Dr. ANM,
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THE 111th ASIAN-PACIFIC CORROSION CONTROL CONFERENCE
ORGANIZING COMMITTEE
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Date: 5 June 1999

To: **Dr**. S.K. NARANG
Deputy Director & Head
Corrosion Protection Division
India

Dear Dr. S.K.Narang

Re: *Cathodic* ***Protection – Introduction and Recent Developments***

On behalf of the Organizing Committee, I would like to thank you for your contribution. Your abstract was accepted for oral presentation.
We attach herewith the Second Circular and Guideline for full paper. Please send your full paper not later than 31 July 1997. Papers submitted in time will be published in the main Proceedings of the Conference, and late in Supplement.
Many thanks for your participation in the 11th APCCC. We look forward to receiving your paper and welcoming you to Vietnam.

Yours sincerely

NGUYEN NHI TRU
Executive Secretary

CATHODIC PROTECTION -INTRODUCTION AND RECENT DEVELOPMENTS

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ABSTRACT

Corrosion of metals and alloys, on which the modern world depends completely, from electronic components to printed circuit boards, from nuts and bolts to bridges, from automobiles to railway parts to boiler tubes and nuclear reactors, is a practical problem of tremendous technological significance. Corrosion leads to colossal financial losses, which are estimated to be 3-4% of GNP of a nation, not to speak of the loss of human lives, reputation, environment, aesthetics as well as shut-down and production losses. Of the various preventive measures like alloying, corrosion inhibitors, protective coatings, paints, design etc. to combat corrosion, only cathodic protection can guarantee 100% protection, if properly designed, executed and supplemented by protective coatings. The ABC of corrosion, principle of cathodic protection, with special reference to the development of aluminium based sacrificial anodes like SUPERAL (medium output) and HOPAL (high output) as also insoluble anode like Sintered Magnetite Anode (SMA) in the National Metallurgical Laboratory in India, have been included in the paper. While the technology for the sacrificial Al-based anodes has been transferred to two parties in India, SMA developed by NML is found to be the best because of its unique properties and low cost, compared to the conventionally used insoluble anodes. A cathodic protection system has also been designed and developed by NML with SMA, which is auto-controlled and very economical. AML has also successfully designed and executed the cathodic protection of the old water main lines (made from bare steel) in Calcutta, using Al-based sacrificial anodes. Merits and demerits of galvanic system compared to impressed current system and major research institutes engaged in corrosion area are listed Pertinent references have been cited for access to the original and detailed literature.

INTRODUCTION

All metallic structures e.g. bridges, underground pipes, water storage tanks, ships and hulls, power plants, industrial plants. Offshore structures and welded structures, are attacked by **Corrosion** under different environmental conditions in service. Corrosion is a global problem of tremendous technological significance and leads to colossal financial losses, which are estimated to be 3-4% of Gross National Product of a nation, besides the loss of human lives, reputation, environment, aesthetics as well as shut-down and production **losses**. In India, in a recent year, this loss is reported to be Rs.40x109 ($ 8.9x 108) [1]. It is believed that a definite 25 to 30% of the corrosion losses can be prevented by the proper application of already known methods and another 20% by implementing special measures [2]. Of the various preventive measures like alloying, corrosion inhibitors, protective coatings, paints, design etc., only *cathodic protection* can guarantee 100% protection, if designed and operated correctly and supplemented by protective coatings. Cathodic protection(CP) is a long established and proven electrochemical method for protecting metals and alloys, especially steel, that are exposed to all types of soils and aqueous media. Besides, stress corrosion

cracking of brass, stainless steels, steels, aluminium and magnesium alloys, dezincification of brass, pitting etc. can be effectively checked by Cathodic Protection. Comprehensive research and development work at the National Metallurgical Laboratory, Jamshedpur, India has led to the development of aluminium based sacrificial anodes, sintered magnetite insoluble anodes and also an auto controlled cathodic protection system using these anodes suitable for cathodic protection of ship hulls, harbour installations, offshore drilling and processing platforms, underground pipelines, heat exchanger components, liquid storage tanks and also for protection of reinforcing steel bars in concretel3]. The present paper is an attempt to introduce and focus the importance of cathodic protection with special reference to the work done at NML.

ABC of CORROSION & CATHODIC PROTECTION

The basic principle behind any corrosion or even deposition processes is that they are all *electrochemical.* All these processes take place in an electrochemical cell , i.e. the corrosion involves the *transfer of electrons.* Any such cell is composed of three parts-A, B and C [4], where

A is ANODE
B is BREW or ELECTROLYTE
C is CATHODE

While all the electrodeposition(or reduction) takes place at the cathode, the anodic reactions(oxidation) are metal dissolution, oxygen evolution and oxidative reactions like conversion of ferrous to ferric ions. For corrosion to occur, the formation of an electrochemical cell and presence of all the three connected together are essential. Also corrosion can occur only at the anode(where current leaves the metal surface and enters the electrolyte) and so if direct current is supplied to the metal or metallic structure through an external anode so that it acquires a negative potential (cathode), it will be protected. Cathodic protection is thus an electrochemical process of mitigating corrosion of structures that are exposed to electrolytes such as soil, fresh water and sea water. In this method, the required corrosion control is achieved by forcing proper amount of direct current to flow from auxiliary anodes through the electrolyte onto the structure to be protected, such that the structure **is maintained** at an optimum range of negative potential. Thus cathodic protection does not require access to the structure except at a few points (for current drainage and potential measurement) and the structure can be maintained easily. Although the principle of cathodic protection is simple, its effective application in practice needs serious consideration of the different parameters involved. The successful application of CP to a structure requires proper selection of the system-either galvanic anode or impressed current system, proper coating and design to suit the conditions and the use of necessary monitoring and control system. There are two basic methods of applying cathodic protection, either by galvanic e.g. the use of zinc, magnesium, aluminium, manganese or their alloys as sacrificial anodes) or by impressed current from an external source e.g. a D.C. rectifier, battery or photo-voltaic solar cells.

MERITS AND DEMERITS OF THE TWO SYSTEMS

Galvanic system is advantageous where electricity is not available, and the system does not affect the neighbouring structures. Maintenance in this is comparatively easy, but it is not economical for large structures and not suitable for high resistance soil. Also life of the anodes is less and so frequent replacements become necessary[5,6].

Of the two systems, the use and design of impressed current systems are much more flexible than galvanic anode system. Impressed current systems are used for CP when current requirements are high, and long life protection is desirable and they are suitable for high resistance soils where galvanic systems cannot be used. These are cheap where electric current is high and is readily available. In this, anode requirement is less and renewal of anode is comparatively less. Insoluble anodes used in the impressed systems can also be used as lightning arrester when necessary. However, there may be interference effect to the neighbouring structures and regular control and maintenance of the current are essential[5-8].

Development of Aluminium base SUPERAL and HOPAL Anodes

Although NML has developed both soluble and insoluble anodes for cathodic protection, the technology for the sacrificial anodes base on aluminium has been transferred to two parties in India. SUPERAL [9] a medium output aluminium alloy has been developed for protection of ship hull, harbour installation and underground pipelines whereas HOPAL [10] a high output aluminium alloy has been tailor made for the protection of off-shore drilling and processing platform where high efficiency and long life are desirable. The HOPAL anode has an electrode potential of -1.2 V SCE in 3% NaCl solution and anode life of 3.0 Kgm per ampere year with an efficiency of 96% at ambient temperature and has been able to substitute the imported anodes used to protect oil platforms at Bombay High. Cost of aluminium alloy anodes for 100% current efficiency is the least (about 1/3) compared to Mg and Zn alloys. It has been observed that HOPAL anode of 1 square centimetre could give complete protection to steel cathode of 300 sq. cm and potential remained at 1100 mV SCE while most of the galvanic anodes can provide protection to steel surface of 30-40 times larger than its own surface [11].The alloy is easily workable and can be rolled down or drawn in the form of strip or wire for special use in small sectional areas where housing of normal size anodes is difficult. NML has also successfully designed and executed the cathodic protection of the old water main lines (made from bare steel) in Calcutta, using sacrificial soluble anodes[12]. Design of HOPAL anode for a typical offshore structure in Indian conditions [11] and backfill have been outlined[5].

Development of Sintered Magnetite Anode and C.P. **System**

Sintered Magnetite Anodes suitable for impressed current cathodic protection have been developed in NML and conditions optimised for getting the best anodes from standard raw material (yellow pigment iron oxide as per IS grade). Typical properties [13]of the sintered magnetite anode were:

(a)	Current carrying capacity	:	1000A/sq. meter
(b)	Dissolution Rate	:	10x105 kgm/A.Y
(c)	Bulk Density	:	4.790 gms/cc
(d)	Porosity		8%
(e)	Resistivity		0.3- 1.0 ohm.cm
(f)	Resistance to Corrosion	:	Excellent
(g	Brittleness	:	Not so brittle as Cast
			magnetite or cast high
			silicon -iron alloy

Further, it was observed **that the anode contained** 97% of **magnetite and had saturation magnetization** of 90**.0 emu**/**g compared to the standard** value of 92.0 for 100% **magnetite. It**

may be noted that the cost of cast magnetite is higher to Sintered Magnetite Anode and the consumption of cast magnetite anode(WIMCO) at 300 A/m2 was 800x 10-5 kgms/Ampere Year compared to that of SMA 10x10-5 kgms/Ampere Year as stated above. A process for the preparation of Sintered Magnetite Anode for Cathodic Protection as well as an Improved Device useful for Cathodic Proection of Steel Structures using Sintered Magnetite Insoluble Anode have been patented [14-15]. The cathodic protection system designed and developed by NML is autocontrolled and very economical.

Major Research Institutes in India for Corrosion

In India, most of our research studies are applied but there is ample scope for in-depth fundamental studies and joint collaboration with other countries. Major research institutes engaged in Corrosion Science and Technology in India are listed below:

(1) National Metallurgical Laboratory (NML), Jamshedpur-831 007.
Phone: 91-0657-431131 E-mail: nml,n^csnml ren ttic in

(2) Central Electrochemical Research Institute (CECRI), Karaikudi-623 006
Phone: 04565-22064 E-mail: cecrik(cscecri_ren_nic,in

(3) Regional Research Laboratory(RRL), Bhubaneswar-751 013.
Phone: 0674-581456 E-mail: director@csrrlbhu.ren.nic.in

(4) Indian Institute of Chemical Technology (IICT), Hyderabad-500 007.
Phone: 040-7173289 E-mail : root(Lbcsiict ren nic in

(5) Central Salt and Marine Chemical Research Institute (CSMCRI), Bhavnagar-364 002.
Phone: 0278-569496 E-mail: general (il.cscsmcri.ren.nic.in

(6) Central Building Research Institute (CBRI), Roorkee-247 667.
Phone: 01332-72391 E-mail: cbri(a)sirnetd ernet in

(7) Structural Engineering Research Institute (SERC), Post Bag No.8287, Chennai- 600 113
Phone: 044-2352139 E-mail : sercmr"cl)sirnetm.ernet in

(8) Indian Institute of Petroleum (IIP), Dehradun-248 005.
Phone: 0135-660098 E-mail: iipddn(«de12 vsnl net in

(9) Bhabha Atomic Research Centre (BARC), Trombay, Mumbai-400 085
Phone: 022-2022543 Fax No. 022-5060750

(10) Defence Research Laboratory(Materials) (DRLM), Kanpur(UP)

(11) Research, Development and Standards Organisation (RDSO), Manak Nagar, Lucknow-226 011
Phone: 0522-451200 Fax No. 0522-456015

(12) Indian Institute of Technology (IIT) , Kharagpur- 721302
Phone: 03222-55221 E-mail: dnb@matsc.iitkgp.ernet.in

(13) Indian Institute of Technology (IIT), Mumbai- 400 076
Phone: 022-576 7891 E-mail: khanna@cc.iitb.ernet.in

(14) Indian Institute of Science (IISc), Bangalore-560 012.
Phone: 080-309-226 E-mail: daasu@metalrg.iisc.ernet.in

(15) Naval Materials Research Laboratory (NMRL), Ambernath-421 506

(16) National Institute of Oceanography (NIO), Goa-403 004.
Phone: 0832-226253 E-mail:acanil@csnio.reen.nic.in

(17) National Thermal Power Corporation Ltd. (NTPC), Noida-201301(UP).
Phone: 011-8536333 E-mail: sinhaL^Jntpcrd ernet in

Conclusions

Corrosion is a natural process of deterioration of metals and is basically electrochemical in nature. Identification of a Corrosion Cell will indicate the type and significance of damage that may be caused. Corrosion is a global problem of enormous technological importance. The existing knowledge on corrosion prevention can easily save 25-30% of the corrosion losses. Of all the various preventive measures to combat corrosion, cathodic protection is one of the most effective approach to control it. Cathodic protection only can guarantee 100% protection, if properly designed and executed. NNIL has been active in the area of corrosion protection and there is good scope of improving the situation by co-ordinating more research programs in the area of corrosion abatement.

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[15] Indian Patent Application No. 802/DEL/97 dated 27.3.1997.

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