Limitations and Economics of Cathodic Protection

V. T. PUROHIT,

Electro Corr-Damp, Bombay

INTRODUCTION

It can be safely said that the technique of cathodic protection has already overcome the initial resistance to its acceptance which is normally encountered by any new concept or a new development. The resistance to the use of cathodic protection had been on the following basis :—

(a) Everybody thought that corrosion of steel when buried in ground or immersed in water must be accepted as inevitable, and nothing could be done to prevent the losses due to corrosion except by keeping more spares or standby capacity, and by regular maintenance and replacement programme.

(b) It was accepted that the application of paints or coating to steel buried in ground or immersed in water was all that one could do to prevent corrosion as painting or coating was the only practice known to many for preventing corrosion.

(c) The claim that cathodic protection would prevent all further corrosion and give the structure almost indefinite life appeared to the customer that he is being sold something which is not as good as is spoken of.

But since its first application about 20 years ago in this country, cathodic protection has been found very useful, and technically a feasible proposition. Everybody familiar with it would agree that it does work, it prevents leaks and minimises repair cost. What was, a few years back, termed as a sales talk or a gimmick, has been found to be a sound engineering practice. On the other hand, many who have been associated with cathodic protection one way or the other believe that cathodic protection can prevent corrosion of all underground and underwater structures. But this is also not true.

The purpose of this paper is therefore to discuss some of the technical limitations of applying cathodic protection and then explain the economics of cathodic protection when it has been successfully applied.

Structural requirements for cathodic protection

In order that any structure can be cathodically protected at an economic cost these should be :

(a) Uniform in cross section as far as possible. A pipe network of different diameters is economically more costly and technically more difficult to protect. A cast iron pipe with lead spigot joints or with flanged joints is less amenable to cathodic protection than a welded pipe.

(b) Painted with a good quality coating and wrapping.

Better and better coating means less and less metallic area exposed to the corrosive media. As the size of the cathodic protection equipment depends on the area exposed to the corrosive media, a very good coating is complementary to cathodic protection. In all those installations where coating or painting is physically and technically feasible, cathodic protection should be treated as a second line of defence only. There is no substitute for good coating. But it is imperative to have cathodic protection as a second line of defence. The small areas or pinholes will act as anodes where the current is discharged and hence where corrosion takes place. For equal value of current discharged, the rate of penetration of corrosion pits will be highly accelerated compared to when larger areas discharge the same current and in which case the corrosion is uniformally spread and the rate of loss of thickness is also uniform.

Geographical Limitations

A bare or poorly coated structure will demand very large current for protection. This is most of the time inadvisable to do in urban areas or where other underground structures may be detrimentaly affected by electrolysis. The degree of such an effect called interference is more pronounced when large currents are used for protection.

The distance of the anodes discharging current will have to be at a certain minimum distance away from the structure to be protected. This distance depends on the value of the current to be discharged and the corrosivity of the media. A plot of land away from a pipeline route is usually difficult and more expensive to obtain in an urban or industrialised areas.

In order that cathodic protection can be more easily and economically applied, it is important for the above two reasons to have well coated pipes, piling, etc., buried underground in or near populated or industrial areas.

(b) Lower depreciation

The life of a structure buried in soils of normal corrosivity is about 20 to 25 years. When a structure like a long pipeline is protected by cathodic protection, its life is increased to almost an indefinite length. There have been cases where the pipielines had to be discontinued either because they had become obsolete or became too small to be operated economically. This would mean that the depriciation charge on the pipeline becomes insignificant when cathodic protection is applied. The annual depriciation charge which was allowed at 4 to 5% can now be allowed for at much reduced rate. In addition the structure may have higher salvage value.

(c) Saving in replacement cost

When the structure has outlived its useful life, it is to be replaced. The cost of materials and labour at a future date when this replacement is due will be much higher than what it is today. Assuming that the above costs increase at the rate of 4% every year, a project requiring say, 1 lakh of rupees will cost about 2 lakhs of rupees after 25 years. Whereas if additional Rs. 10,000 to Rs. 15,000 were spent now over this project towards cathodic protection, there will not be any need of procuring finances for a capital work of Rs. 2 lakhs of rupees at a later period.

(d) Reduced repairs and maintenance

Every public utility will have to spend vast amount of money for (a) staff, (b) equipment, (c) labour, (d) inspection, etc., for carrying out regular maintenance and repair works so long as the corrosion problems are not solved satisfactorily. Application of cathodic protection may not do away with these items altogether but there will be a significant reduction in cost of these items.

(e) Reduced spares and standby capacities

When a reliable method of corrosion mitigation programme is carried out by any undertaking, it need not block its capital in standby plants and spares and maintain large inventory.

(f) Reduced plant shut downs

If a leak occurs, it may be that the plant will have to stop at a considerable loss of production. Consequences of stopping a power plant, an oil refinery, a petro-chemical complex or a fertiliser project can be easily appreciated by all. Such a shut down will result in inevitable loss of production or contamination or both and will result in direct leakage losses in the case of gas holders, tanks and pipelines.

(g) Civil works

In many cases, the leak is very difficult to find out and the structure may have to be exposed at several places. Excavation of roads carrying heavy traffic is not a welcome proposition to many including the maintenance staff, traffic department and the public. Complete prevention of corrosion and of leaks due to corrosion will go a long way to create a favourable public opinion.

(h) Fire hazards

In case of oil or gas pipelines, there is a continuous danger of fire hazard and pollution; any leak from an oil pipeline near a source of drinking water would create serious problem of obtaining alternative source of drinking water. The water life in the sea or river will also be affected. If a leak occurs in the agricultural land, the area affected by oil would destroy the whole crop. Further, this land will not raise any crop for several years to come. Thus, there will be heavy claim for this type of damages against the owners, besides loss of goodwill.

Conclusions

It has only been possible to outline in general terms, some of the limitations encountered by corrosion engineers in executing cathodic protection schemes once the structure is designed, installed and commissioned. It is very expensive to carry out any further alternations in the structure so that cathodic protection can be applied with reasonable economy. If, however, some of the important points mentioned in the first part of this paper are adequately attended to at the design stage, application of cathodic protection becomes very economical and efficient.

As for the economics of corrosion prevention in general and of cathodic protection in particular, from the above discussion it will be observed that prevention of corrosion goes a long way in reducing various types of losses. The execution of cathodic protection and the subsequent total cost of cathodic protection will vary according to the design features involved and the margin of profit will vary according to the trade practices of a firm. Further, different utilities have different practices for budgeting depreciation charges, repairs cost, etc. It will be, therefore, necessary to evaluate separately for each project the exact economy affected by cathodic protection.

Perhaps not all the data necessary to evaluate the total corrosion loss will be available with the owners. But when all these losses described above are considered in proper perspective, it may be found that the total annual corrosion loss to the country will not be much out of the estimated figure of Rs. 200 crores. This would emphasise that the corrosion has got to be controlled at all levels and the management and engineers have a challenging roll to play in this task.

DISCUSSION

Mr. P. L. Santra (Gauhati Refinery, Gauhati)

I would like to know from Dr. Lahiri and other fellow delegates certain clarifications regarding cathodic protection in our condenser system. In this condenser, steam and oil vapour get condensed and at points near the shell and baffle plates (made of dissimilar metals—steel and copper alloys) heavy corrosion of steel shell occurs. The corrosion in this case is due to galvanic corrosion and I would like to know if in such a situation cathodic protection can be applied or not.

Dr. A. K. Lahiri (Corrosion Advisory Bureau, Jamshedpur)

The corrosion in the present case is in an oil/water environment where temperature is comparatively high and the pH of the water condensed is on lower side. The corrosion of steel will be concentrated near the brass plate and would occur mainly where the shell is in contact with the water. There will be some difficulty in applying cathodic protection in the present case because of the presence of oil which is non-conducting. As you are aware, for cathodic protection there should be a continuous flow of current for which it will be necessary to maintain a continuous layer of water of the thickness sufficient to house an anode. In my opinion, this case can be tackled in a better way by the use of inhibitor than by cathodic protection. Inhibitors are at present available which can give protection in oil/water system. However, the possibilities of cathodic protection can be examined by providing a sufficiently deep and continuous layer of water. Use of galvanic anodes may give good results in the present case. Use of impressed current systems in my opinion may be hazardous, considering the presence of oil vapours in the system.

The best method may be to change the baffle material to steel or to apply an epoxy type coating to the brass, provided the temperature conditions are favourable.

Mr. R. Srinivasan (ESSO Standard Co. Ltd., Bombay)

We faced a similar problem of corrosion in our condensers. Our experience has been that it is best to use corrosion inhibitor in such a way as to maintain a pH of about 7. This is quite possible by injecting some ammonia or its salt in the system at proper locations.

Dr. A. K. Lahiri (Corrosion Advisory Bureau, Jamshedpur)

I feel the remedial measure suggested by Mr. Srinivasan is a correct one but I would like to add a word of caution. If ammonia added is not properly controlled there is a chance of enhanced corrosion and stress corrosion cracking of copper alloys. So ammonia injection is to be done very carefully so that free ammonia is not present in high concentrations. The proper dose of ammonia to neutralise HCl, combined with use of film forming inhibitors, I think, would give good results.

Mr. S. N. Mookerjee (Acc-Vickers-Babcock Ltd., Durgapur)

Dr. Lahiri correctly pointed out that pH cannot be increased very much because the ammonia may attack the brass tubes. Our own experience has been that the addition of ammonia to increase pH above 6 or 7 is dangerous and better avoided.

MR. A. G. NENE (Shriram Chemical Industries, Kota)

My problem is connected with the use of galvanic anodes for cathodic protection. In industry zinc blocks for galvanic protection have been extensively used. I would like to know the method by which the size of anode blocks, their location and number used for any particular condenser systems can be determined. Normally the anodes are fixed on the tube sheets but sometimes there is no place on the tube sheet. I would also like to know the minimum distance required and how far this type of protection will be effective.

DR. A. K. LAHIRI (Corrosion Advisory Bureau, Jamshedpur)

In condensers cathodic protection is used for the protection of steel shell at the entry or exit end of water. Due to the use of dissimilar metals like steel and copper alloys in contact with each other galvanic cells are created. To avoid very intense corrosion near the plate it is general practice to apply top quality coatings, e.g., coal tar epoxy or epoxy coatings on the plate to which the brass or copper alloy tubes are expanded. This should be followed by proper coating of the steel shell of water box. Unless good quality coatings are applied, the current requirement for cathodic protection may be too high to be economical or practically feasible. We have to keep in view that cathodic protection can be best utilised if it is supplimented with good coating.

As far as the placement of the zinc anode or other design details are concerned, it would depend on the conductivity of the water, the whole contour of the area that is to be protected, the desired life, etc. In the case of galvanic protection we are limited by the type of available anode material. As the driving voltage is low, in case of galvanic anode you cannot remove your anode very far from the surface you are going to protect. Thus each particular situation will have to be considered separately and then evaluated.

When zinc alloy anodes (alloys are used and not pure zinc as anode material) anodes are used it is to be ensured that purity of zinc is more than 99.9%. If it has impurities zinc anode will not work as it will get polarised easily. Further, if temperature is greater than 70°C it would turn cathodic to steel and again it would not work, properly. Other sacrifical anodes which can be used are based on magnesium and aluminium alloys. Aluminium being available in plenty has a good scope in India and in the National Metallurgical Laboratory work for the development of aluminium anode has been successful.

PROF. S. J. ARCEIVALA (CPHERI, Nagpur)

I am not feeling very satisfied with the data given by Mr. Purohit in his paper from the point of view of cost. I would request either of the speakers to give me a few more data. What is the kind of anode which we should use, availability being assured in India? Is zinc of 99.9% is used as it is or does contain something else? What is the cost of such anode per kg? What is the requirement of current in mA/sq. ft. for steel?

DR. A. K. LAHIRI (Corrosion Advisory Bureau, Jamshedpur)

About the cost of anode and other particulars, Mr. Purohit will be in a better position to throw more light. One thing I have felt during the technical consultancy provided by NML is that during the last few years the cost of cathodic protection has shown a decrease compared to general increase in prices. However, there is still much scope for economising on this aspect. One of the reasons for high price is that the specialised materials required are not produced in mass scale and therefore, prices asked are much more than the actual price. I am, however, definite that installation cost will come down if this system of protection is adopted extensively.

As regards the different types of galvanic anodes, magnesium gives highest potential though its efficiency is low; so it may not be as economical as aluminium which on the basis of amp-hr/kg is the most economical. For magnesium, aluminium and zinc alloys, the most important criterian is the purity of base metal specially with regards to iron content which should be very low. As far as aluminium alloys for cathodic protection are concerned, I understand that those based on Al-Zn are manufactured in India when ordered for. However, better aluminium alloys have been developed in this country.

MR. V. T. PUROHIT (Electro Corr-Damp, Bombay)

As regards the current required to give protection it may be mentioned that in impressed current system an economical rectifier will have a minimum current capacity of 5-10 amps. The cost of such units in Bombay will be Rs. 6000/- to 7000/-. But price may vary in other cities. The proportional cost of the rectifier would go down with the size of the equipment. If higher amount of current is required per unit, capital cost would be reduced. As far as total investment is concerned the cost of coating will come to Rs. 2.50/sq. ft. When it is cathodically protected it would be Rs. 4.0 to 5.0/sq. ft.

If galvanic anode system is used it will be necessary to use large number of anodes. I cannot give any data for the system using magnesium anode as the anodes are not being manufactured by any firm in India till now. I would only quote for aluminium anodes which have been successfully used even for underground protection. The cost would be about Rs. 25/- per kg.

DR. A. K. LAHIRI (Corrosion Advisory Bureau, Jamshedpur)

The actual current requirement depends on the polarisation characteristic of iron in a particular environment. Under most corrosive condition max. of 5-10 mA/sq. ft. will be required for bare iron though for soil a value of 1-2 mA/sq. ft. will be a reasonable value under most conditions. If proper coating is given the current requirement will come down by 1/10th.

MR. L. M. AGARWAL (Sudbury Laboratory of India, Calcutta)

I would like to know the practical usefulness of the cathodic protection system under the following conditions:

1. In a cooling water system the same water is used under variety of conditions and also for condensers made of multi-metals. Can cathodic protection be used in such systems?

2. There are some industries located in sea shore using sea water for cooling system. Whether this method of protection can be used there or not?

3. Has cathodic protection any advantage in preventing or reducing carbonate scale formation in condenser tubes?

MR. V. T. PUROHIT (Electro Corr-Damp, Bombay)

I think cathodic protection is feasible under any situation provided there is water or soil. Only criteria is that there should be a continuous path of electrolytes for the flow of current. About formation of carbonate scale I would leave it to Dr. Lahiri.

DR. A. K. LAHIRI (Corrosion Advisory Bureau, Jamshedpur)

About the internal protection of pipes, if it is copper or copper alloys, cathodic protection is not required. But if it is steel and you want to protect it cathodically, number of methods are available. The problem is comparatively easy for large diameter pipes, where anodes can be easily housed. The difficulties come with small diameter pipes, specially those used for condensers, where it is difficult to properly place the anodes. Wire and ribbon anodes may be used wherever possible. Recent patents however show that it is possible to protect the internal surface of the pipes by circulating along with water granulated or powered anode which is capable of extending cathodic protection during repeated contacts of short durations with the metal surface.

About carbonate scaling it may be said that cathodic protection will increase it. At cathode there is naturally an increase in pH which results in the formation of carbonate scale. As a matter of fact, the carbonate scaling is utilised fruitfully for forming a coating on the metal surface where the formation of scale reduces the current requirement for the pipes or underground structures.