RECLAMATION
Managing Water in the West

Technical Memorandum No. MERL-2011-36

Guidelines for Reporting Corroded Pipe

U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center, Denver, CO

September 2011

Mission Statements

The mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to Indian Tribes and our commitments to island communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

BUREAU OF RECLAMATION
Technical Service Center, Denver, Colorado
Materials Group, 86-68180

Technical Memorandum No. MERL-2011-36

Guidelines for Reporting Corroded Pipe

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Date 9/14/2011

REVISIONS				
Date	Description	Prepared	Technical Approval	Peer Review

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Introduction

Deterioration of Reclamation pipelines can lead to leaks and very detrimental results as shown in Figure 1 and 2. Resulting costs include property damage, replacement costs, and loss of service. Injury and even loss of life can be real possibilities. Additionally, Figure 3 and Figure 4 show that leaks can develop in both buried pipe and above ground pipe.

There are numerous reasons why a pipe may develop leaks, including improper foundation or embedment, overpressure and transients, poor joining, inadequate restraint or blocking, and corrosion. This technical memorandum is focused specifically on degradation due corrosion.

The objective of this technical memorandum is to provide:

- Information as to some of the more commonly encountered Reclamation pipe types.
- Information as to the type of corrosion issues these pipe types might encounter.
- Provide direction as to what information to gather for site records when pipe corrosion is discovered and to whom this information should be distributed within Reclamation.

In this way, Reclamation can develop a better understanding of how different piping systems are performing and which maintenance, monitoring, and corrosion mitigation measures are most effective. Knowing common recurring problems will allow Reclamation to focus efforts more efficiently on future improvements.

A simple to complete reporting form and instructions are attached. Send the form, pictures, and all collected information to the Materials Engineering and Research Laboratory (MERL) of the Technical Service Center (TSC). Contact information can be found on the Reclamation website and at this writing is as follows:

Attn: Group Manager
Materials Engineering and Research Laboratory (MERL)
Denver Federal Center
Bldg. 56, Wing 1400
P.O. Box 25007 (86-68180)
Denver, CO 80225-0007

Fax: 303-445-6341

E-mail: wkepler@usbr.gov

Observations, ideally with pictures, should be recorded immediately while information is fresh and accurate. Contact a corrosion expert at MERL anytime further information or assistance is required.

Figure 1. Failure of a pipeline in a residential neighborhood resulting in extensive damage to the house.

Figure 2. Perforation resulting from corrosion of a pipeline.

Figure 3. Leak on an elevated coated and lined pipeline.

Figure 4. Leaking joint on elevated section of Halls Coulee Siphon.

General Information

The obvious priority following a pipeline failure is to contain the damage, replace the failed section, and get the system back on-line. However, determining the root cause of the failure can help prevent future recurrences. As thorough documentation as possible of the condition of the damaged pipe is important. Any peculiar or unusual observations of the pipe condition or environment should be noted along with common facts (service, age, etc.). If possible, photos of the damaged pipe should be taken prior to removal, and additional detailed photos should be taken after the pipe section has been removed and more details of the failure location are apparent. Before repairing the line, check the remaining uncovered pipe in the vicinity of the intended repair to ensure it is structurally sound. In particular, carefully inspect any welds in that area.

Similar information should be recorded when damage is observed while performing maintenance activities. In such instances, assessing the newly found damage and making timely repairs may eliminate the need for re-excavating in the future.

When excavating the pipe, take care not to cause any further damage to the affected area even if that section of pipe is to be removed. Further damage introduced during excavation could mask some important details; and close examination of such details can be critical in determining the root cause of failure. Often, much of this close examination can be performed after the section is removed and the system is operational again. Information that might be useful to the failure investigation should also be noted prior to backfilling. For instance, is a foreign pipeline observed in the vicinity of the failed pipeline? Such a foreign pipeline can lead to additional follow-up issues. Other information which would be useful to report includes the condition of the coating. Photographs of the overall failure location could be useful to a failure analyst doing following up work.

After removal of a failed section of pipe, it may be useful to mark observations directly on the pipe and to take detailed pictures for the record, as shown in Figure 5. However, do not mark over a fracture or corrosion feature; mark around or next to it. Since it is informative to have some idea of the size of the failed region, a ruler or similar object can be used to show the approximate magnitude of features in the picture, as shown in Figure 6. Figure 7 shows details of the fracture surface, and Figure 8 and Figure 9 show different appearances of surface defects. Such details could provide useful clues as to the root cause of a problem, especially if the part is not immediately available to the corrosion consultant. They could also raise questions as to the condition of the remainder of the pipeline and suggest a need for further examination or non-destructive testing (NDT). When a pipe fails at a particular feature, other similar features (e.g. girth weld) along the pipeline might be suspect as well. In some instances, establishing a service agreement and sending the failed area to the corrosion technology experts at MERL for failure analysis may be highly desirable. When this decision is made, the section should be carefully boxed or crated and sent in the same condition as it was found. Excessive cleaning of the pipe can remove possible critical evidence necessary to determine the cause of failure.

Figure 5. Failed region on pipe with detailed information written on pipe to show the original leak hole, misaligned joint, direction of flow and where the hole was on the pipe (e.g. top or bottom).

Figure 6. Hole in pipe with dimensional scale shown using a ruler.

Figure 7. Edge view of pipe section showing the fracture surface morphology.

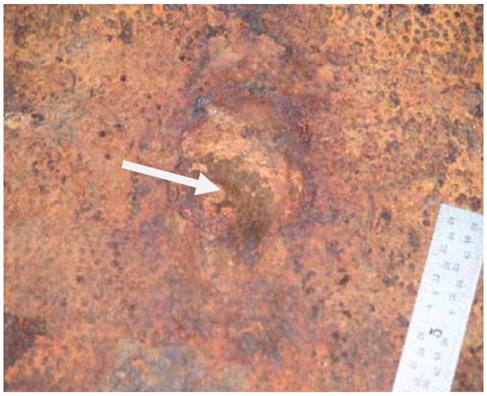

Figure 8. Appearance of pitting which occurred on the surface of a failed pipe.

Figure 9. Alternate appearance of pitting after surface cleaning.

Gray Cast Iron, Ductile Iron, or Steel Pipe

Buried Pipeline – Soil-Side Corrosion

Gray cast iron pipe was commonly used in the U.S. water industry until the 1970's. Ductile cast iron pipe supplanted gray cast iron pipe at that time, having been introduced in the late 1950's. The chemical composition of ductile iron is quite similar to that of gray cast iron. However, by adding very small amounts of elements such as magnesium, manufacturers found that the resulting metal had significant ductility, making it much less likely to crack under mechanical loads. This improvement occurs because the graphite in gray cast iron forms a continuous flake structure while the graphite in ductile iron forms isolated nodules in an iron matrix. As a result, gray cast iron when impacted will crack along the brittle graphite flake structure. Ductile cast iron will tend to deform along the much more ductile continuous iron matrix.

A common corrosion problem with gray cast iron pipes was a form of dealloying called graphitic corrosion. When graphitic corrosion occurs, the iron corrodes preferentially, leaving behind the interconnected graphite flake network, often with rust filling the voids. As a result, the dimensions and general appearance of the pipe are largely unchanged; the presence, extent, and severity of corrosion are not obvious. However, mechanical properties are vastly less than those of the original pipe. Graphitized areas, as they are sometimes called, are soft and can be carved away a knife, screwdriver, pencil or the like. Graphitic corrosion of gray cast iron pipe can cover large areas of a pipe.

Ductile iron typically suffers a form of corrosion resembling graphitic corrosion. However, ductile iron can't form a continuous network of graphite flakes since its graphite is in the form of discrete nodules. In the case of ductile iron, a continuous network of rust can form which contains embedded graphite nodules. Nonetheless, the dimensions and appearance of the corroded pipe can also resemble the original pipe. Affected areas of ductile iron pipe are typically isolated pits, plugs, or patches instead of broad regions or segments.

Gray and ductile cast iron are usually shipped with a 1 mil (0.001 in.) thick asphaltic coating. This shop coating is intended to prevent rusting while in transit or storage and will not provide reasonable protection in buried service. The surface of ductile iron is often textured from a permanent mold used in the centrifugal casting process; and this can be detected through the asphaltic coating. However, some larger diameter ductile iron pipe centrifugally cast against a sand mold may have a smooth surface.

Gray or ductile iron pipe often has a mortar lining. However, a bonded dielectric lining system is sometimes employed instead.

In soils thought to be non-corrosive or only mildly corrosive, ductile and gray cast iron pipe are sometimes buried with only the shop coating and no further protection. An unbonded polyethylene wrap or sleeve is sometimes used to provide some corrosion protection as well. However, corrosion can take place under such loose coverings as well as at tears and cuts in the polyethylene. Cathodic protection, when applied, will not protect under intact areas of polyethylene wrap; it will only protect at tears, cuts, and the like. Likewise, corrosion potential monitoring of a polyethylene wrapped pipe will only detect areas where the wrap is damaged. Reclamation recommends that, in the most corrosive soils, a good bonded coating with cathodic protection should be used for optimum corrosion protection.

Even in generally benign soils, the Reclamation policy has typically been to apply monitoring stations for checking electrochemical potentials and for bonding to pipe segments for cathodic protection should it become necessary. Thus, a pipeline with monitoring stations should not be assumed to have cathodic protection.

Gray and ductile iron pipe sections are normally joined by means of bell and spigot joints. Mechanical restraints are also sometimes used.

Buried steel pipe can suffer various types of corrosion including areas of general corrosion, crevice corrosion, differential aeration, pitting attack, as well as some other possible forms of corrosion. The rate of penetration is usually considered about the same as would be experienced with gray or ductile iron pipe. In some environments, steel pipe has been known to suffer stress corrosion cracking in which the corrosion mechanism causes cracking but no perceptible metal loss. Welded steel pipe may at times suffer particular corrosion problems at welds. This can be due to defective welding leaving slag inclusions, porosity, lack of fusion, etc., or it may be due to metallurgical differences between the weld metal and the base metal. Fillet welds can leave crevices where ground water can accumulate and could lead to crevice corrosion. Rivets are also potential areas of crevice corrosion, but this form of assembly should be seen only on older piping systems. A bell and spigot type of assembly is sometimes used to join steel pipe instead of welding.

In non-corrosive or mildly corrosive soils, steel pipe may be buried with only a mortar coating, a mortar coating with a dielectric system on top, or with a dielectric coating. The high pH of mortar can allow the surface of the steel to "passivate." In a passive state, corrosion of the steel slows down to negligible levels. Should areas of the steel lose their mortar and become exposed to soil, corrosion may be accelerated at the exposed steel due to what is termed a pH cell effect. Also, if the mortar absorbs chlorides from the soil moisture, or if dissolved carbon dioxide carbonates a thin mortar coating, passivation can be lost, and corrosion of the steel will proceed. Rust formed by corrosion will expand and crack or spall the mortar coating, increasing the likelihood of further corrosion.

In more corrosive soils, steel is normally buried with a bonded dielectric coating such as coal tar epoxy. Under such aggressive conditions, coatings are usually assisted by cathodic protection systems. If a coating is not properly applied and well adhered to the steel, ground water may migrate through the coating and cause a blister with corrosion occurring beneath the coating. At holidays, coatings may also sometimes loose adhesion and peel from the steel. Cathodic protection will not protect through blisters, or very far under a peeled coating. Coating quality assurance/quality control is therefore very important to the control of these issues.

The above are only the more common forms of corrosion observed with gray cast iron, ductile cast iron, and steel pipe. Other forms such as microbial induced corrosion (MIC) may be experienced; this form of corrosion has not been frequently reported on water pipe, possibly because it has not been recognized. Many different types of micro-organisms can cause MIC, and its appearance may take several forms (e.g. black manganese oxide deposits due to metal-depositing bacteria; orange-red tubercles due to iron oxidizing bacteria; etc.). In addition, all of these pipes may be subject to stray current corrosion. This typically happens if an impressed current groundbed is located near the pipe in question, or if a cathodically protected foreign pipe crosses the Reclamation pipe. Stray current attack is usually very localized.

Questions which should be answered and reported for gray cast iron, ductile cast iron, and steel pipe are contained in the Corroded Pipe Reporting Form attached to this document.

Water-Side Corrosion

Gray cast iron, ductile iron, and steel pipes are often lined with a thin layer of mortar or with a bonded dielectric coating system. Where the lining is missing or damaged, corrosion inside these pipes can take several forms. Rusty areas or patches may show up. Tubercles of corrosion products may jut into the water stream, not only thinning the pipe wall, but also clogging the interior and slowing the flow of fluids. Pits may develop that can eventually penetrate the pipe wall. Corrosion metal loss from the inside will typically be wider on the inside of the pipe with only a small, sharp-edged hole on the outside of the pipe. In some instances, large-scale failure of a lining system, or failure to use a lining system, may lead to extensive corrosion inside the pipe.

Exposed or Elevated Pipeline

When elevated or above ground pipes fail, there is obviously no need to excavate. This eliminates the possibility of doing further damage to the affected area in digging up the pipe, or in trying to clean up the damaged area for examination. As with buried pipe, however, careful observations are important.

The same Corroded Pipe Reporting Form attached to this document can again be used to document pertinent information when elevated pipes fail.

One particular area of concern with above ground piping is at saddles or supports, as shown in Figure 10. Deteriorated saddles or supports can cause the pipe to sag. This introduces additional mechanical stresses that, in combination with corrosion damage, can cause a pipe to fail. A sagging pipe may also not drain properly,

Figure 10. Cracked and deteriorating concrete saddles leading to sagging of the pipe, added stress on the joints, and damage to the coating on Halls Coulee Siphon. Also shows deteriorated coating on pipe.

Figure 11. Cracked and leaning concrete saddles leading to added stress on the joints and damage to the coating on Halls Coulee Siphon.

allowing more opportunity for corrosion to take place on the inside at low points. Furthermore, saddles and supports, especially if deteriorated, may allow precipitation to puddle against uncoated external areas, resulting in corrosion at those locations.

Concrete Pipes

The Nature of Reinforced Concrete and Its Corrosion

Concrete as used in pipe and other construction is basically a composite material consisting of aggregate, Portland cement (which acts as a binder when activated by water), and, possibly, chemical additives. Largely because concrete has excellent compressive strength but poor tensile resistance, steel reinforcement is often added to create reinforced concrete with improved overall mechanical properties.

With regards to corrosion, concrete may be described as a solid sponge. It will tend to soak up and retain moisture. Nonetheless, even though rebar in concrete may be considered as being in a moist environment, concrete can be a beneficial environment for iron and steel. The high pH (about 12.5) of concrete causes the surface of iron or steel to become passive, and in that passive state, ferrous corrosion slows down to a generally negligible level. However, under certain circumstances, both the concrete and the steel within it can still be subject to corrosion processes.

Concrete and mortar (Portland cement and sand) are alkaline materials and can be degraded by various sources, including acids and sulfates. A common acidic material found all around us is carbon dioxide, a gaseous component of the atmosphere that in water forms carbonic acid. Absorbed into rain drops, carbon dioxide will permeate soil and exposed concrete. In the soil, it can form carbonates and bicarbonates, establishing a chemical equilibrium. Carbonates and bicarbonates may also already be present in the soil from various mineral sources. Carbonation of concrete, as attack of concrete by dissolved carbon dioxide is known, causes the pH of concrete to become less basic. As a result, a steel rebar surface may lose its protective film and begin to corrode, forming rust. Since rust takes up significantly more space than the steel from which it came, corroding rebar swells, causing cracks in the concrete; these cracks in turn allow additional corrosion to take place. Carbonation naturally occurs from the outer surface of concrete inward, and can take quite some time to reach deeply embedded steel.

Soils containing chlorides can also lead to a loss of passivation. This may be experienced near roadways where de-icing salts are used. Corrosion of embedded steel due to chlorides is generally considered a more likely problem than carbonation of concrete.

Sulfates react with the concrete itself, creating expansive corrosion products. The concrete then crumbles away, eventually exposing rebar and allowing it to corrode. Concretes made with Type II and particularly Type V cements, and sometimes with pozzolanic materials added to these, are usually specified for high sulfate soils.

A form of corrosion occurs on iron or steel that is only partially embedded in concrete or mortar. The ferrous metal embedded in the concrete or mortar is at a more noble electrochemical potential than that in soil or water. As a result, a pH cell forms in which the ferrous metal in the concrete or mortar accelerates corrosion of that in soil or water. This effect is normally most severe immediately where the metal protrudes out of the concrete or mortar.

Concrete and mortar, while therefore desirable environments, may not always provide sufficient corrosion protection for iron or steel. However, the thicker the layer of concrete or mortar over the metal, the more likely it is to mitigate corrosion of the iron or steel.

Types of Concrete Pipe

Concrete pipes are manufactured in a number of different styles. Reinforced concrete pipe is intended for lower pressure applications. For higher pressure applications, pre-tensioned concrete pipe is sometimes used. Finally, for the highest pressure applications where concrete pipe is specified, pre-stressed concrete pipe has been employed. Due to problems with that type of construction, Reclamation has had a moratorium on the specification of pre-stressed concrete pipe since March 12, 1990. Other variations of concrete pipe, such as asbestos cement, also exist.

Concrete pipe is often buried bare where soils are non-corrosive or mildly corrosive to steel, relying on the high pH of the concrete to maintain the embedded steel in a passive state. However, monitoring stations are still normally recommended. In more corrosive situations, a coal-tar epoxy may be applied over the concrete along with cathodic protection. The coating is intended to help limit the cathodic protection current needed to protect the steel; it also slows migration of damaging corrosive species such as chlorides into the concrete.

The Corroded Pipe Reporting Form attached to this document should also be used to report pertinent information for corroded concrete pipes of all types.

Reinforced Concrete Pipe

Reinforced concrete pipe has rebar or a heavy wire mesh embedded in the concrete. It may have steel joint rings or concrete joints.

Pre-tensioned Concrete Pipe

Pre-tensioned concrete pipe resembles the pre-stressed concrete cylinder pipe described below; however, pre-tensioned pipe is normally 5 feet or less in diameter. This composite pipe has a steel cylinder with steel joint rings welded to its ends. The cylinder is lined with centrifugally placed cement mortar or concrete; then, a continuous reinforcing rod is helically wound (under controlled and lower tension than pre-stressed pipe) around the lined cylinder. A mortar coating is placed on top of this by means of high velocity impaction. The helical rod is not of high strength steel, may be slightly larger in diameter than on pre-stressed pipe, and is under less tension.

Experience with pre-tensioned concrete pipe suggests that it is less likely to have a catastrophic failure as compared to pre-stressed concrete pipe. Leaks on pre-tensioned pipe are more likely to be found around the joints. As of this writing, Reclamation has in fact not had a significant history of failures with this type of pipe; and Reclamation has no moratorium on its use. However, as with any pipe failure, should one occur on pre-tensioned concrete pipe, it is important to document everything during the excavation and inspection of the failure.

Pre-stressed Concrete Pipe

Pre-stressed concrete pipe comes in three basic forms: lined cylinder, non-cylinder, and embedded cylinder. All are typically large diameter than pre-tensioned pipe and contain high pressure fluid. When such pipes fail, they typically fail catastrophically and can be extremely dangerous. Due to a history of problems with pre-stressed concrete pipe, Reclamation has had a moratorium on the further installation of such pipe as of this writing; however, there are a number of such pipelines still in service.

Because of the catastrophic nature of pre-stressed concrete pipe failures, it is particularly important to understand the reason for a failure, the extent of damaged pipe, and proper repair techniques to restore pressure integrity. Personnel from the Materials Engineering Lab (MERL) and from the Water Conveyance Group should be involved whenever a pre-stressed concrete pipe failure is experienced or when a repair is planned.

Figure 12 and Figure 13 show the results following the failure of a 66 inch diameter embedded cylinder pre-stressed concrete pipe. Figure 14 shows spalling of the mortar coating on the outside of a similar pipe. Had this latter damage not been caught early, it could have also have lead to a catastrophic and costly failure.

Figure 12. Failure of a 66 inch diameter pre-stressed concrete pipe.

Figure 13. Failed section of 66 inch diameter pre-stressed concrete cylinder pipe.

Figure 14. Spalling of the mortar coating on a pre-stressed concrete pipe which could eventually lead to failure of the pipeline.

Plastic Pipes

Types of Plastic Pipes and Issues

The most commonly used polymer or plastic pipe materials employed by Reclamation are PVC (Polyvinyl Chloride) and high-density polyethylene (HDPE). However, some FRP pipe (Fiber Reinforced Polymer or fiberglass pipe, as it is sometimes called) may be encountered. FRP is a composite material, typically with glass fibers reinforcing a thermosetting resin polymer; the Water Conveyance Branch imposed a temporary moratorium on the specification of an FRP pipe option in 1990. A form of FRP pipe once manufactured under the brand name Techite® has had a particular history of problems and is no longer employed by Reclamation; however, it may be encountered in the field.

Degradation of plastic pipe materials in soil or water is not electrochemical in nature, as it is in the case of metallic or metal containing pipe. Nonetheless, plastic pipe can be affected by a contaminated environment, becoming brittle or soft, and breaking or leaking. Plastics subject to oils, gasoline, or other organic fluids in particular may suffer such problems. This can occur over time when a plastic pipe passes though contaminated soil, or is affected by another pipeline that is leaking such chemicals.

In above ground applications, degradation by UV light rays can be a problem. PVC in particular is known to be susceptible to embrittlement by UV (e.g. sunlight) over time. Sudden brittle fracture can subsequently occur without warning. Therefore above ground use of PVC in an outdoor environment can be problematic; underground use shields it from UV.

Plastics will also usually expand and contract much more than ferrous materials when subjected to temperature variations. This can lead to wear abrasion, buckling, or tensile damage if allowances are not made.

Unlike steel, some polymer materials such as FRP may readily crack or break instead of deforming if stressed. Plastic materials become more brittle when exposed to cold temperatures.

One may join plastic pipe together in a number of ways. Solvent welding is a common method of connecting small diameter PVC pipe together. This technique uses a solvent to chemically dissolve together some of the pipe and some of a coupling or other fitting of PVC material. The PVC then re-solidifies into one continuous piece of plastic. Larger diameter PVC pipe often employs a bell and spigot joint. Connecting HDPE pipe together commonly employs fusion bonding, a method in which the ends of two pipes are heated to a prescribed temperature and forced together, causing the material to fuse together. Fusion bonding is also used for some PVC pipe systems.

The Corroded Pipe Reporting Form attached to this document should also be used for documenting failures of damage to all types of plastic pipe.

Conclusions

Reclamation has and continues to employ a number of different types of pipe. These include, but may not be limited to:

- Steel (welded, bell and spigot, or riveted) pipe
- Gray cast iron pipe
- Ductile cast iron pipe
- Reinforced concrete pipe
- Pre-tensioned concrete pipe

- Pre-stressed cylinder concrete pipe
- Pre-stressed non-cylinder concrete pipe
- Pre-stressed lined cylinder concrete pipe
- Asbestos-cement pipe
- PVC pipe
- HDPE pipe
- FRP pipe

All are susceptible to deterioration due to a reaction with their environment – the definition of corrosion. All are susceptible to leaks and failures.

To ensure a long service life, proper measures must be taken in the design and installation stage of the various pipe systems. These measures include a mechanical design that addresses the particular mechanical characteristics of the pipe, and corrosion control measures that address the particular corrosion characteristics of the pipe material in a particular environment (e.g. soil or water). Accurate records reflecting feed-back from the field can provide a valuable way of informing Reclamation as to whether a pipe provides the service life it should.

Personnel in the field should document failures, their observations during maintenance and repairs or during inspections, and maintain records of these findings. It is also beneficial to report such findings to MERL where reports from various Reclamation sites can be analyzed for commonly recurring issues. This can lead to improved designs or more effective corrosion mitigation measures. Reports detailing pipe failures can also serve as a starting point for a failure analysis should the reporting authority require one. In the hands of specialized personnel, a failure report may further serve as an indicator of similar upcoming problems on the remainder of that pipeline, or on similar pipelines elsewhere within Reclamation. Reports can serve as the basis for additional inspection and testing of a specific nature at given locations, thereby preventing future pipeline failures. The Corroded Pipe Reporting Form provided with this technical memorandum is a simple and easy method for accomplishing all this with a minimum amount of time involved. Users are encouraged to supplement it with photos and any additional data; and to contact the TSC by phone, e-mail, or fax as needed.

APPENDIX A

CORRODED PIPE REPORTING FORM

CORRODED PIPE REPORTING FORM (page 1)

Person Reporting:________________________________ **Date:**__________________

Project & Location: __________________________**Phone:**______________________

Age of Pipe:____________ **Buried or Above Ground:**__________________________

Pipe Diameter:_________ **Pipe Design Press.:**_________ **Use:**__________________

<table>
<tr><th colspan="4">Question</th><th>Comments/Specifics</th></tr>
<tr><td colspan="5"></td></tr>
<tr><td rowspan="9">Pipe Material</td><td colspan="2">Steel</td><td></td><td></td></tr>
<tr><td colspan="2">Gray Cast Iron[a]</td><td></td><td></td></tr>
<tr><td colspan="2">Ductile Iron[a]</td><td></td><td></td></tr>
<tr><td rowspan="3">Concrete[b]</td><td>Pre-stressed</td><td></td><td></td></tr>
<tr><td>Pre-tensioned</td><td></td><td></td></tr>
<tr><td>Reinforced</td><td></td><td></td></tr>
<tr><td rowspan="3">Plastic[c]</td><td>PVC</td><td></td><td></td></tr>
<tr><td>HDPE</td><td></td><td></td></tr>
<tr><td>FRP</td><td></td><td></td></tr>
<tr><td></td><td colspan="2">Other</td><td></td><td></td></tr>
<tr><td colspan="5"></td></tr>
<tr><td rowspan="6">Coating (outside) and condition[d]</td><td colspan="2">Bonded dielectric (paint, tape, etc.)</td><td></td><td></td></tr>
<tr><td colspan="2">Mortar</td><td></td><td></td></tr>
<tr><td colspan="2">Thin, black, shop coat on cast or ductile iron</td><td></td><td></td></tr>
<tr><td colspan="2">Polyethylene wrap</td><td></td><td></td></tr>
<tr><td colspan="2">None</td><td></td><td></td></tr>
<tr><td colspan="2">Other</td><td></td><td></td></tr>
<tr><td>Soil side deposits[e]</td><td colspan="4"></td></tr>
<tr><td colspan="5"></td></tr>
<tr><td rowspan="4">Lining (inside) and condition[d]</td><td colspan="2">Bonded dielectric (paint, etc.); describe</td><td></td><td></td></tr>
<tr><td colspan="2">Mortar</td><td></td><td></td></tr>
<tr><td colspan="2">None</td><td></td><td></td></tr>
<tr><td colspan="2">Other</td><td></td><td></td></tr>
<tr><td>Internal deposits[e]</td><td colspan="4"></td></tr>
<tr><td colspan="5"></td></tr>
<tr><td>Backfill conditions[f]</td><td colspan="4"></td></tr>
<tr><td colspan="5"></td></tr>
</table>

CORRODED PIPE REPORTING FORM (page 2)

Person Reporting:________________________________ Date:__________________

Project & Location: __________________________Phone:______________________

Age of Pipe:____________ Buried or Above Ground:__________________________

Pipe Diameter:_________ Pipe Design Press.:_________ Use:__________________

Question				Comments/Specifics
Is pipe cathodically protected?	None			
	Rectifier			
	Sacrificial anode			
Test Stations?				
Other buried structures near this pipe?[g]				
Nature of failure or damage	Hole or cavity			
		From outside[h]		
		From inside[i]		
	Cracking[j]			
	Weeping[k]			
	Pits			
	Mechanical damage[l]			
	Leaking joint			
	Other			
Location of failure or damage[m]	Clock position			
	At weld			
		Girth weld		
		Axial weld		
	At bell and spigot			
	At flange			
	Other			
Maintenance History Notes				
Action taken on this occasion and estimated cost				

Notes and Instructions:

a: Gray cast iron will fracture when struck forcefully and the fracture surface will be a dark charcoal gray. Unless it is very cold, ductile iron will normally bend when struck forcefully.

b: Pre-stressed, pre-tensioned, and reinforced concrete pipes may be difficult to distinguish from one another. If the pipe has wire rods (1/4 in. or less) wound on a concrete core not containing a steel cylinder, then it is a non-cylinder pre-stressed concrete pipe. If this pipe has an embedded 16 gauge steel cylinder in the core, then it is an embedded cylinder pre-stressed concrete pipe. A third variation, rarely if ever used on Reclamation projects, is the lined cylinder pre-stressed concrete pipe in which the 16 gauge steel cylinder is external to the concrete core and the wire rods are directly on the steel cylinder. Pre-tensioned concrete cylinder pipe resembles this latter variation of pre-stressed pipe; however, in pre-tensioned pipe, the wire rod is ¼ in. or thicker, and the steel cylinder is thicker. If there is axial as well as circumferential reinforcement present, then this is reinforced concrete pipe; this pipe may have ½ in. or thicker rebar or a rod cage embedded in the concrete. Describe in the comments column whether this pipe has a cylinder or not, the size of the reinforcing rod or wire, thickness of the cylinder, if any, and any other distinguishing characteristics and details noted (e.g. manufacturer).

c: Describe in the comments column what kind of plastic (PVC, HDPE, FRP etc.), the manufacturer, and any other details known.

d: Coatings (outside pipe) and linings (inside pipe) may soften, form blisters, which may be dry or contain liquid, crack, peel away from the pipe, have pinholes (typically rust spots showing on a painted surface), or they may show scorch marks from nearby welding, or other features. Describe these or other findings in as much detail as possible. Provide the coating type and manufacturer.

e: Describe deposits and their color, such as orange-red tubercles, which might indicate iron oxidizing bacteria, black deposits, which may indicate manganese oxide-depositing bacteria, white calcareous deposits, which might result from electrical current getting onto the pipe, etc.

f: Describe the type of backfill used (e.g. sand, pea gravel, etc.), whether the area is wet or dry (e.g. swampy area; leaking sewer pipe in area; etc.), smells (e.g. rotten egg odor), and any other distinguishing features of the ground and site where the pipe is buried.

g: Describe on this form the type of foreign structure (e.g. pipe, cable, etc.), if it is known to be under cathodic protection, whether there is a resistance bond to the foreign structure, etc.

h:A corrosion hole that starts on the outside is typically narrower on the inside of the pipe.

i: A corrosion hole that starts on the inside is typically narrower on the outside of the pipe.

j: Indicate number of cracks, their orientation (e.g. whether they run axially, circumferentially, etc.), size, etc.

k: Weeping may indicate selective leaching has taken place (e.g. graphitic corrosion of gray cast iron). Areas suffering from selective leaching may not show metal loss but are soft; they can easily be breached by a shovel or other tool. Note in the comments whether this appearance is observed or if other features are present.

l: Describe the nature and source of the mechanical damage if known (e.g. installation damage).

m:Facing downstream, consider the top of the pipe to be 12 o'clock; on a vertical run of pipe, consider North to be 12 o'clock. In the comment column, also provide distance from next pipe joint or weld downstream of the failure point. If at a weld, bell and spigot, or flange, clarify specifically where (e.g. edge of weld; middle of weld bead; ¼ in. from toe of weld; etc.)

Send copies of completed forms, pictures, sketches, and any supplemental information to:

Attn: Group Manager
Materials Engineering and Research Laboratory (MERL)
Denver Federal Center
Bldg. 56, Rm. 2766
P.O. Box 25007 (86-68180)
Denver, CO 80225-0007 Fax: 303-445-6341 E-mail: wkepler@usbr.gov

Additional Comments:

APPENDIX B

SAMPLE CORRODED PIPE REPORTING FORM FILLED OUT

CORRODED PIPE REPORTING FORM (page 1)

Person Reporting:_John Doe, Maintenance Foreman___ Date:_9/10/11__________

Project & Location: CUP, Provo Utah _____Phone:_123-456-7899_________

Age of Pipe:_35 yr._____ Buried or Above Ground:__Buried__________________

Pipe Diameter:_36 in.__ Pipe Design Press.:_250 psi. Use:_Water Transmission_

Question				Comments/Specifics
Pipe material	Steel		X	Spiral welded pipe; butt welded segments.
	Gray Cast Iron[a]			
	Ductile Iron[a]			
	Concrete[b]	Pre-stressed		
		Pre-tensioned		
		Reinforced		
	Plastic[c]	PVC		
		HDPE		
		FRP		
	Other			
Coating (outside) and condition[d]	Bonded dielectric (paint, tape, etc.)		X	Epoxy coating in fair condition; noted 3 areas of shallow rusting at apparent scratches in the coating; 1 water-filled blister w/no pit; 2 mounds of rust about ¼ in. deep.
	Mortar			
	Thin, black, shop coat on cast or ductile iron			
	Polyethylene wrap			
	None			
	Other			
Soil side deposits[e]	2 orange red tubercles (mounds of rust) at coating defects with ¼ in. deep pits beneath.			
Lining (inside) and condition[d]	Bonded dielectric (paint, etc.); describe			
	Mortar		X	No problems noted except at leak point in weld.
	None			
	Other			
Internal deposits[e]	None.			
Backfill conditions[f]	Sand backfill had been used. Area was very wet due to low point geographically; area stays wet much of the time.			

CORRODED PIPE REPORTING FORM (page 2)

Person Reporting:_John Doe, Maintenance Foreman___ Date:_9/10/11___________

Project & Location: _CUP, Provo Utah__________Phone:_123-456-7899_________

Age of Pipe:_35 yr._____ Buried or Above Ground:_Buried____________________

Pipe Diameter:_36 in.___ Pipe Design Press.:_250 psi.__ Use:_Water Transmission_

Question				Comments/Specifics
Is pipe cathodically protected?	None			
	Rectifier		X	Has been turned off for past three years.
	Sacrificial anode			
Test Stations?	Yes, nearest test station is about 50 ft. away.			
Other buried structures near this pipe?[g]	Gas pipeline crossing about 500 ft. away.			
Nature of failure or damage	Hole or cavity			
		From outside[h]	X	At a girth weld.
		From inside[i]		
	Cracking[j]			
	Weeping[k]			
	Pits		X	The 2 rust mounds had 1/8 in. deep pits on soil side.
	Mechanical damage[l]			
	Leaking joint			
	Other			
Location of failure or damage[m]	Clock position			
	At weld			
		Girth weld	X	At 6:00 o'clock position; approx. center of weld.
		Axial weld		
	At bell and spigot			
	At flange			
	Other			
Maintenance History Notes	First failure noted on this pipe.			
Action taken on this occasion and estimated cost	Cut out a 3-foot length of corroded pipe and welded new section. Field coated with same coating system after surface preparation by hand. Installed a 17 lb. anode through nearest test station. Approximate cost of materials and labor - $15,000.			

Notes and Instructions:

a: Gray cast iron will fracture when struck forcefully and the fracture surface will be a dark charcoal gray. Unless it is very cold, ductile iron will normally bend when struck forcefully.

b: Pre-stressed, pre-tensioned, and reinforced concrete pipes may be difficult to distinguish from one another. If the pipe has wire rods (1/4 in. or less) wound on a concrete core not containing a steel cylinder, then it is a non-cylinder pre-stressed concrete pipe. If this pipe has an embedded 16 gauge steel cylinder in the core, then it is an embedded cylinder pre-stressed concrete pipe. A third variation, rarely if ever used on Reclamation projects, is the lined cylinder pre-stressed concrete pipe in which the 16 gauge steel cylinder is external to the concrete core and the wire rods are directly on the steel cylinder. Pre-tensioned concrete cylinder pipe resembles this latter variation of pre-stressed pipe; however, in pre-tensioned pipe, the wire rod is ¼ in. or thicker, and the steel cylinder is thicker. If there is axial as well as circumferential reinforcement present, then this is reinforced concrete pipe; this pipe may have ½ in. or thicker rebar or a rod cage embedded in the concrete. Describe in the comments column whether this pipe has a cylinder or not, the size of the reinforcing rod or wire, thickness of the cylinder, if any, and any other distinguishing characteristics and details noted (e.g. manufacturer).

c: Describe in the comments column what kind of plastic (PVC, HDPE, FRP etc.), the manufacturer, and any other details known.

d: Coatings (outside pipe) and linings (inside pipe) may soften, form blisters, which may be dry or contain liquid, crack, peel away from the pipe, have pinholes (typically rust spots showing on a painted surface), or they may show scorch marks from nearby welding, or other features. Describe these or other findings in as much detail as possible. Provide the coating type and manufacturer.

e: Describe deposits and their color, such as orange-red tubercles, which might indicate iron oxidizing bacteria, black deposits, which may indicate manganese oxide-depositing bacteria, white calcareous deposits, which might result from electrical current getting onto the pipe, etc.

f: Describe the type of backfill used (e.g. sand, pea gravel, etc.), whether the area is wet or dry (e.g. swampy area; leaking sewer pipe in area; etc.), smells (e.g. rotten egg odor), and any other distinguishing features of the ground and site where the pipe is buried.

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Additional Comments:

Rectifier was turned off about 3 years ago because it was determined that the anode bed was consumed and rectifier was not able to pass any significant amount of current. A decision was made not to replace the anode bed because this pipe was to be replaced within 5 years.

Magnesium anode was installed on repaired section per Materials Engineering and Research Lab (MERL) corrosion team recommendation.

Section of pipe removed is being shipped to MERL for closer inspection.