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CORROSION OF MECHANICAL JOINT BOLTS

INTRODUCTION

The mechanical joint has been in use since 1927 and the corrosion of mechanical joint bolts has been the subject of many studies. Most studies searched for ways to prevent the bolts from failing prior to the pipe. It was found that in corrosive soils, the bolts were the most vulnerable component of the system. In many cases, the bolts failed due to corrosion, long before the pipe became unserviceable.

TESTING

In cast-iron pipe, the products of corrosion remain in place and exhibit enough strength, coupled with the surrounding metal, to withstand considerable pressure without failure. This phenomenon has been repeatedly demonstrated by the Cast-Iron Pipe Research Association (CIPRA), the predecessor of the Ductile-Iron Pipe Research Association (DIPRA). This phenomenon was also reported by the National Bureau of Standards in a paper by Melvin Romanoff in the September 1964 issue of the "Journal of the American Water Works Association." Some pipes held as much as 500 psi even with complete perforation of the pipe wall by graphitic corrosion. However, even though the pipe could have remained serviceable in this condition, if the joint leaked due to bolts that had corroded, the pipeline had to be repaired.

Consequently, studies and proposed solutions to the problem were being made as early as the 1940's. C.K. Donoho and Dr. J.T. MacKenzie proposed the addition of copper to the gray-iron bolts in 1946 in "Corrosion" Vol. 2, 1946.

> The theory was: cathodic bolts would be protected by the anodic pipe. The corrosion currents generated by the dissimilar metals would be dissipated over the larger area of the cast-iron pipe. The pipe, being much more massive than the bolts could be sacrificial to the bolts without significantly affecting the performance of the pipe.

The theory works in some cases. However, it works only if the bolt remains the cathode and the current is dissipated. The National Bureau of Standards also conducted a long term study on the corrosion of bolts and the results were published in the summary in the "Journal of Research of the NBS", Vol. 5, No. 5, May, 1954. These studies supported the addition of 0.5% copper to the chemistry of the gray-iron T-bolt then used with the mechanical joint. In the majority of cases, the 0.5% copper, gray-iron T-bolt performed well. However, there continued to be failures in the field. These failures caused CIPRA to initiate a study which was to last 16 years.

The study involved the burial of mechanical joints with various kinds of T-bolts, in four different locations, all severely corrosive. One joint with each bolt type was removed for examination at two year intervals. These materials included: high strength gray-iron, high strength gray iron with 0.5% copper, malleable-iron from two manufacturers, mild steel, low alloy steel from two manufacturers, silicon bronze, stainless steel and several types of coatings and wrappings.

After removal of the corrosion products, the bolts were examined, weighed, and photographed. The average weight loss was used to calculate the weight loss per year for each type of material used. Although the silicon bronze and the stainless steel bolts lost the least amount of weight during the study, they caused severe corrosion of the nearby glands. As a result of these tests, most pipe manufacturers began to recommend the use of low alloy steel bolts over high strength gray-iron with 0.5% Cu. Since that time, the low alloy steel bolt has been used extensively with success in the large majority of cases. However, just as the case of the high strength gray-iron bolt, it has not been 100% successful.

As part of the first test conducted in Atlantic City, five sets of low alloy steel bolts were installed in what is assumed to be the same general area. The bolts were cathodic most of the time. In the ten years required to complete the study, these bolts averaged a corrosion rate of only 3.6 grams per year. Please note that the corrosion was most probably not distributed evenly among the total of 30 bolts tested. In the second and third tests, however, the tests were of shorter duration lasting only six and four years respectively. The later tests performed in Atlantic City were most probably conducted at a location somewhat removed from the first tests. The corrosion rate during the second test was 5 times that in the first test, and the corrosion rate in the third test averaged 10 times that of the first. This would indicate that the bolts were anodic in the last two tests. Also, the total weight loss in each of the last two tests (258 and 225 grams involving a total of twelve bolts each) was over twice the total weight loss of the first test involving a total of thirty bolts. The first test lasted ten years while the third test lasted only four years.

The tests in Atlantic City showed that potential reversal is a problem in highly corrosive, saturated soils. Unless the bolt remains cathodic for a long period, the protection by galvanic currents is completely unreliable. The tests in other locations also showed that the galvanic potential of the bolts in relation to the pipe was greatly dependent upon the soil chemistry. Tests performed in Lombard, Arizona ad Spanish Forks, Utah showed that bolts could remain a stable cathode in some soils while the test in Casper, Wyoming and the Everglades showed again how dependent the galvanic potential is on the surrounding electrolyte.

Although the low alloy steel bolts may be stable cathodes compared to cast-iron in a 3.0% sodium chloride solution, the CIPRA study indicated that the corrosion current may reverse when the low alloy steel / cast-iron joints are placed in certain soils. When metals are close to each other on a standard galvanic series, the soil chemistry plays a big part in determining which metal is cathodic and which metal is anodic. With this phenomenon well in mind, reports of the failure of low alloy steel bolts coupled with ductile-iron pipe in corrosive situations are explainable.

BOLTS AS STRONG CATHODES

One could assume that the only way to insure that a bolt remains the cathode and thus loses no weight in the ground, would be to greatly increase the potential difference between the cathode bolt and the anodic pipe. Such a situation was tried in the study just mentioned. Although in theory the corrosion current would be spread over the much larger anodic pipe or fitting, this was not the case with several glands in highly corrosive soils with highly cathodic bolts. Because the glands were an isolated smaller anodic area, or possibly because they were the closest anodic area to a strong cathode, these glands were the target of severe corrosion. In some cases the gland was completely destroyed immediately adjacent to the bolts.

ADDITIONAL FINDINGS

A galvanic series can be made by listing all bolts in the CIPRA study tested in the same soil from the most cathodic (or least weight loss per set per year) to the most anodic (the greatest weight loss per set per year). It can be seen that in each case when the installation site changed, the order of the galvanic series changed. Bolts made of the same material appeared in different locations in the series when placed in the same soil at different times. This all seems to confirm the fact that the electrolyte plays a very important part in the electrical potential between iron or steel parts. The affect of the electrolyte diminishes when the metals are more dissimilar.

One series of bolts continuously stayed near the end of the series suffering the least weight loss whether in saturated or unsaturated soils. These bolts were made from 0.5% Cu. gray-iron with various coatings, some applied at the factory and some field applied. Even bolts that were individually taped prior to installation were more stable than either uncoated bolts or bolts in joints wrapped in polyethylene. The effects of polyethylene and coatings are discussed in Connections™ bulletin GI-3.

SUMMARY

It can be postulated that perhaps the corrosion of the early cast-iron bolts was not necessarily accelerated but that they corroded along with and at about the same rate as the pipe to which they were attached. However, the pipe being much more massive and certainly under a much lower level of stress performed its intended function much longer than the bolts, even with the corrosion taking place. (Generally, stressed areas are more anodic than non-stressed areas.) Altering the bolt chemistry to make it a cathode in order to protect it, while sacrificing the nearby pipe or gland, is only successful part of the time. If the bolt is different enough to provide a stable cathode, the corrosion current increases to such an extent that the nearby gland can be severely corroded.

It is much more reasonable, then, to reduce the corrosion current to its lowest value possible and provide protection to the bolts, either by wrapping in polyethylene, providing cathodic protection to the whole system, or simply coating each individual bolt with a protective coating.

REFERENCE LIST

AWWA Manual M27; External Corrosion- Introduction to Chemistry and Control, 1st . ed., American Water Works Association, Denver, CO, 1987.
"Corrosion in Underground Restrained Piping System," EBAA Iron Inc. Technical Bulletin.
NACE, NACE Basic Corrosion Course, 11th Printing, National Association of Corrosion Engineers, Houston, TX, 1980.

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