ENHANCEMENT OF THE CATHODIC PROTECTION SYSTEM EFFICIENCY OF BURIED METALLIC PIPES TO LIMIT ENVIRONMENTAL POLLUTION RISKS RESULTING FROM LEAKAGE

by

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B.Sc. in Power Engineering, Zagazig University, 1988
Diploma in Environmental Science, Ain Shams University, 2002
M.SC. in Environmental Science, Ain Shams University, 2005

A thesis submitted as Partial fulfillment
of
The Requirements for the Doctor of Philosophy Degree
in
Environmental science

Department of Environmental Engineering
Institute of Environmental Studies and Research
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ABSTRACT

The investigation described in this thesis is carried out - on a laboratory scale - to evaluate the effects of anodes positions relative to a condensed buried piping in a confined area on their cathodic protection performance. For this purpose, three identical sets of steel bars of two different lengths and three different diameters (representing pipes) were weighed and installed in three separate basins (on 6 different crossing levels) on identical holding frames and immersed in NaCl solution of same concentration 3.4 wt %.

Corrosion was studied on the three identical sets of bars; nominated set in basin (A), set in basin (B) and set in basin (C). Set (A) was cathodically protected utilizing uniformly distributed anodes between the bars; set (B) protected by a single anode placed close the basin middle bottom (close bed anode), while set (C) protected by a single anode installed facing the middle side of the set.

The experimental system was energized in parallel through a stabilized DC power source. Prior to system energization the polarized native potential for all bars in all basins was (0.45 V) relative to zinc reference electrode.

Daily measurements recording of the protraction system parameters for the three sets were carried out, included: driving voltage and consumed current for each set, as well as potential differences between the steel bars and the electrolyte taken at four points for each bar for two conditions ON (protected current applied) and OFF (immediately after switching off protection current). Pure zinc reference electrodes were used for this purpose. The test period continued for 60 days and the main finding can

be summarized in the following:

1- Bars in the three basins suffered from metal loss to different degrees which indicate presence of interference current of different values in all basins. Minimum loss was for set (C) then set (A); loss in set (B) being approximately, twice that of (A) and four times of (C).

2- Basin (C) showed the best performance of CP system regarding potential and stability followed by set (A) and the worst was set (B).

3- Minimum current consumption was for set (A) then set (C). The A-h consumption for sets (B) and (C) being, approximately four and 1.65 times that for (A), respectively.

4- Best protection level was observed for set (C) then set (A) and minimum protection for set (B).

5- Maximum protection shift was observed for set (C) then set (A) then set (B).

6- In general, performance of set (C) was the most favorable.

In brief, the following conclusions can be made:

- In relatively small areas crowded with buried pipes close single anode, as in set (B) are absolutely not recommended since it leads to unsteady protection performance due to severe interference and proximity effect.
- Remote anode position proved to be the optimum case.
- Performance of systems with distributed anodes comes in between remote and close anode systems.

Finally, the thesis includes intensive review of the environmental impacts and damages recorded nationally and internationally caused by corrosion leaks in piping systems and similar catastrophic accidents. Direct and indirect effects, monitoring, treatment of oil spills are also included with particular emphasis placed on the relevant international treaties.

SUMMARY

The present work investigates - on a laboratory scale - the effect of anodes position relative to cathodically protected condensed buried piping area. For this reason three identical sets of steel bars of two different lengths and three different diameters (representing pipes) were weighed and installed in three separate basins on identical racks and immersed in NaCl solution of same concentration 3.4 wt %.

Three different anode configurations were applied, one for each bar set as follows: Configuration A (distributed) small anodes suspended uniformly in between steel bars oriented parallel to the long bars and connected in parallel to the positive terminal; Configuration B (close) one main anode laid on the bottom of the basin at the centre of the bar set and oriented parallel to the long bars; and Configuration C (remote) one main anode suspended on the basin side at the middle level of bars set and oriented parallel to the short bars.

The experimental system was energized in parallel through a stabilized DC source. Prior to system energization the polarized native potential for all bars in all basins was (0.45 V) relative to zinc reference electrode.
Daily recording of system parameters for the three sets was carried out, measurements included:

(i) Potential difference between steel bars and electrolyte taken at four points for each bar for two conditions ON (protected current applied) and OFF (immediately after switching of protection current) pure zinc reference electrode was used for this purpose;

(ii) Current consumption for each basin; and

(iii) Driving voltage for each basin.

Elaboration of results was implemented in the following fashion:

a- The average potential difference of the four ON/OFF readings for each bar were calculated and plotted against time all along the test period (60 days).

b- The averages of daily readings for each bar were averaged to a gross average value over the test period.

c- The gross average ON and OFF readings were plotted on a bar diagram for each bar in each basin, in order to evaluate the degree of polarization during the test period and consequently the average potential shift.

d- Electric current for each basin was measured at the same time of potential measurement and the gross ampere-hour consumed during the test period was calculated for each basin separately.

By the end of test period the bars were cleaned in diluted HCL according to relevant standards and weighed. Reduction in weight represents corrosion loss.

Examination of obtained experimental results revealed the following features:

1- Bars in the three basins suffered from metal loss to different degrees which indicate presence of interference current of different values in all basins. Minimum loss was in basin (C) than (A) [doubled that of (C)] then (B) four times as that of (C).

2- Basin (C) showed the best performance of CP system regarding potential and stability followed by basin A and the worst was basin B.

3- Minimum current consumption was in basin (A) then (C)

approximately, 1.65 that in (A) and the maximum was in basin (B) which was four times that of basin (A).

4- Best protection level was observed in basin (C) then (A) and minimum protection in basin (B).

5- Maximum protection shift was in basin (C) then Basin (A) then basin (B).

6- In general performance of basin (C) was the most favorable.

Potential variation with time shows the following:

1- The general trend of basin (C) is the increase of protection level with time along the test period which is attributed to systematic precipitation of calcium/magnesium deposits on the bars surfaces.

2- Regarding basin (A) the average protection level is almost the same along the test period which is an indication of steady state with constant amount of interference current flowing in between different bars.

3- As for basin (B) completely unsteady state was prevailing, severe interference currents flew in between different bars, most probably due to substantial proximity effects.

From above the following conclusions can be made:

- In relatively small areas crowded with pipes close single anode (as in basin B) are absolutely not recommended since it leads to unsteady protection performance due to severe interference and proximity effect.
- Remote anode position proved to be the optimum case.
- Performance of systems with distributed anodes comes in between remote and close systems.

Finally, the thesis includes intensive review of the environmental impacts and damages recorded nationally and internationally caused by corrosion leaks in piping systems. Direct and indirect effects, monitoring, treatment of oil spills are also induced with particular emphasis placed on the relevant international treaties.

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