EXAMPLE

Design of a Galvanic Anode Cathodic Protection System For a Pipeline

Assumptions: Multiple Anode Groundbed System with Magnesium Anodes
Pipe length is 2500 ft.
Pipe diameter is 6 in. OD = 6.625 in.
Coating quality is 98%
Desired Current density is 2 mA/sq.ft.
Soil Resistivity is 1000 ohm-cm
Anode type is standard potential magnesium.
Anode size is 17 lb. Package length is 2 ft. Package diameter is 0.5416 ft.
Anode spacing is 20 ft.
Design life is 20 years.

Calculations and Design:
(Blue items in this example refer to the corresponding items as detailed in the companion document titled "Design of a Galvanic Anode Cathodic Protection System For a Pipeline". Referenced formulas refer to formulas listed in the same document)

(Step 1) Surface Area is 4334 sq.ft.
(Step 2) Current Requirement is 0.173 Amps
(Step 3) Dwight's Formula for a Single Vertical anode yields a groundbed resistance of 6.2147 ohms
(Step 4) Current output is then $I = \frac{P_a - P_c}{R_{gb}} = \frac{1.55 - .85}{6.2147} = 0.1126$ **Amps** which is less than the required current.
(Step 5) Divide the current requirement by the above current output to obtain the number of anodes necessary to produce a current greater than or equal to the required current. In this example the calculation is $\frac{0.1734}{0.1126} = 1.54$ from which we conclude that two anodes are required.

(Step 6) Sunde's Formula for two anodes produces a groundbed resistance of 3.178 ohms.
(Step 7) Then the current output is 0.2203 Amps.
(Step 8) Expected life is 7.4878 years.
(Step 9) An expected life of 8 years and Formula 5a produces a driving voltage of 0.6551 volts.
(Step 10) Then Formula 5b produces a polarized potential of 0.89 volts.
(Step 11) Using Formula 7, current output is calculated to be 0.2061 Amps.
(Step 12) Formula 3a produces an expected life of 8.0036 years.

(Comment 3) Therefore a minumum of two anodes will protect the pipe. However, a two anode system will provide protection for no more than 8 years.
(Comment 4) The next phase of the process is designed to determine the number of anodes required to satisfy both the current requirement criteria and the design life criteria. This part of the process will result in another set of output data.

To extend the life of the system anodes must be added. The number of anodes to add in a first attempt is calculated with

(Step 14) $$x = \frac{\textbf{(design life)(number of anodes from Step 5)}}{\textbf{(years of expected life from Step 12)}} = \frac{(20)(2)}{8} = 5$$

(Step 15) For a five anode system Sunde's Formula yields a groundbed resistance of 1.3667 ohms.
(Step 16) Formula 5a with design life then yields a driving voltage of 0.2817 volts.
(Step 17) Formula 5b produces a polarized potential of 1.268 volts.

(Comment 5) According to much of the literature and the official position of NACE technical committee the maximum polarized potential of a steel pipe will be 1.2 Volts.

(Step 18) We therefore restrict the polarized potential to 1.2 volts.

(Comment 6) To achieve a life equal to the design life, the pipe would have to polarize beyond the maximum polarized potential for steel of 1.2 volts. Therefore all following calculations are based on polarized potential for the pipe of 1.2 volts. This will result in a system life shorter than the design life.

(Step 19) With Formula 5b the driving voltage is recalculated to be 0.35 volts.
(Step 20) Formula 6 is used to calculate current output to be 0.256 Amps which exceeds the current requirement.
(Step 21) Expected life is then calculated to be 16.1088 years.

Therefore a five anode system should protect the pipe for 16 years. The output current should be 0.256 Amps and the pipe should polarize to 1.2 volts.

(Step 22) Because the output current is higher than required and the system "wanted" to polarize the pipe higher than the maximum we consider a system of four anodes to see if protection can be achieved for the same length of time.

(Loop through Steps 15-22) For a four anode system Sunde's Formula gives a groundbed resistance of 1.6796 ohms. This gives a driving voltage of 0.277 volts and a polarized potential of 1.273 volts. The polarized potential is reset to the maximum of 1.2 volts and driving voltage is recalculated to be 0.35 volts Current output in this system is 0.208 Amps and expected life is 15.82 years.

Therefore a four anode system will protect the pipe for the same number of years (16), the pipe will polarize to the same potential (1.2 volts), and the current output will be greater than but closer to the required current.