WANTED
A Long-Term Perspective on Public Infrastructure Maintenance

By Jose L. Villalobos and Carl Perry

In recent years, the total direct cost of corrosion in the United States has been about $276 billion a year, or a little over 3 percent of the annual GDP. This is an impressive figure, and one that we believe points directly to a pervasive problem in the management programs and strategies used to maintain the country's public and private assets. The simple truth is that corrosion can occur virtually anywhere in a facility, and it can cause significant damage in less than a year — in some cases, only a few weeks or months — yet there is no formalized process or standard, in most cases, for addressing corrosion control.

We believe a better approach is possible and long overdue. One part of this approach is to make better and more consistent use of the wide range of affordable corrosion protection technologies now available. The other part — and this may be the harder part — is to change the way we as a society think about both corrosion and about our determination to seriously protect and preserve the enormous investment represented by our public and private infrastructure facilities.

We make no claim to originality here. Over the last 10 to 15 years there has been a great deal of interest in asset management for several reasons, including stringent new public accounting standards as well as the continuing reduction of local funding for schools, streets, pipelines, treatment facilities and other infrastructure needs. Much of the pioneering work in this area has been completed in Australia, where the Government Asset Management Committee of New South Wales, in its Total Asset Management Manual, has laid out a sound methodological foundation for developing a comprehensive asset management plan. In general, such a plan would comprise:

1. A thorough, up-to-date inventory of the system;
2. A comprehensive condition assessment;
3. Life-cycle and cost analysis;
4. Planning for new facilities and repair/replacement of existing ones as needed; and
5. A structured and systematic program of operation and preventive maintenance.

A Case in Point: Metallic Municipal Water Lines

Defined as pipelines generally 24 in. and larger in diameter conveying raw or potable water, metallic municipal transmission pipelines (MMTPs) are in many ways an excellent example. Currently, municipal utility managers utilize a wide range of asset management programs for MMTPs, but all can be broadly grouped under three headings or approaches:

- Run to failure;
- Run to failure and repair as required; and
- Operate with preventive maintenance to achieve indefinite useful life.

Let's consider each of these in turn.

Run to Failure

Most run-to-failure O&M strategies are based on getting facilities built for the lowest possible initial total construction cost. Somewhere during the project design it is decided, explicitly or otherwise, that none of the existing conditions is likely to ever change, and that all present and future considerations have been properly evaluated. No safeguards are included for identifying future changes or making operational modifications. Protective systems (linings and coatings) may be used, but with little or no planned maintenance and no ability to monitor the installation. The approach is best summed up as: "Bury it and forget it."

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. Proponents of this strategy also assume that cast iron and ductile iron will provide similar service life — not a very reasonable assumption, given that both materials corrode at approximately the same rate, and that the ductile iron pipe wall thickness for a given design class can be less than one-third that of old cast iron pipe.

As corrosion progresses — at some rate that is often unknown at the time of construction — the pipeline wall effectively becomes thinner, reducing all the safety factors used in the initial pipeline designs and directly impacting the pipeline's safety, operation, maintenance and asset loss. Thus, the MMTPs may need replacing in 10 years, or they may last 100 years.

Excellent data on pipeline failures, their costs and their consequences are available from several published papers and reports. Many failures occurred only 15 years after the project was built.

Other papers and reports show that the cost to replace MMTPs exceeds 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 this magazine 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.

In short, run-to-failure must be considered an inefficient asset management strategy for MMTPs. At the very least, an MMTP should be installed with a corrosion monitoring system consisting of welded or bonded joints, with insulating joints as needed, and electrical testing stations. Such a low-cost monitoring system, in effect, provides a "window" into 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 to Failure and Repair

"Run to failure and repair" strategies incorporate many of the extended-life corrosion-control procedures outlined in a number of reports and manuals, such as coatings or exterior encasements, monitoring systems and corrosion-reducing galvanic-anode or impressed-current systems. Like the run-to-failure strategy, this approach allows corrosion to occur as part of the strategy. But again, controlling corrosion to only meet design life does not protect assets.

Many of the recommended strategies for extended life corrosion control exclude bonded joints. One recommended strategy for ductile iron pipe in corrosive environments is loose polyethylene encasement without bonded joints. But obviously, it is impossible to know if your strategy is working if you cannot 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" (emphasis added).

In practice, this requirement is almost impossible to achieve, and some minimal damage to the encasement (at least) almost always occurs during field installation, such that 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.

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.

Thus, the run-to-failure-and-repair strategy, like the run-to-failure approach, cannot be accepted as an efficient asset management strategy. It is also inefficient in that it requires more and more unscheduled repairs, which can be very costly. 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 discussed below.

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 requirements for the facility. These pipelines 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 decisions 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 more than 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 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 1600s. 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 1940s. 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 percent 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. Shutdowns for repairs are 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 Case for Indefinite Life

An asset management strategy represents, in the first instance, an effort to optimize the resources of the community while delivering a certain level of service.

In the case of MMTPs, the run-to-failure strategy is likely to prove inefficient and ultimately costly due to any one or more of several possible factors, including the corrosivity of either the soils along the planned alignment or the water being conveyed, the occurrence of future activities such as light rail projects that may cross or run perpendicular to the pipeline, fluctuations of nearby groundwater and others. The run-to-failure-and-repair strategy is also inefficient for the reasons mentioned above: with increasing age, this approach demands more and more unscheduled repairs, whose costs, direct and indirect, always tend to be higher than expected.

In contrast, a strategy of operating and maintaining facilities to achieve an indefinite life will yield significant long-term savings and other benefits. Resources are used efficiently because work is planned over a long period of time and is specifically directed at achieving asset retention. For example, MMTPs could be so designed as to provide access points for inspection, with redundancies to allow for shutdowns, and with internal and external monitoring points that allow the owner to determine the condition of the interior and exterior surfaces at any time. Then, if anything out of the ordinary occurred, it could be addressed immediately. The payoff will be a more reliable source of delivery for water or wastewater, with fewer unplanned repairs and ultimately a far lower total cost of operation.

A recent editorial in *Engineering News-Record* referred to "high quality structures with indefinite life spans" and suggested that 50 years — the general average for many modern facilities — should be considered a woefully inadequate life span for public infrastructure assets.

And why not? At Versailles, in France, there is a 15-mile water main, the first full-scale cast-iron pipe system for the distribution of water, which was installed in 1664 and is still in service more than 300 years after it was built. For that matter, another French landmark, the 883-ft-long, 160-ft-high Pont du Gard aqueduct in Nimes, was begun by the emperor Agrippa in about 19 B.C. and is still standing more than 20 centuries later. And closer to home, we can point to functioning steel pipelines in San Francisco that date back to 1863. The point is, indefinite lifetime is not a fantasy or chimera; it can be and has been done.

But is it really possible, given today's financial and political realities, to build public infrastructure with an indefinite life? We believe it is, if four main conditions are met, some of which, admittedly, will require a major shift in the way we now approach and think about these projects and assets. These are:

1. Longer planning horizons. A review will be required to determine which public infrastructure projects demand this type of an approach. A major structure such as a bridge or a wastewater treatment plant in a major urban setting would need to look at a 100 year-plus planning horizon.
2. Coordination of a multi-disciplinary project implementation team. Successful implementation of a major indefinite-life infrastructure project will require significant long-term involvement by many team players during the planning, design, construction and O&M phases. A partial list includes ratepayers, agency managers, financial managers, planners, engineers, operations and maintenance staffs, vendors, contractors and 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 owners, ratepayers, engineers, contractors and O&M staffs. All of the listed participants of the project must see the project as the challenge that everyone must cooperate to achieve.

This article has focused on water supply systems, but corrosion of water-supply systems, together with wastewater systems, represents only about 13 percent of the total annual corrosion damage in this country, which equates to $36 billion. However, what's true of these systems applies equally to every other aspect of public (or for that matter, private) infrastructure. The choices we make today about how we develop and maintain pipelines and other assets will have an enormous impact, for better or worse, on the ability of future generations to maintain and develop those facilities with whatever funds they have available for the purpose.

Our argument, in a nutshell, is to urge, in the words of the NSW Manual, "a structured and systematic resource allocation approach to infrastructure and physical asset management," in which "government's social, ecological and financial service outcomes are achieved by the most efficient means and within the resource limits of the community."

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