SECTION 3

TABLES

Table 3-1. Range of current density requirements for cathodic protection of uncoated steel.

Environment	Current density (mA/sq ft of bare steel) APM 88-9[a]	Gerrard[b]	Others[c]
Neutral soil	0.4 to 1.5	0.4 to 1.5	0.5 to 1.5
Well—aerated neutral soil	2 to 3	2 to 3	1.5 to 3
Wet soil	1 to 6	2.5 to 6	1 to 3
Highly acidic soil	3 to 15	5 to 15	3 to 15
Soil-supporting active sulfate-reducing bacteria	6 to 42	Up to 42	----------
Heated soil	3 to 25	5 to 25	3 or more
Stationary freshwater	1 to 6	Up to 5	1.5 to 3
Moving freshwater	----------	--------	3 to 8
Moving freshwater containing dissolved oxygen	5 to 15	5 to 15	----------
Seawater (depending on velocity, temperature & oxygen content	3 to 10	5 to 25	5 to 50

[a]*Corrosion Control*, Air Force Manual (AFM) 88—9 (Headquarters, U.S. Air Force, August, 1962), ch. 4, p. 203.
[b]J.S. Gerrard, "Practical Applications of Cathodic Protection," *Corrosion,* (Newnes-Butterworths, London, 1976), vol. 2, p 11:65. Used with permission.
[c]Data based on the experience of other Professional Cathodic Protection engineers.

Table 3—2. Typical Surface Area Per Linear Foot of Common Size Pipe.

Nominal Pipe Size	Outside Diameter (in.)	Sq Ft/Lin Ft
½	0.840	0.220
3/4	1.050	0.275
1	1.315	0.344
1 1/4	1.660	0.434
1 ½	1.900	0.497
2	2.375	0.621
2 ½	2.875	0.752
3	3.500	0.916
3 ½	4.000	1.047
4	4.500	1.178
5	5.563	1.456
6	6.625	1.734
8	8.625	2.258
10	10.750	2.814
12	12.750	3.338
14	14.000	3.665
16	16.000	4.189
18	18.000	4.712
20	20.000	5.236
22	22.000	5.760
24	24.000	6.283

NOTE: Data on anodes shapes and sizes as well as recommended operating limits were obtained from the following manufacturers:

APS—Materials Inc.
153 Walbrook
Dayton, OH 45405
(513) 278—6547
FAX: (513) 278—4352

Oronzio De Nora S.A.
P.O. Box 3387
Houston, TX 77253—3387
(713) 978—3925
FAX: (713) 978—3930

Materials Protection Company
P.O. Box 31354
Houston, TX 77231—1354
(713) 270—0952
FAX: (713) 988—0673

As their specifications change from time to time, it is recommended that the designer contact the companies prior to specifying a particular anode to determine what is currently available.

Table 3–3. Dimensions and ratings of ceramic anodes.
Underground Usage

Wire and Rod Anodes (Packaged)

Anode Element Dimension	Package Size	Weight	Current Rating - Amperes				
			10-Year Design Life	15-Year Design Life		20-Year Design Life	
			HDC*	HDC*	SC**	HDC*	SC**
1/8" x 2'	2" x 30"	6 lbs.	1.3 amps	1.10 amps	0.6 amps	0.9 amps	0.5 amps
1/16" x 5'	2" x 72"	14 lbs.	1.5 amps	1.25 amps	0.7 amps	1.0 amps	0.6 amps
1/16" x 5'	3" x 72"	26 lbs.	1.5 amps	1.25 amps	0.7 amps	1.0 amps	0.6 amps
1/8" x 4'	2" x 60"	12 lbs.	2.7 amps	2.2 amps	1.2 amps	1.8 amps	1.0 amps
1/8" x 4'	3" x 60"	22 lbs.	2.7 amps	2.2 amps	1.2 amps	1.8 amps	1.0 amps
1/4" x 4'	3" x 60"	22 lbs.	5.5 amps	4.4 amps	2.4 amps	3.5 amps	2.0 amps
1/8" x 6'	3" x 96"	35 lbs.	4.0 amps	3.3 amps	1.8 amps	2.7 amps	1.5 amps
3/8" x 4'	3" x 60"	22 lbs.	7.5 amps	6.0 amps	3.6 amps	5.1 amps	3.0 amps
½" x 4'	3" x 60"	23 lbs	10.0 amps	8.0 amps	4.8 amps	6.8 amps	4.0 amps
3/4" x 4'	3" x 60"	24 lbs	15.0 amps	12.0 amps	7.2 amps	10.0 amps	6.0 amps
1/8" x 6'	3" x 96"	35 lbs.	4.0 amps	3.3 amps	1.8 amps	2.7 amps	1.5 amps
1/4" x 6'	3" x 96"	35 lbs.	8.2 amps	6.6 amps	3.6 amps	5.3 amps	3.0 amps
1/8" x 8'	3" x 120"	44 lbs.	5.4 amps	4.4 amps	2.4 amps	3.6 amps	2.0 amps
1/4" x 8'	3" x 120"	44 lbs.	11.0 amps	8.8 amps	4.8 amps	7.0 amps	4.0 amps

*Heavy Duty Coating Tubular Anodes (in Coke Breeze)
**Standard Coating Tubular Anodes (in Coke Breeze)

Table 3-3. (Cont*d)

Anode Element Dimension	Current Rating - Amp 20-Year Design Life
1" x 9.8"	2.00 amp
1" x 19.7"	4.00 amp
1" x 39.4"	8.00 amp
0.63" x 9.8"	1.25 amp
0.63" x 19.7"	2.50 amp
0.63" x 39.4”	5.00 amp

Table 3—3 (Cont*d). Fresh and Seawater Usage

Wire and Rod Anodes (Bare)

Life (years)	Fresh Water	Brackish Water	Seawater
Maximum Current/1-ft Length for 20-Year Design Life of .0625 in. Dia. Wire			
10	0.39	0.51	0.85
15	0.31	0.44	0.74
20	0.26	0.39	0.67
Maximum Current/1-ft Length for 20—Year Design Life of .125 in. Dia. Rod or Wire			
10	0.79	1.02	1.70
15	0.62	0.88	1.47
20	0.52	0.79	1.33
Maximum Current/1-ft Length for 20—Year Design Life of .25 in. Dia. Rod			
10	1.58	2.04	3.41
15	1.24	1.76	2.95
20	1.04	1.58	2.66
Maximum Current/1-ft Length for 20-Year Design Life of .325 in. Dia. Rod			
10	2.37	3.06	5.11
15	1.85	2.63	4.42
20	1.56	2.37	3.99
Maximum Current/1—ft Length for 20-Year Design Life of .5 in. Dia. Rod			
10	3.16	4.08	6.81
15	2.47	3.51	5.90
20	2.08	3.16	5.33
Maximum Current/1-ft Length for 20—Year Design Life of .625 in. Dia. Rod			
10	3.95	5.10	8.52
15	3.09	4.39	7.37
20	2.60	3.95	6.66
Maximum Current Per 1-ft Length for 20—Year Design Life of .75 in. Dia. Rod			
10	4.74	6.12	10.22
15	3.71	5.27	8.85
20	3.12	4.74	7.99

Tubular Anodes (Bare)

Seawater — Current in amp per anode (15—Year Design Life)	
1 in. x 19.7 in.	25 amp
1 in. x 39.4 in.	50 amp
0.63 in. x 19.7 in.	15 amp
0.63 in. x 39.4 in.	30 amp
Sea Mud - Current in amp per anode (20-Year Design Life)	
1 in. x 19.7 in.	6 amp
1 in. x 39.4 in.	12 amp
Fresh Water — Current in amp per anode (20—Year Design Life)	
1 in. x 19.7 in.	4.00 amp
1 in. x 39.4 in.	8.00 amp
0.63 in. x 19.7 in.	2.50 amp
0.63 in. x 39.4 in.	5.00 amp

Current Density Limitations

Wire and Rod Anode
Anode Life Versus Maximum Current Density (ampere/sq ft)

Life (years)	Coke	Fresh Water	Brackish Water	Seawater
10	19	24	31	52
15	15	19	27	45
20	13	16	24	41

* Anode packaged in coke breeze

Tubular Anodes
Anode Life Versus Maximum Current Density (ampere/sq ft)

Life (years)	Coke	Fresh Water	Brackish Water	Seawater
20	9.3	9.3	9.3	56 **

*Anode packaged in coke breeze
**15-Year Design Life

Disc Anodes (see figure 2-28)

Size: 5—in, diameter (Typical — Other sizes available)
Active Area: 19 sq in.
Weight: 2.0 lb

	Fresh Water	Salt Water
Current Capacity - 20-year life (amp/anode)	0.84	5.0
Operating voltage - 20-year life (V)	20.0	10.0

Segmented Rod Anodes (see figure 2-2 9)

Size: 4—ft lenglth; 0.138 in. diameter
Active Area: 22 sq in.
Weight: 2.3 oz

	Fresh Water	Salt Water
Current Capacity - 20-year life (amp/anode)*	1.00	2.5
Operating voltage - 20-year life (V)	50.0	10.0

*Standard Coating

Table 3—4. Shape functions (K) for impressed current cathodic protection anodes where L is effective anode/backfill length and d is anode/backfill diameter.

L/d	K	L/d	K
5	0.0140	20	0.0213
6	0.0150	25	0.0224
7	0.0158	30	0.0234
8	0.0165	35	0.0242
9	0.0171	40	0.0249
10	0.0177	45	0.0255
12	0.0186	50	0.0261
14	0.0194	55	0.0266
16	0.0201	60	0.0270
18	0.0207		

Table 3-5. Anode paralleling factors (P) for various numbers of anodes (N) installed in parallel.

N	P	N	P
2	0.00261	14	0.00168
3	0.00289	16	0.00155
4	0.00283	18	0.00145
5	0.00268	20	0.00135
6	0.00252	22	0.00128
7	0.00237	24	0.00121
8	0.00224	26	0.00114
9	0.00212	28	0.00109
10	0.00201	30	0.00104
12	0.00182		

Table 3—6. Resistance and other parameters for stranded copper conductors.

Size ** AWG	Overall Diameter Not Incl. Insulation (in.)	Approximate Weight Not Incl. Insulation (lb/M ft)	Maximum Breaking Strength (lb)	Maximum DC Resistance at 20 °C (ohms/M ft)	Maximum Allowable DC Current Capacity (ampere)
14	0.0726	12.68	130	2.5800	15
12	0.0915	20.16	207	1.6200	20
10	0.1160	32.06	329	1.0200	30
8	0.1460	50.97	525	0.6400	45
6	0.1840	81.05	832	0.4030	65
4	0.2320	128.90	1320	0.2540	85
3	0.2600	162.50	1670	0.2010	100
2	0.2920	204.90	21.10	0.1590	115
1	0.3320	258.40	2660	0.1260	130
1/0	0.3730	325.80	3350	0.1000	150
2/0	0.4190	410.90	4230	0.0795	175
3/0	0.4700	518.10	5320	0.0631	200
4/0	0.5280	653.30	6453	0.0500	230
250 MCM	0.5750	771.90	7930	0.0423	255
EPR/HY-50*	0.3730(1)	75.0(1)	1896	0.1183	150
EPR/HY-16*	0.1840(2)	87.0(2)	628	0.3658	50

(1) With insulation: Overall diameter = 0.88 in.; weight — 610 lb/l000 ft.
(2) With insulation: Overall diameter = 0.51 in.; weight - 200 lb/1000 ft.
* Data from Dow Chemical
** Data from Rome Cable Company

Table 3—7. suggested number of anode rings for various size tanks.

Tank Diameter (ft)	Number of rings of anodes	
	Coated	Bare
24	1	1
30	1	1
36	1	1
42	1	1
48	1	2
54	1	2
60	2	2
66	2	2
72	2	2
78	2	3
84	2	3

Table 3—8. Recommended number of support points for loop anode systems.

Tank Diameter (ft)	Number of Support Points
24	6
30	6
36	6
42	6
48	6
54	8
60	8
66	8
72	10
78	10
84	10

Table 3-9. Adjusting factors for parallel anodes.

No. of Anodes in Parallel	Adjusting Factors — Anode Spacing in Feet 5 ft	10 ft	15 ft	20 ft	25 ft
2	0.652	0.576	0.551	0.538	0.530
3	0.586	0.460	0.418	0.397	0.384
4	0.520	0.385	0.340	0.318	0.304
5	0.466	0.333	0.289	0.267	0.253
6	0.423	0.295	0.252	0.231	0.218
7	0.387	0.265	0.224	0.204	0.192
8	0.361	0.243	0.204	0.184	0.172
9	0.332	0.222	0.185	0.166	0.155
10	0.311	0.205	0.170	0.153	0.142
11	0.292	0.192	0.158	0.141	0.131
12	0.276	0.180	0.143	0.132	0.122
13	0.262	0.169	0.139	0.123	0.114
14	0.249	0.160	0.131	0.116	0.107
15	0.238	0.152	0.124	0.109	0.101
16	0.226	0.144	0.117	0.103	0.095
17	0.218	0.138	0.112	0.099	0.091
18	0.209	0.132	0.107	0.094	0.086
19	0.202	0.127	0.102	0.090	0.082
20	0.194	0.122	0.098	0.086	0.079
22	0.182	0.114	0.091	0.079	0.073
24	0.171	0.106	0.085	0.074	0.067
26	0.161	0.100	0.079	0.069	0.063
28	0.152	0.094	0.075	0.065	0.059
30	0.145	0.089	0.070	0.061	0.056

Table 3—10. Cathodic Protection System Recommended Allowable Circuit Resistance

System Current (I) (amp)	Resistance (RT) in ohm Maximum	Typical
5	10	5
10	6	3
20	3	2
30	2	1.3
40	1.5	1.0
60	1.0	0.6
80	0.75	0.4