough when dry. 20–30 abrupt change to a light gray sandy clay. More friable than upper horizon due to higher sand content. 30–48 sand content decreases, color slightly darker and texture more compact than above horizon. Type is highly alkaline, and white streaks and splotches of concentrated salts occur abundantly throughout the profile except in the surface soil.	Poor	Level	30

Table B3
National Bureau of Standards test sites — Continued

Site No.	Soil type	Location	Description of soil profile (Depths are in inches)	Internal drainage	Topography	Depth of specimens
						Inches
46	Unidentified sandy loam	Denver, Colo.	0–12 brown or light brown sandy loam. 12–14 layer of brickbats and debris. 14–20 light brown sandy loam. All the above material is loose and friable. 20–22 hard compact layer of cinders. All the above material is full and the next horizon is probably the original surface of the profile. 22–36 hard, compact brown sandy loam. 36–120 light brown sandy loam which gets a little lighter in color and is calcareous below 60 inches, where it is slightly cemented.	Good	Very gentle, uniform slope.	50
47	Unidentified silt loam	Salt Lake City, Utah	0–12 grayish brown or brown silt loam containing considerable organic matter. Highly calcareous at all depths. 12–72 light gray moderately compact clay containing occasional mottlings of brownish yellow and reddish brown. A few lime concretions and occasional water-worn pebbles that are partly coated with lime are present.	Poor	Moderate slope.	36
51	Acadia clay	Spindletop, Tex.	The area is a transition from Acadia clay to prairie of Lake Charles clay. The test site is in the two soil types. The 20 feet of south end of trench is Lake Charles clay. Acadia clay, prairie phase. 0–12 very dark gray (almost black) heavy acid clay spotted with yellowish brown. 12–30 dense gummy dark-acid clay with yellowish brown and rust brown spots and splotches. 30–60+ gray dense clay with yellow and yellowish brown spots. Large amount of fine soft crystals of gypsum, neutral in reaction. Lake Charles clay. 0–24 black heavy clay. 24–40+ yellow heavy clay with some gray mottling and fine crystals of gypsum.	Very poor	Level	30
52	Lake Charles clay loam (mound phase).	League City, Tex.	0–12 dark gray silt loam. White incrustation of soluble salts on the surface. 12–20 gray silty clay loam mottled with yellowish brown, containing some black concretions. 20–30+ gray and yellow dense gummy mottled clay containing a few calcium carbonate concretions. Parent material of calcareous clay lies several feet beneath the surface.	do	do	30
53	Cecil clay loam	Atlanta, Ga.	Same as site 3.			
54	Fairmount silt loam	Cincinnati, Ohio	0–5 gray or light yellowish gray gritty, friable, silt loam stained or specked with light gray and rust brown. Moderate quantity of small calcareous shale chips present. 5–12 light gray or light brownish gray gritty, slightly compact friable silt loam containing a large amount of small chips of calcareous shale and limestone. 12–24 gray calcareous thin beds of shale partly weathered to clay stained light gray. 24–34 dark gray bedded calcareous shale containing small irregular pockets of gray, plastic, heavy clay or partly weathered shale.	Poor	Steep slope	30
55	Hagerstown loam	Loch Raven, Md.	Same as site 11.			
56	Lake Charles clay	El Vista, Tex.	0–12 black, noncalcareous, very heavy clay. 12–32 dark bluish, gray, noncalcareous, waxy clay. 32–48+ light gray waxy, noncalcareous, clay with some yellow spots.	Very poor	do	30
57	Merced clay adobe	Tranquillity, Calif.	Same as site 117.	Poor		
58	Muck	New Orleans, La.	Description not available. Soil very similar to site 29.	do		
59	Carlisle muck	Kalamazoo, Mich.	0–13 black or very dark gray granular, smooth, loamy, thoroughly decomposed organic material. Moderately acid. 13–30 dark gray fibrous, stringy, moderately compact plant remains partially decomposed and containing brown raw felty peat. Slightly acid. 30+ partly decomposed remains of swamp-loving plants displayed.	Very poor	do	20

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