ANOTEC Industries Ltd

5701 Production Way, Langley, BC V3A 4N5 Canada   web site: www.anotec.com   email: info@anotec.com

Technical Bulletin 95-13

NOMINAL GUIDE FOR ANOTEC ANODES

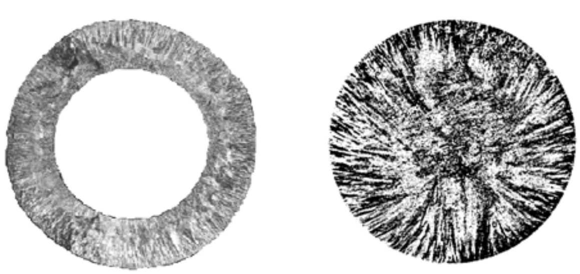
ANOTEC ANODE TYPE	Nominal Weight	NOMINAL DISCHARGE amps per unit area		Nominal Diameter	Nominal Length	Nominal Area
		per square ft. 0.75 - 1.0 (Note 1)	per M^2 8.1 - 11 (Note 1)			
STICK	**lbs (kgs)**	**AMPS -**	**AMPS**	**inch (mm)**	**inch (mm)**	**sq. ft. (M^2)**
SHA, EHA	44 (20)	2.0 -	2.6	2 (50)	60 (1520)	2.6 (.24)
EHM	60 (27)	2.0 -	2.7	2 (50)	60 (1520)	2.7 (.25)
EHK, EMK	26 (12)	1.5 -	2.0	1.5 (38)	60 (1520)	2.0 (.19)
EHR	110 (50)	3.0 -	6.0	3 (76)	60 (1520)	4.0 (.37)
TUBULAR	**lbs (kgs)**	**AMPS -**	**AMPS**	**inch (mm)**	**inch (mm)**	**sq. ft. (M^2)**
2260	36 (16)	2.3 -	2.7	2.2 (56)	60 (1520)	3.0 (.28)
2284	48 (22)	3.2 -	3.8	2.2 (56)	84 (2130)	4.2 (.39)
2660	50 (23)	2.6 -	3.5	2.6 (66)	60 (1520)	3.5 (.33)
2684	69 (31)	3.7 -	5.0	2.6 (66)	84 (2130)	4.9 (.46)
3860	75 (34)	3.8 -	5.0	3.8 (97)	60 (1520)	5.0 (.47)
3884	94 (43)	5.3 -	7.0	3.8 (97)	84 (2130)	7.0 (.65)
4860 L	93 (42)	4.7 -	6.3	4.8 (122)	60 (1520)	6.3 (.58)
4884 L	128 (58)	6.6 -	8.8	4.8 (122)	84 (2130)	8.8 (.82)
4860 H	126 (57)	4.7 -	7.1	4.8 (122)	60 (1520)	6.3 (.58)
4884 H	177 (80)	6.6 -	10	4.8 (122)	84 (2130)	8.8 (.82)
4860 X	164 (75)	4.7 -	7.1	4.8 (122)	60 (1520)	6.3 (.58)
4884 X	230 (104)	6.6 -	10	4.8 (122)	84 (2130)	8.8 (.82)
4884 XX	315 (143)	6.6 -	10	4.8 (122)	84 (2130)	8.8 (.82)

Note (1) Maximum amperage based on maximum value in manufacturer publications, 15 year minimum life criterion [0.7lb/ampyr (0.31 kg/ampyr) at 80% utilization], or 1 amp/square foot (10.8 amp/M^2)

Warning: Reduce current density in clay beds with high osmotic drying potential. Refer to **Anode Consumption and Current Density Limitations** in this Bulletin.

Reference: NACE Technical Committee Report "Impressed Current Anodes for Underground Cathodic Protection Systems" [10A196}.

CHILL CAST MAKES A DIFFERENCE



The difference between Chill Cast and Sand Cast can be clearly seen. Pages 2 and 3 of this Bulletin explain why Chill Cast is better.

Typical ANOTEC Anode Cross Sections

Typical Cross Section of a Sand Cast Anode

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Effect of Microstructure on the Corrosion Resistance and Mechanical Properties of High Silicon Cast Iron

R.S. Charlton, P.Eng., B.H. Levelton & Associates, Richmond, BC Canada

Introduction

As for most, if not all alloys, the corrosion resistance and mechanical properties of high silicon cast iron is affected by a number of metallurgical and microstructural factors. For high silicon cast iron these factors include:

- Shape or form of graphite
- Segregation
- Presence of secondary phases such as brittle silicides and inter-dendritic carbides
- Grain size

The following sections discuss these factors as they relate to the corrosion resistance and mechanical properties of chill cast and sand cast high silicon cast iron anodes.

Corrosion Resistance

The corrosion resistance of high silicon cast iron is attributed to the development of a thin passive barrier film of hydrated oxides of silicon on the metal surface. This film develops with time due to the dissolution of iron from the metal matrix leaving behind silicon which hydrates due to the presence of moisture. Any flaws in the barrier film will reduce its effectiveness.

The passive hydrated silicon film will bridge over and form an impervious barrier layer on a fine grained high silicon cast iron with spheroidal graphite areas much more readily than on a high silicon cast iron with coarse graphite flakes. Thus, a coarse grained high silicon cast iron that contains graphite flakes is much more likely to have structural defects/flaws in the passive film than a fine grained material with spheroidal graphite.

It is well documented that a uniform metallurgical structure normally has better corrosion resistance than a non-uniform structure. Segregation (non-uniform composition) will produce a non-uniform passive film due to varying silicon content (segregation) and the presence of second phases. In addition these can also result in localized anodic and cathodic areas on the metal surface which will result in increased localized corrosion due to the galvanic action.

Flaws in the passive film are sites for film breakdown. Penetration of the corrosive medium below the film results in localized areas of corrosion and preferential current flow due to lower resistance at graphite flakes etc. than on the hydrated silicon film.

Thus, due to the fine grain size with spheroidal graphite and more uniform composition, chill cast high silicon cast iron would be expected to have better corrosion resistance than a sand cast high silicon cast iron.

Mechanical Properties

The shape of the graphite present in an alloy affects the mechanical properties of the material. Flake graphite acts as a severe stress raiser while the spheroidal graphite does not. A classic example of this effect is the difference between grey cast iron and ductile iron.

Fine grained materials normally have higher strength and are more ductile than similar coarse grained materials. In addition, the lack of segregation and/or second phases also contributes to higher strength and ductility of materials since there are fewer areas for localized yielding and stress raisers.

Thus, a fine grained silicon cast iron with spheroidal graphite should have better mechanical properties than a high silicon cast iron with flake graphite. There are numerous references that show that this is in fact the case, although it is still a brittle material.

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Relative Rate of Consumption

In order to compare the performance of "Chill Cast" High Silicon Iron anodes to the "Sand Cast" variety, Anotec ran a series of accelerated corrosion tests in accordance with Jakobs & Hewes procedure published in Materials Performance. In the first (January 1988) tests, results indicated a significant improvement in performance for Chill Cast compared to Sand Cast, especially in sulphate environments. To confirm reproducibility and to add technical and statistical credence a second series of tests were run and reported in October 1989. Results of the tests are summarized as follows:

Test: 2" diameter Specimens of each of Chill Cast and Sand Cast anodes of 0.11 sqM (1.2 sqft) surface area, tested at either 2.5Amps/sqft or 8.3Amps/sqft.

Results: With a statistical confidence of 99% (ASTM GI 6-17) taken from Test Report October 1989:

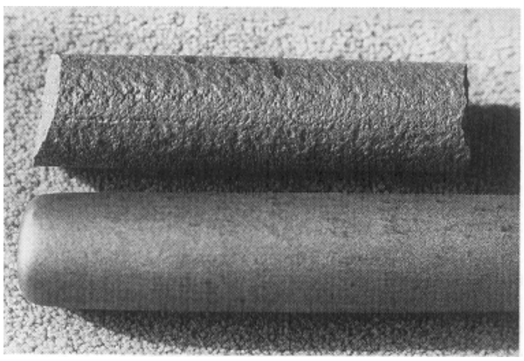

FIGURE 1

	Consumption in grams		DIFFERENCE
	SAND CAST	CHILL CAST	
Chloride solution	403	345	17%
Sulphate Solution	458	385	19%

Typical as-found surfaces of Chill cast (smooth) and Sand Cast (severe pitting) are clearly contrasted in Figure 1. The complete report is available from Anotec.

Relative Impact Strength

In order to compare the impact strength of "Chill Cast" High Silicon Cast Iron anodes to the "Sand Cast" variety, B.H. Levelton & Associates proposed a straightforward test which has been used by Anotec since 1988 to test hundreds of chill cast anodes, and some sand cast anodes from other manufacturers. The test anode is centered in a steel frame, and the end is raised as shown in Figure 2. The anode is then dropped to impact against a fixed steel anvil. Sand Cast anodes break at 2" to 4" drop. All Chill Cast anodes exceed 6"; the majority exceed 10"; and many remain unbroken at successive drops up to 13". Chill Cast strength is supported by field "survival" anecdotes.

A typical comparative test result for 2" stick anodes is:

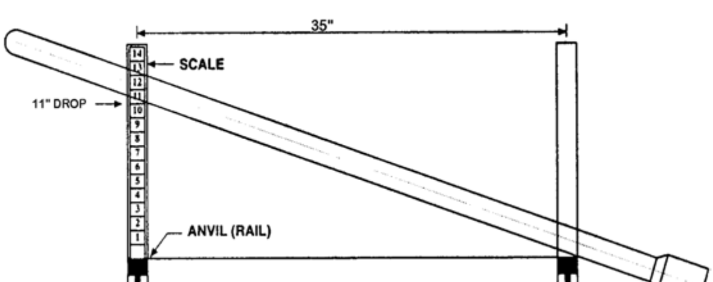

Figure 2

<table>
<tr><th colspan="4">SUCCESIVE DROP HEIGHTS</th><th>SAND CAST</th><th>CHILL CAST</th></tr>
<tr><td colspan="4">2"/25mm</td><td>OK</td><td>OK</td></tr>
<tr><td colspan="4">4"/50mm</td><td>FAILURE</td><td>OK</td></tr>
<tr><td>6"
150mm</td><td>7"
175mm</td><td>8"
200mm</td><td>9"
225mm</td><td></td><td>OK</td></tr>
<tr><td colspan="4">10"/250mm</td><td></td><td>FAILURE</td></tr>
</table>

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Anode Consumption

The consumption rate of High Silicon Cast Iron anodes has been found to be between 0.2 and 1.2 pounds per ampere year. For anodes of the same chemistry and microstructure, variance in consumption is primarily due to the chemical and physical characteristics of the anode environment. The consumption rate does not appear to be significantly affected by current density (amperes per unit area of anode surface). The use of coke breeze around the anode in soil ground beds will tend to lower the consumption rate. A generally accepted design guideline for anodes buried in coke breeze is 0.7 pounds per amp year.

Current Density Limitations

The maximum stable current density of discharge may be limited by the environment regardless of the anode type. In free flowing water or in very wet soil ground beds, there is very little restriction on current density. However, anodes buried in clay soils tend to suffer "electro osmotic drying", a phenomenon of magnitude directly proportional to current density. For any particular soil with electro osmotic characteristics there will tend to be a critical maximum current density at the anode soil (or coke breeze to soil) interface, above which progressive drying occurs, with corresponding increases in anode-soil resistance. Drying is usually reversible by increasing soil moisture and/or lowering current density.

As a guideline to minimization of electro osmotic drying in groundbeds installed in clay soils, use of the following design maxima has resulted in stability of 90 to 95 percent of beds in areas of high osmotic drying potential.

Average Soil Resistivity Along Ground Bed Ohm-Cm	Maximum Amps Per Anode in a Coke Breeze Column 12" OD by 60" Long	Equivalent Current Density on Surface of Coke Breeze Column Milli Amps/Sq. Foot
less than 1000	.001	127 (See Note)
1000 - 1500	.751	111 (See Note)
1500 - 2000	.501	96
2000 - 3000	.251	80
over 3000	.00	64

Note: For greater success, limit current density to less than 100mA/sq ft for soils of less than 1500 ohm cm resistivity.