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Cathodic protection system for internal surfaces of piping/pipeline

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ABSTRACT

Metallic Pipelines transporting corrosive media (eg. Untreated sea water) would require internal corrosion protection by internal lining as primary protection supported by Internal Cathodic Protection System by suitable Galvanic Anodes or ICCP systems. This paper as case study discuss for various parameters involved for selection of system design calculations pertaining to the design of CP system for the internal surface of the underground lined metallic pipeline, Sea water pipeline & Brine water pipeline. Selection of anode system and installation configuration considering pipeline diameter and lengths is discussed in paper.

Keywords: CP system internal corrosion protection sea water pipeline, design parameter & installation configuration.

INTRODUCTION

This abstract comprises of cathodic protection system for internal surfaces of piping/pipeline design basis and material requirements and includes the following:

- Calculation of current requirements
- Calculation of anode requirements
- Calculation of anode resistances

Details of underground piping that has to be cathodically protected are tabulated below.

Table 1: Details of Underground piping

Sr.No.	P/ Line Dia in Inches	P/ Line Dia in m	P/ Line Length in m L_P	P/ Line Area in $m^{2.}$
1	30	0.7620	5187	12417.16
2	36	0.9144	4824	13857.80
3	42	1.0668	6578	22045.90
4	48	1.2192	27324	104657.44
5	54	1.3716	10173	43835.65
6	60	1.5240	1200	5745.36

BASIC DESIGN PHILOSOPHY

The key objectives of SACP system design include:

i. Cathodic protection using sacrificial (Aluminum) anode have been considered for internal protection of UG piping for the design life of 10 years.
ii. The anodes will be attached to manhole lid through welding by means of flat bars and studs.
iii. Manway inserts are generally spaced at 75m spacing. But aluminum anodes are to be installed at every 150m spacing manway inserts.

CRITERIA FOR CATHODIC PROTECTION

The criterion used for determining the adequacy of CP shall be the I.R. free potential of the relevant structure with respect to a Ag/AgCl half-cell reference electrode. The value of protection potential for steel used shall be -0.85 volts (or -0.80 volts in case of Ag/AgCl)
Note: However it is important to note that that it will not be possible to measure the potentials inside the pipe once the anodes are fitted inside the pipes and fluid starts flowing.

DESIGN PARAMETERS

Design and detailed engineering of cathodic protection system is based on various parameters; few of them are considerations and others based on the pre-design surveys and local conditions. The following are the parameters considered/obtained for the cathodic protection on internal surface of piping/pipeline.

Table 2: Design Parameters

Description	Value
Type of CP System	SACP system
Design Life	10 years
Coating Breakdown Factor	5%
Bare Current Density	50 mA/m^2
Type of Anode	Aluminium anode (Galvallum III or equivalent)
Bare anode weight	68 kg
Anode cross section	Circular
Anode diameter	508 mm
Anode height	125 mm
Utilization factor	0.90
Anode capacity	2500 A. hr/ kg
Anode potential	(-)1.10 V vs. $Cu/CuSO_4$ (CSE) or more negative

FORMULAE USED FOR SACP DESIGN CALCULATIONS

i) Surface Area

$S_A = \pi \times D \times L$
Where, S_A – Surface area of pipe in m_2
D – Diameter of pipeline in m
L – Length of pipeline in m

ii) Surface area after considering coating breakdown factor

$S_{CB} = S_A \times 5\%$
Where, S_{CB} – Surface area after considering coating breakdown in m^2

iii) Current required for pipeline by considering coating breakdown

$I = S_{CB} \times C_d$
Where I – Current required by considering coating breakdown in Amperes
S_{CB} – Surface area of after considering coating breakdown in m^2
C_d- Protective Current density in mA/ m^2

iv) Anode weight requirement

$W = I_T \times C \times F / U_F$
Where W = Anode Weight in kg.
I_T – Total current required in Amps
F – Design life in years
C_R – Anode consumption rate (7.9 kg/A yr)
U_F – Utilization factor

v) Number of anodes required by mass criterion

NM = W/w
Where NM – Number of anodes required by weight in Nos.
W – Anode weight requirement in kg
w – Individual anode weight in kg

vi) Estimated resistance of bracelet anode

$R_a = 0.315 \times \rho_{\text{sea water}} / \text{SQRT}(A)$
Where R_a - Estimated resistance of bracelet anode
ρsea water – Sea water Resistivity in Ohm- m.
A – Surface area of Al anode in m^2

vii) Individual anode current output

$I_A = V_D / R_a$
Where I_A – Individual anode current in Amps
V_D – Driving voltage in volts

R_T – Estimated resistance of bracelet anode

viii) Number of anodes required based on resistance criterion

$N_R = I / I_A$
Where N_R – Number of anodes required in Nos.
I – Total current required in Amps
I_A - Individual anode current in Amps

SACP DESIGN CALCULATIONS

Detailed design calculation is tabulated with surface area, current required, anode required by weight, anode required by resistance and number of anodes proposed are attached as Design calculation.

Table 3: Design Calculation 1

Current Density	j	50	mA/m^2
Coating Breakdown factor	C_{BF}	0.05	
Final current density for the UG piping	j_F	2.5	mA/m^2
Safety factor	S_f	1.25	
Design life	F	10	Years
Aluminium anode potential	V_{MG}ANODE	1.16	Volts
Minimum protective potential	V_{MIN}	0.85	Volts
Aluminium anode consumption rate	MG_{CR}	3.14	Kg/A.year
Aluminium anode utilisation factor	U_F	0.90	
Anode length	L_A	0.125	m
Anode diameter	D_A	0.508	m
Spacing of anodes (horizontal / vertical)	S_A	150	m
Sea Water Resistivity	$\rho_{sea\ water}$	0.20	Ohm-m

Design data: Anode material –

Aluminium - (Bare wt. 68.0 kgs.)

Anode resistance at 0.25 ohm m (Ra) = 0.315 X $\rho_{sea\ water}$ / SQRT A
= 0.315 X 0.25 / SQRT 0.1995
= 0.14 Ohms

Where, A = Anode surface area in m^2
= 3.1416 X 0.508 X 0.125

= 0.1995 m^2

Driving voltage (V_D) = -0.35 V
0.35 V

Current output from one Aluminium anode = V_D / Ra
= 2.4814 A

Table 4: Design Calculation 2

Sr. No.	P/ Line Dia in Inches	P/ Line Dia in m	P/ Line Length in m L_P	P/ Line Area in m^2.	Total current in A I_P	Min.Wt. Of Al anodes Reqd. in Kgs.	Min.No. of 68 kg Al Anodes Required by weight	Current output of one Al anode in amps	Span of protection in metres
1	30	0.7620	5187	12417.16	38.8036	1353.8	28	2.4814	332
2	36	0.9144	4824	13857.80	43.3056	1510.9	31	2.4814	277
3	42	1.0668	6578	22045.90	68.8934	2403.6	42	2.4814	237
4	48	1.2192	27324	104657.44	327.054	11410.6	178	2.4814	208
5	54	1.3716	10173	43835.65	136.986	4779.3	79	2.4814	185
6	60	1.5240	1200	5745.36	17.9542	626.4	10	2.4814	166

MATERIAL SPECIFICATION OF 68 KG ALUMINIUM ANODE

The sacrificial anode material required for internal CP of the piping shall be of the aluminum indium zinc alloy type (bismuth or mercury containing alloys will not be considered).Typical details of the anode type required and anode composition requirements for piping are given below.

Anode Details

Alloy Type	Al-In-Zn
Anode Cross Section	circular
Anode Diameter	508 mm
Insert Type	Straight Centrally Located 40 x 6 mm strip
Insert thickness	6 mm
Insert Length	extending 50 mm on both sides and bent for ease of welding
Anode Height	125 mm (for 68 kg) and 50 mm (for 27 kgs)

Alloy Net Weight	68 kg
Potential (Ag/AgCl)	-1.16 V (or more negative)
Capacity	2500 Ahr/kg (min) at 20° C

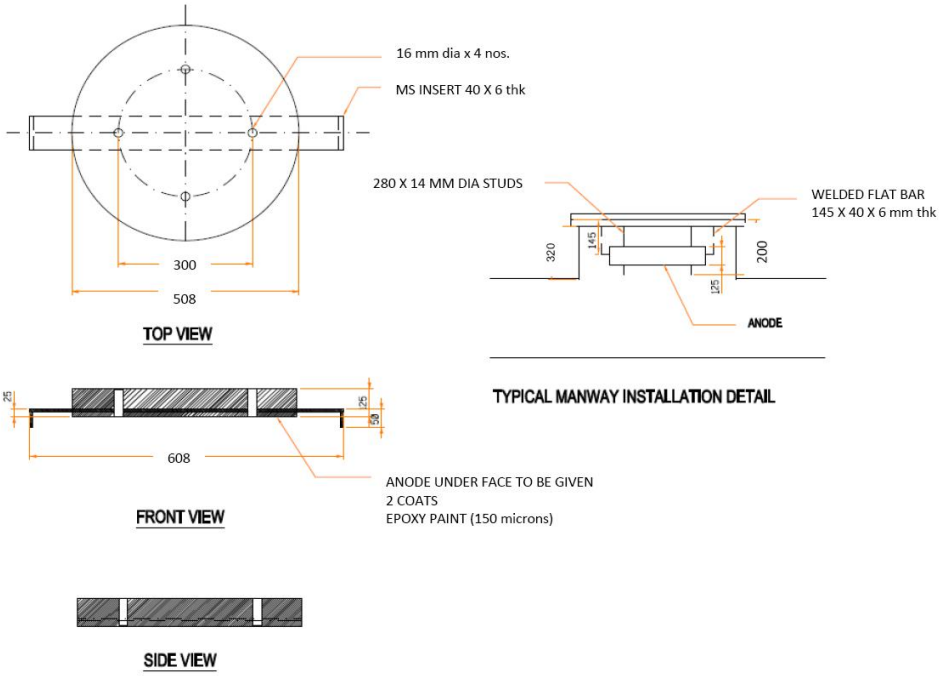

Figure 1: Schematic installation of Aluminum Anodes

CONCLUSION

The internal surface of piping is well CP protected after nearly 2 years which indicates sufficiency of system for design life.

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