ASSET MANAGEMENT STRATEGIES FOR METALLIC MUNICIPAL TRANSMISSION PIPELINES

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Abstract: This paper presents strategies for the control of external corrosion on municipal transmission pipelines as part of a comprehensive Asset Management Program. Several Asset Management strategies are available to municipal utility managers including run to failure; run until failure and repair as required; and operate and maintain using preventative maintenance to provide an indefinite life. Examples of these strategies would include operating a water pump to failure, operating a pipeline until a failure occurs and then making repairs as required, and operating and maintaining a facility such that the facility has an indefinite life. Several asset management strategies are currently being used in the municipal transmission pipeline arena. This paper discusses the short term and long term impacts of these strategies.

Introduction:

There have been many recent reports covering the enormous costs associated with corrosion in the U.S. One noteworthy study and report released in 2002 by the U.S. Federal Highway Administration (FHWA) concludes that the total annual estimated direct cost of corrosion in the U.S. is $276 billion, with drinking water and wastewater systems representing $36 billion of the total. How we develop and maintain infrastructure pipelines (assets) today will impact how future generations are able to maintain and develop facilities with limited funds. Historically (and presently) large diameter water and sewer pressure transmission pipelines are constructed using primarily ferrous based materials such as steel, grey iron and cast iron. There are several asset management strategies presently in use dealing with the potential for external corrosion of buried ferrous based pipelines. The three operation and maintenance strategies that this paper will review are:

1. Run to Failure
2. Run Until Failure and Repair as Required
3. Operate and Maintain to Provide an Indefinite Life

Background:

For the purposes of this paper, Metallic Municipal Transmission Pipelines (MMTPs) are defined as pipelines generally 24 inches and larger in diameter conveying raw or potable water. Over the last 10 to 15 years there has been a great deal of interest in Asset Management because of the continuing reduction of local funding for schools, streets, pipelines, treatment facilities and other infrastructure needs. Much of the pioneering

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work in this area has been completed in Australia. The Total Asset Management Manual (1) lays out a sound foundation for the methodology for a comprehensive Asset Management Plan (AMP) that can be used for MMTPs. The key components of the plan are:

1. A Thorough Up To Date Inventory of the System
2. Condition Assessment
3. Life Cycle Analysis
4. Plan for New MMTPs or Repair or Replacement of Existing MMTPs
5. Operation and Maintenance

One way to look at asset management of MMTPs is to compare them with a school. In the case of the school, the operating costs can consume the equivalent of the initial construction capital cost every 4 to 5 years and the school remains in service for over 100 years (2). Conversely, in the case of the MMTPs, the capital cost is very high and the annual operating costs are generally low. Depending on the operation and maintenance of the MMTPs, the service life could range from 10 years to indefinite. For pipelines, the major cost impact is not from annual operation and maintenance costs, but from the ultimate replacement costs of the MMTPs.

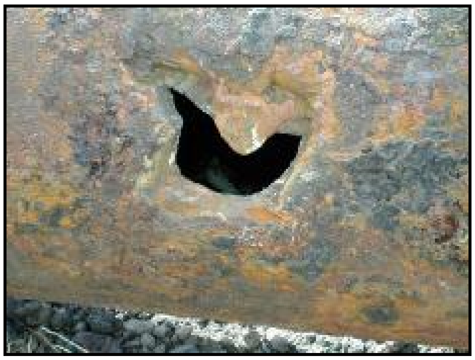
The cost of maintaining the MMTPs is relatively small compared to the capital cost. However if due to the operation and maintenance, or lack thereof, the MMTPs fail in less than 20 years, then the cost of replacement is generally much higher than the original capital cost. This is due to changes along the alignment, increased costs of construction and regulatory requirements to name a few.

Operation and Maintenance Strategies:

Run to Failure

Most run to failure strategies are based on building facilities for the lowest initial total construction cost. The decision is reached during project design that there is a very high probability that none of the existing conditions will ever change and all present and future considerations have been properly evaluated. No safeguards are included for identifying future changes or making operational modifications. When run to failure strategies are used for designing MMTPs for water transmission facilities, the design engineers and pipeline owners are committing themselves to major future expenditures for the replacement of the facility. The run to failure strategies allow for corrosion along the pipeline as long as failure does not occur before the end of design life (3). Proponents of this strategy also imply that cast iron and ductile iron will provide similar service life, even though for a given design class, the ductile iron pipe wall thickness can be less than one-third the wall thickness of old cast iron pipe (3, 4). It is unreasonable to conclude that both materials will provide the same useful life in the same corrosive environment when one material is only one-third the thickness of the other given that both materials corrode at approximately the same rate for a given environment.

As corrosion progresses there is a reduction in the effective wall thickness of ferrous pipeline materials which reduces all the safety factors used in the initial pipeline designs. These reductions have direct effects on safety, operation, maintenance, and asset loss. This strategy assumes that the materials of construction will be allowed to corrode at some rate which is not known at the time the decision is made to proceed. The replacement of the MMTPs may have to occur in 10 years or 100 years. The two photos below are for installations where no protective measures were taken and the MMTPs were operated until they failed.



Detail of Perforation of Ductile Iron Sewer Force Main After Approximately 20 years of service

Detail of Graphitized Ductile Iron Pipe at Perforation of Sewer Force Main

Recently published papers (3,10) addressing corrosion topics use the terms “Corrosion Control” and "Corrosion Protection" interchangeably, Procedures that extend life expectancy by reducing the rate of corrosion are "Corrosion Control". Procedures that prevent or eliminate corrosion are "Corrosion Protection”. The two terms are not interchangeable. Corrosion control does not necessarily protect assets, whereas corrosion protection does protect assets.

Several published papers and reports provide data on pipeline failures, and the costs and consequences of the failures (5, 6, and 7). Many failures occurred 15 years after construction had been completed on the project. There are also papers and reports (8, 9, 10) showing that the cost to replace MMTPs exceed the minimal costs of providing monitoring systems with new construction and cathodic protection when needed. Full life cycle cost evaluations should be considered for all new major water transmission facilities. A recent article in Underground Infrastructure Management found that when the annualized wear-out maintenance cost exceeds the amortized annual replacement cost of an MMTP, that segment of pipe is a candidate for replacement (11).

Run to failure, in the opinion of the Authors, is an inefficient asset management strategy for MMTPs. At a minimum, ferrous based material pipelines should be installed with a corrosion monitoring system consisting of welded or bonded joints, with insulating joints as needed, and electrical testing stations. The very low cost monitoring system, in effect, provides a “window” to the pipeline enabling operators to determine if and when corrosion conditions exist as well as the means to mitigate changing corrosive conditions. The monitoring system is the very basis of an asset retention strategy.

Run Until Failure and Repair

Run until failure and repair strategies incorporate many of the extended life corrosion control procedures outlined in published reports and manuals (3, 4, 12) including: coatings or exterior encasements; monitoring systems; and corrosion reducing galvanic anode or impressed current systems. Once again, as with the run to failure strategies discussed above, allowing corrosion to occur is part of the strategy. Controlling corrosion to only meet design life does not protect assets.

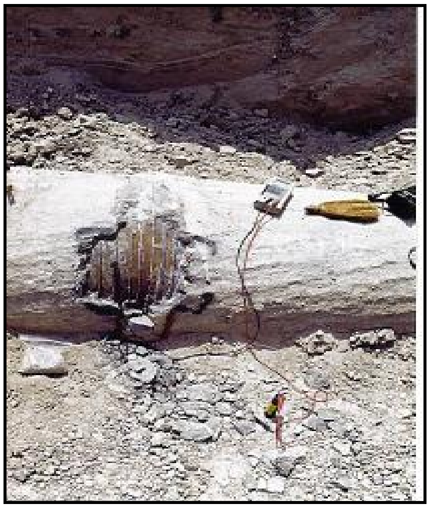
Many of the recommended strategies for extended life corrosion control exclude bonded joints (3, 4). One of the recommended strategies for ductile iron pipe in corrosive environments is loose polyethylene encasement without bonded joints. How do you know if the strategy is working if you can not monitor the system? AWWA Manual M41 Ductile Iron Pipe states that for loose wrapped polyethylene encasement, "The single most important installation criterion is that the polyethylene material completely encase the pipe and prevent contact between the pipe and surrounding soil.” This requirement is almost impossible to achieve and damage to the encasement occurs during field installation. The damaged areas allow for electrolyte and corrosive elements to migrate between the pipe and the encasement. M41 recommends field hydrostatic testing of completed pipelines and prescribes an allowable leakage allowance. If the pipeline is encased with loose wrapped polyethylene, the water (electrolyte) leakage will migrate between the pipe and the encasement increasing the potential for corrosion. Sound engineering should require that any pipeline material with loose wrapped polyethylene encasement meet a zero leakage test requirement.

Run until failure and repair and run to failure strategies for MMTPs are not efficient asset management strategies.

The recommendations for designing and installing steel pipe in accordance with AWWA Manual M11, Steel Pipe, do not include allowing corrosion, or asset depletion, as an acceptable design premise. The basic recommendations for large diameter steel water transmission pipelines include high quality bonded mortar or dielectric coatings; monitoring systems including welded or bonded joints, insulating joints where required, and test leads; and cathodic protection when needed. These recommendations are more in line with operation and maintenance strategies that are covered in the next section.

It is well documented that in corrosive environments, steel, cast iron, and ductile iron all corrode at essentially the same rate. Therefore, whatever level of corrosion control or asset management strategy is elected for one should be applicable to all. If the strategy works for one material it should work for all three.

The photos below illustrate a case were the MMTPs were operated until a failure was detected in the mortar coating and repaired before they failed.



Detail of Cement Mortar Coated Pipe Repair of Joint Mortar before Failure Occurs

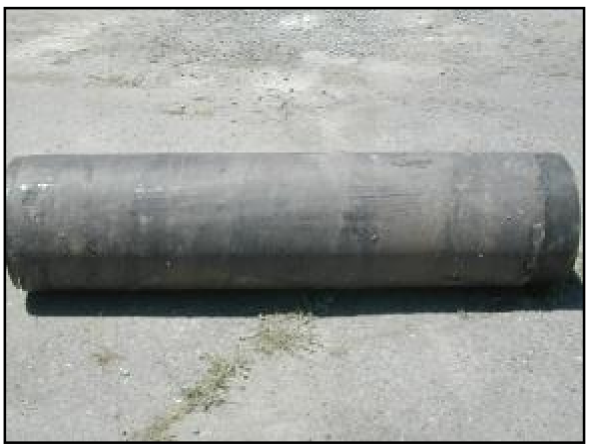
Detail of Steel Pipe to Concrete Connection Repair Before Failure Occurs

Operate and Maintain to an Indefinite Life

The operate and maintain to an indefinite life strategy for MMTPs looks at the total present and future requirement for the facility. The MMTPs are large projects that impact many aspects of a community. The amount of planning and study up front in terms of total asset management will have a very large impact on the overall cost of the project. The life cycle cost is mostly impacted by making the right decision up front. If changes are made after the initial design is completed, the cost of those changes can be significant.

For an MMTP, the wear surfaces are the interior and exterior ferrous surfaces. In the case of the interior surface, such products as cement mortar have over 50 years of empirical data. If the water quality is monitored, the interior of the MMTPs can have in excess of a 100-year life with metered inspections and repairs. For the exterior surfaces of the MMTPs, the primary driver in terms of corrosion is the soil corrosivity and future changed conditions such as stray current sources from light rail projects or adjacent cathodic protection systems. If the soils are neutral, then the MMTPs can have an indefinite life. There are cast iron pipes in France that have been in service since the 1600's (13). If the soils are corrosive, then proactive measures can be taken to protect the MMTPs from corrosion. Using a combination of coatings and cathodic protection, the life of MMTPs can be extended indefinitely. There are pipelines in service today that have been under cathodic protection since the 1940's. The Authors have had opportunities to observe pipelines with cathodic protection that had been exposed to corrosive environments. When the cathodic protection systems have been maintained, the piping was in excellent shape and should provide an indefinite service life.

The relative cost of the regular inspection, completion of minor repairs and cathodic protection will range between 2% to 5% of the initial capital cost of the MMTP. These estimates are based on designing the MMTPs such that routine inspections can be completed without a major service interruption and related costs. Many existing MMTPs have no redundancy or bypassing capabilities. Shut downs for repairs are very costly and difficult to complete. There are significant service interruptions as a result of both internal and external inspection activities. For this reason it is not uncommon to find MMTPs that have not been inspected since construction. The MMTPs shown below have performed very well over the years due to their initial design and the properties of the environment into which they were installed. The MMTP in the photo on the right below with the cement mortar armor shield and dielectric coating over the steel has been in service for over 56 years and is installed in a very severely corrosive environment. The pipeline has been under continuous cathodic protection since it was installed. Both of these installations could have an indefinite life based on their continued monitoring and maintenance.



Detail of Tape Wrapped Steel Pipe After 35 Years of Service. No Signs of Deterioration.

Steel Pipe with Dielectric Coating, Concrete Armor Shield and Cathodic Protection on Buried Sections. No Sign of Deterioration After 55 Years of Service.

Summary and Conclusions

Asset management seeks to optimize the resources of the community while delivering a certain level of service. In the case of MMTPs, the **Run to Failure Strategy** can be a very inefficient strategy depending on the corrosivity of the water being conveyed or the corrosivity of the soil along the alignment of the MMTP. A key step in the planning process for the owner of an MMTP is to determine the corrosivity of the water being conveyed and the corrosivity of the soils along the planned alignment. A review should be made of possible future activities such as Light Rail projects which may cross or run perpendicular to the MMTPs. A significant corrosion impact results from alignments that are close to fluctuating ground water.

Run Until Failure and Repair Strategy is also inefficient in that it requires more and more unscheduled repairs, which can be very costly.

Operate and Maintain to an Indefinite Life Strategy will yield significant long term savings and makes efficient use of resources because work is planned over a long period of time for asset retention. For example, the design of the MMTP would provide access points for inspection, redundancies to allow for shut downs, and internal and external monitoring points which would allow the owner to determine the condition of the interior and exterior surfaces at any time. If anything out of the ordinary is occurring it can be addressed immediately. This strategy will yield significant benefits. Recently an editorial in the March 13, 2006 issue of Engineering News record made reference to "high quality structures with indefinite life spans" (14). The editorial indicated that public infrastructure with a life span of 50 years is inadequate. Structures such as the Pont du Gard aqueduct in Nimes France is still standing after 20 centuries (14). It is possible to build public infrastructure with an indefinite life. The major challenges in the implementation of this strategy are:

1. Longer Planning Horizon. A review will be required to determine which public infrastructure projects demand this type of an approach. A major structure such as the Golden Gate Bridge or a wastewater treatment plant in a major urban setting like New York or Los Angeles would need to look at a 100-year plus planning horizon.

2. Coordination of a Multi-Disciplinary Project Implementation Team. The implementation team for these types of projects would require significant long term involvement by the following during the planning, design, construction and operation and maintenance of the project:

   a) Rate Payers

   b) Agency Managers

   c) Financial Managers

   d) Planners

   e) Engineers

   f) Operations and Maintenance Staffs

   g) Vendors

   h) Contractors

   i) Environmental Planners

3. Financial Planning and Life Cycle Cost Analysis. Once the concept of the project is determined, a life cycle cost analysis would need to be completed. The analysis would need to consider the extended life of the project and its effect on the comparison between initial costs and long term total project costs.

4. Buy In by Owner, Rate Payers, Engineers, Contractors, and Operation and Maintenance Staffs. All of the listed participants of the project must see the project as the challenge that everyone must cooperate to achieve.

From our experience, it appears that a significant benefit could be derived by utility owners if they consider the Operate and Maintain to an Indefinite Life Strategy for their existing and future MMTPs. The primary benefit will be a more reliable source of delivery for water or wastewater in the case of MMTPs with fewer unplanned repairs, and in the long term, a lower total cost of operation.

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