STUDY OF CONDUCTOR STRENGTH CHANGES THROUGH TIME IN COMMON, ACIDIC, AND SALTY SOILS

Such as: Acadia Clay in Spindletop, Texas

Cecil Clay Loam in Atlanta, Georgia

Hagerstown Loam in Loch Raven, Maryland

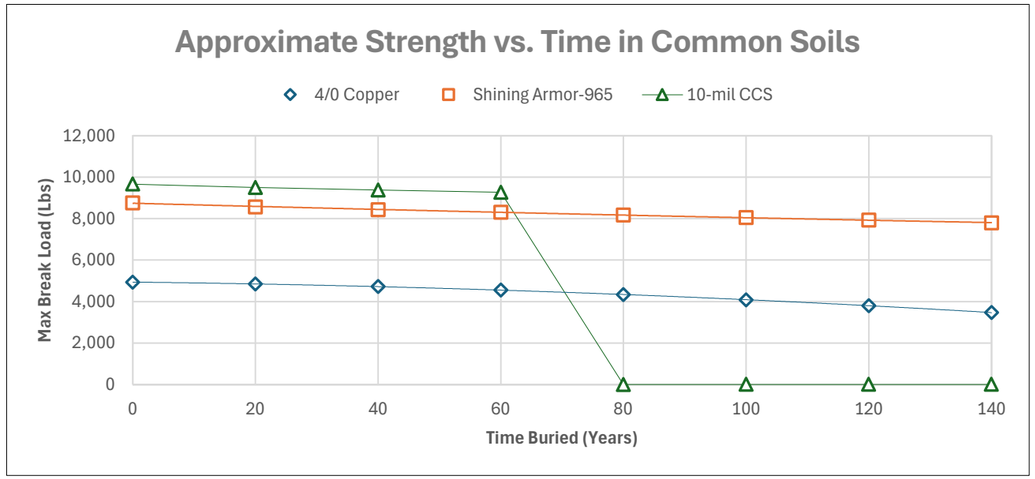
Lake Charles Clay in El Vista, Texas

Carlisle Muck in Kalamazoo, Michigan

Sharkey Clay in New Orleans, Lousianna

Susquehanna Clay in Meridian, Mississippi

Mohave Gravel Loam in Phoenix, Arizona



*3.)

YEAR	4/0 COPPER, TOUGH PITCH						Shining Armor-965™, OXYGEN FREE						10-mil CCS (Ground Rod, 19#9, etc.), OXYGEN FREE					
	WIRE SIZE (INCH)	CU THICK (INCH)	CABLE (INCH)	SECT AREA (IN2)	TENSILE (KSI)	MAX LOAD (LBS)	WIDTH (INCH)	THICKNESS (INCH)	CU THICK (INCH)	SECT AREA (FT2)	TENSILE (KSI)	MAX LOAD (LBS)	WIRE SIZE (INCH)	CU THICK (INCH)	CABLE (INCH)	SECT AREA (FT2)	TENSILE (KSI)	MAX LOAD (LBS)
						4/0 Copper						Shining Armor-965						10-mil CCS
0	0.1055	0.053	0.528	0.1661	33,000	4,933	2.500	0.0830	0.024	0.2075	42,226	8,762	0.1144	0.010	0.570	0.1953	55,000	9,667
20	0.1046	0.052	-	0.1634	33,000	4,853	2.499	0.0820	0.023	0.2049	41,807	8,565	0.1134	0.009	0.569	0.1918	55,000	9,496
40	0.1033	0.052	-	0.1591	33,000	4,726	2.498	0.0813	0.022	0.2031	41,528	8,435	0.1127	0.007	0.568	0.1895	55,000	9,382
60	0.1014	0.051	-	0.1533	33,000	4,553	2.498	0.0806	0.022	0.2014	41,249	8,306	0.1120	**0.005**	0.568	0.1873	55,000	9,269
80	0.0989	0.049	-	0.1461	33,000	4,339	2.497	0.0799	0.021	0.1996	40,971	8,178	0	0	0	0	0	0
100	0.0960	0.048	-	0.1375	33,000	4,085	2.496	0.0793	0.020	0.1979	40,692	8,051	0	0	0	0	0	0
120	0.0925	0.046	-	0.1278	33,000	3,795	2.496	0.0786	0.020	0.1961	40,414	7,925	0	0	0	0	0	0
140	0.0886	0.044	-	0.1170	33,000	3,476	2.495	0.0779	0.019	0.1944	40,135	7,800	0	0	0	0	0	0

* 2.)

* 1.) $SL_{STPC} = 0.00060 + 0.000026 * (\text{No. of Years} - 10)$ $SL_{SOFC} = 0.00068 + 0.000034 * (\text{No. of Years} - 10)$ $SL_{SOFC} = 0.00068 + 0.000034 * (\text{No. of Years} - 10)$

* NOTES:

1.) Corrosion rates for Standard Losses (SL) are established on XDWG-104, Sheets 3 and 4.

2.) When copper thickness drops to 0.006 inch, pitting results in rapid corrosion of the CCS steel core.

3.) After about 150 years of corrosion, a 4/0 conductor retains the approximate strength of a 2/0 conductor.

PATENT PENDING

CONFIDENTIAL AND PROPRIETARY INFORMATION OF EXETER GROUND, LLC.

EXETER GROUND, LLC

Title: APPROXIMATE STRENGTH VS TIME FOR BURIED CONDUCTORS IN COMMON SOILS

Drawn	JTJordan	Size	Drawing No.	Rev
Approved	JTJordan	B	XDWG-104	-
Date	10/25/2024			Sheet 1

STUDY OF CONDUCTOR STRENGTH CHANGES THROUGH TIME IN AGGRESSIVE SOILS WITH SULFIDES OR POOR AERATION

Such as: Muck in New Orleans, Louisianna

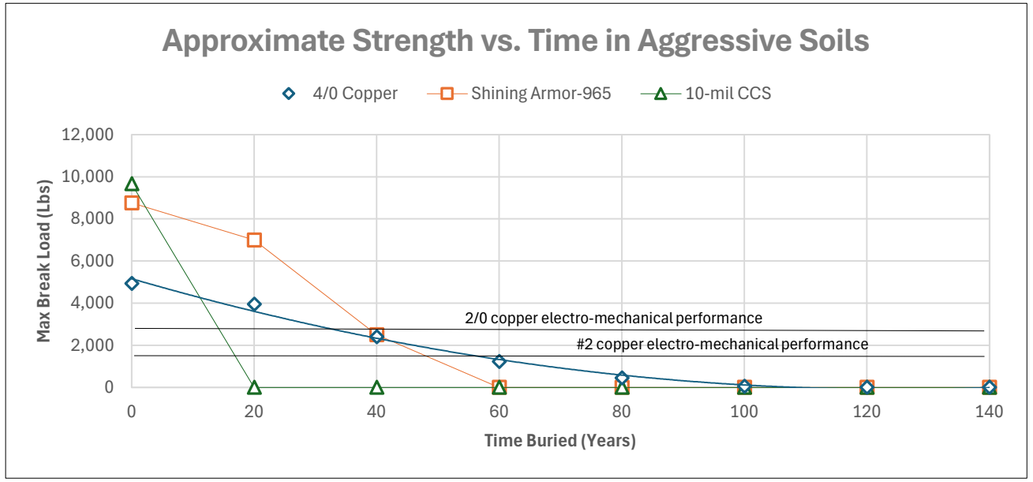
Chino Silt Loam on Wilmington, California

Rifle Peat in Plymouth, Ohio

Tidal Marsh in Charleston, South Carolina

Docas Clay in Cholame, California

Cinders in Milwaukee, Wisconsin



		4/0 COPPER, TOUGH PITCH						Shining Armor-965™, OXYGEN FREE						10-mil CCS (Ground Rod, 19#9, etc.), OXYGEN FREE					
		WIRE SIZE (INCH)	CU THICK (INCH)	CABLE (INCH)	SECT AREA (IN2)	TENSILE (KSI)	MAX LOAD (LBS)	WIDTH (INCH)	THICKNESS (INCH)	CU THICK (INCH)	SECT AREA (FT2)	TENSILE (KSI)	MAX LOAD (LBS)	WIRE SIZE (INCH)	CU THICK (INCH)	CABLE (INCH)	SECT AREA (FT2)	TENSILE (KSI)	MAX LOAD (LBS)
	YEAR						4/0 Copper						Shining Armor-965						10-mil CCS
	0	0.1055	0.053	0.528	0.1661	33,000	4,933	2.500	0.0830	0.024	0.2075	42,226	8,762	0.1144	0.010	0.570	0.1953	55,000	9,667
* 2.)	20	0.0943	0.047	-	0.1328	33,000	3,944	2.490	0.0734	0.014	0.1827	38,285	6,995	0.1048	**0.000**	0	0	0	0
* 3.)	40	0.0735	0.037	-	0.0807	33,001	**2,397**	2.472	0.0554	0	0.1369	18,234	**2,496**	0	0	0	0	0	0
	60	0.0527	0.026	-	0.0415	33,002	1,233	0	0	0	0	0	0	0	0	0	0	0	0
	80	0.0319	0.016	-	0.0152	33,003	452	0	0	0	0	0	0	0	0	0	0	0	0
	100	0.0111	0.006	-	0.0019	33,004	55	0	0	0	0	0	0	0	0	0	0	0	0
	120	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	140	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

* 1.) $AL_{STPC} = 0.00076 + 0.00104 * (\text{No. of Years} - 10)$ $AL_{SOFC} = 0.00063 + 0.00090 * (\text{No. of Years} - 10)$ $AL_{SOFC} = 0.00063 + 0.00090 * (\text{No. of Years} - 10)$

* NOTES:

1.) Corrosion rates for Aggressive Losses (AL) are established on XDWG-104, Sheets 3 and 4.

2.) When copper thickness drops below 0.006 inch, pitting results in rapid corrosion of the CCS steel core.

3.) At 40 years, both ARMOR-965 and 4/0 copper exhibit electro-mechanical performance below that of 2/0 copper.

PATENT PENDING

CONFIDENTIAL AND PROPRIETARY INFORMATION OF EXETER GROUND, LLC.

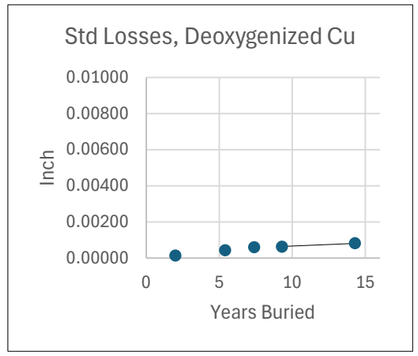
EXETER GROUND, LLC

Title: APPROXIMATE STRENGTH VS TIME FOR BURIED CONDUCTORS IN AGGRESSIVE SOILS

Drawn	JTJordan	Size	Drawing No.	Rev
Approved	JTJordan	B	XDWG-104	-
Date	10/25/2024			Sheet 2

OXYGEN FREE COPPER

IN COMMON SOILS



STANDARD CORROSION DEOXIDIZED COPPER

TIME (YEARS)	LOSS (INCH)	LONG TERM RATE (INCH/YEAR)
2.0	0.00015	
5.4	0.00044	
7.4	0.00062	
9.3	0.00064	
14.3	0.00081	**0.000034** (yrs 9 to 14)

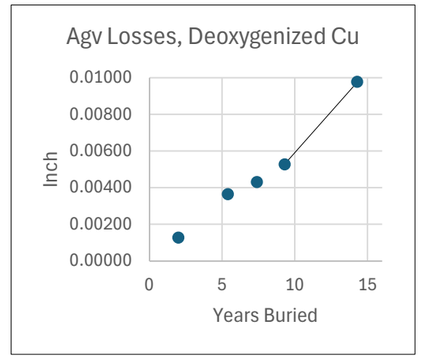
Interpolation for losses at 10 years

10.0 **0.00068**

STANDARD Losses at the Surface of Oxygen Free Copper, L_{SOFC} (inches)

SL_{SOFC} = 0.00068 + 0.000034 * (No. of Years - 10)

IN AGGRESSIVE SOILS



AGGRESSIVE CORROSION DEOXIDIZED COPPER

TIME (YEARS)	LOSS (INCH)	LONG TERM RATE (INCH/YEAR)
2.0	0.00129	
5.4	0.00365	
7.4	0.00432	
9.3	0.00529	
14.3	0.00977	**0.000896** (yrs 9 to 14)

Interpolation for losses at 10 years

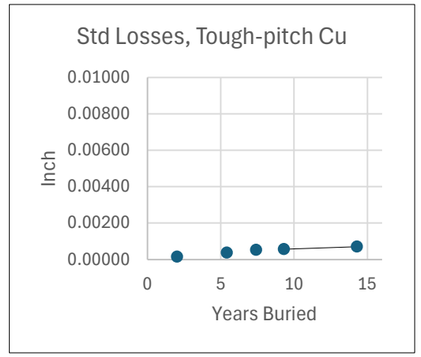
10.0 **0.00625**

AGGRESSIVE Losses at the Surface of Oxygen Free Copper, L_{SOFC} (inches)

AL_{SOFC} = 0.0063 + 0.00090 * (No. of Years - 10)

ELECTROLYTIC TOUGH PITCH COPPER

IN COMMON SOILS



STANDARD CORROSION TOUGH-PITCH COPPER

TIME (YEARS)	LOSS (INCH)	LONG TERM RATE (INCH/YEAR)
2.0	0.00017	
5.4	0.00039	
7.4	0.00054	
9.3	0.00057	
14.3	0.00070	**0.000026** (yrs 9 to 14)

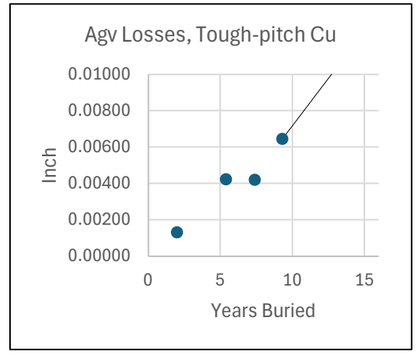
Interpolation for losses at 10 years

10.0 **0.00060**

STANDARD Losses at the Surface of Tough-Pitch Copper, SL_{STPC} (inches)

SL_{STPC} = 0.0006 + 0.000026 * (No. of Years - 10)

IN AGGRESSIVE SOILS



AGGRESSIVE CORROSION TOUGH-PITCH COPPER

TIME (YEARS)	LOSS (INCH)	LONG TERM RATE (INCH/YEAR)
2.0	0.00131	
5.4	0.00423	
7.4	0.00419	
9.3	0.00645	
14.3	0.01164	**0.001039** (yrs 9 to 14)

Interpolation for losses at 10 years

10.0 **0.00756**

AGGRESSIVE Losses at the Surface of Tough-Pitch Copper, L_{STPC} (inches)

AL_{STPC} = 0.0076 + 0.00104 * (No. of Years - 10)

* NOTE:

1.) These graphs match the average penetration curves (Figure 4) published by Denison and Romanoff in their original Research Paper (RP2077) in March 1950 entitled *"Soil-Corrosion Studies, 1946 and 1948: Copper Alloys, Lead, and Zinc"* that was assumed into NBS book *"Underground Corrosion"* (Circular 579) in 1957. Equations are the interpretation of Exeter Ground and not provided by the original study.

EXETER GROUND, LLC

Title: CORROSION RATES BASED ON LOSS OF WEIGHT IGNORING DEPTH AND PENETATION OF PITTING

Drawn	JTJordan	Size	Drawing No.	Rev
Approved	JTJordan	B	XDWG-104	-
Date	10/25/2024			Sheet 3

Underground Corrosion, US Department of Commerce, National Bureau of Standards Circular 579 (April 1957)

Excerpt from Table 49, p.83

LOSS IN WEIGHT OF COPPER BURIED IN 1932															
Material	Average Exposure (Years)	**Standard Corrosion in Common and Acidic Soils**								**Aggressive Corrosion in Soils with Sulfides, Poor Aeration**					
		Acadia Clay Spindletop TX	Cecil Clay Loam Atlanta GA	Hagerstown Loam Loch Raven MD	Lake Charles Clay El Vista TX	Carliske Muck Kalamazoo MI	Sharkey Clay New Orleans LA	Susque-hanna Clay Meridian MS	Mohave Fine Gravel Loam Phoenix AZ	Muck New Orleans LA	Chino Silt Loam Wilmington CA	Rifle Peat Plymouth OH	Tidal Marsh Charleston SC	Docas Clay Cholame CA	Cinders Milwaukee WI
LOSS IN WEIGHT (OUNCES PER SQUARE FOOT)															
Deoxidized	2.0	0.40	**0.12**	0.14	**0.10**	-	**0.06**	**0.16**	0.28	**0.16**	1.71	**1.47**	**1.13**	1.41	3.98
Copper	5.4	1.01	**0.15**	0.14	**0.51**	0.12	**0.35**	**0.26**	0.75	**1.56**	1.02	**3.82**	**2.45**	2.22	9.33
	7.4	0.40	**0.20**	0.15	**0.80**	0.11	**0.38**	**0.38**	1.32	**1.72**	2.37	**1.10**	**4.45**	3.00	4.89
	9.3	-	**0.22**	0.18	**0.78**	0.11	**0.35**	**0.48**	0.62	**2.10**	0.24	**5.01**	**4.22**	5.32	11.50
	14.3	0.60	**0.24**	0.16	**0.89**	0.21	**0.66**	**0.52**	0.54	**2.39**	1.07	**11.97**	**6.57**	5.17	13.77
Tough-pitch	2.0	0.42	**0.12**	0.14	**0.12**	-	**0.09**	**0.15**	0.11	**0.13**	0.50	**1.37**	**1.31**	0.67	3.15
Copper	5.4	0.91	**0.16**	0.19	**0.34**	0.13	**0.34**	**0.26**	0.16	**1.40**	0.47	**4.68**	**2.99**	0.96	8.04
	7.4	0.35	**0.23**	0.17	**0.60**	0.09	**0.37**	**0.33**	0.32	**1.66**	0.55	**1.03**	**4.33**	1.56	1.42
	9.3	-	**0.24**	0.20	**0.71**	0.12	**0.33**	**0.36**	0.45	**1.95**	0.26	**7.26**	**4.46**	2.80	9.84
	14.3	0.46	**0.23**	0.16	**0.61**	0.19	**0.58**	**0.49**	0.27	**1.98**	0.47	**14.66**	**8.31**	1.04	6.71
LOSS IN INCH AT SURFACE (EACH OUNCE PER SQUARE FOOT CORRESPONDS TO AVERAGE PENETRATION OF 0.0014 INCH)															
Deoxidized	2.0	0.0006	**0.0002**	0.0002	**0.0001**	-	**0.0001**	**0.0002**	0.0004	**0.0002**	0.0024	**0.0021**	**0.0016**	0.0020	0.0056
Copper	5.4	0.0014	**0.0002**	0.0002	**0.0007**	0.0002	**0.0005**	**0.0004**	0.0011	**0.0022**	0.0014	**0.0053**	**0.0034**	0.0031	0.0131
	7.4	-	**0.0003**	0.0002	**0.0011**	0.0002	**0.0005**	**0.0005**	0.0018	**0.0024**	-	**-**	**0.0062**	0.0042	-
	9.3	-	**0.0003**	0.0003	**0.0011**	0.0002	**0.0005**	**0.0007**	-	**0.0029**	-	**0.0070**	**0.0059**	0.0074	0.0161
	14.3	-	**0.0003**	-	**0.0012**	0.0003	**0.0009**	**0.0007**	-	**0.0033**	0.0015	**0.0168**	**0.0092**	-	0.0193
Tough-pitch	2.0	0.0006	**0.0002**	0.0002	**0.0002**	-	**0.0001**	**0.0002**	0.0002	**0.0002**	0.0007	**0.0019**	**0.0018**	0.0009	0.0044
Copper	5.4	0.0013	**0.0002**	0.0003	**0.0005**	0.0002	**0.0005**	**0.0004**	0.0002	**0.0020**	0.0007	**0.0066**	**0.0042**	0.0013	0.0113
	7.4	-	**0.0003**	-	**0.0008**	-	**0.0005**	**0.0005**	0.0004	**0.0023**	0.0008	**-**	**0.0061**	0.0022	-
	9.3	-	**0.0003**	0.0003	**0.0010**	0.0002	**0.0005**	**0.0005**	0.0006	**0.0027**	-	**0.0102**	**-**	0.0039	0.0138
	14.3	-	**0.0003**	-	**0.0010**	0.0003	**0.0008**	**0.0007**	-	**0.0028**	-	**0.0205**	**0.0116**	-	-

* NOTE:

1.) Study published in the comprehensive book *"Underground Corrosion"* published by the U.S. National Bureau of Standards in 1957 including burial of 186 copper pipe specimens in 47 test sites. The exposed area of most of the speciments was approximately 0.4 ft2. The study distinguished between weight loss due to corrosion and pitting. The more complete data sets are highlighted in bold.

EXETER GROUND, LLC

Title: OFFICIAL LOSS OF WEIGHT DATA FOR BURIED COPPER

Drawn JTJordan | Approved JTJordan | Date 10/25/2024

Size B | Drawing No. XDWG-104 | Rev - | Sheet 4