RECLAMATION

Managing Water in the West

Durability Testing of Fiberglass Pipe for Reclamation Pipelines

Research and Development Office
Science and Technology Program
Final Report ST-2018-9777-02, 8540-2018-52

U.S. Department of the Interior
Bureau of Reclamation
Research and Development Office

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Mission Statements

Protecting America's Great Outdoors and Powering Our Future

The Department of the Interior protects and manages the Nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated island communities

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14. ABSTRACT *(Maximum 200 words)* The project evaluated reinforced plastic mortar (RPM) fiberglass piping to determine the state of the art and progress made since the failures experienced during the 1970s and 1980s. The report includes the results of a literature review, a manufacturer site visit, field project sites, and laboratory pipe stiffness testing of candidate materials for new installations.

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Durability Testing of Fiberglass Pipe for Reclamation Pipelines

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Acronyms and Abbreviations

ASTM	ASTM International
AWWA	American Water Works Association
CLSM	Controlled low strength material
GRP	Glass reinforced polymer
MPa	Megapascal
NDE	Nondestructive evaluation
psi	pounds per square inch
RPM	Reinforced Plastic Mortar
UV	Ultraviolet

Executive Summary

Fiberglass pipe is a light-weight and corrosion-resistant alternative to pipe made of concrete, steel, and other materials. Between 1967 and 1984, Reclamation installed approximately 100 miles of reinforced plastic mortar (RPM) pressure pipe, some of which failed within 10 years of installation. Preliminary pipe failure investigations revealed several inherent weaknesses in the design, manufacturing, and installation practices of the pipe. In 1997, Reclamation lifted a moratorium on the use of RPM pipe after determining that deficiencies observed previously had been adequately resolved. The use of RPM pipe in Reclamation projects subsequently increased.

The present study investigated current RPM pipe design practices, manufacturing methods, and quality control techniques. This investigation included an in-depth literature review, RPM pipe manufacturer site visits and interviews, field structure performance evaluations, and in-house laboratory testing.

The report appendices provide the results of a literature review and the outcome of site visits to Flowtite, Leadville Mine Drainage Tunnel Water Treatment Plant, and the Navajo Gallup project site. Reclamation conducted stiffness testing according to ASTM D-2412 to determine whether the stiffness of Flowtite fiberglass pipe was at least 0.25 megapascals (MPa), the accepted standard for RPM pipe in the United States. The tested pipe had a stiffness of 0.31 MPa at 5% deflection. This stiffness value represents a significant improvement over stiffness values of pipe made during the 1970s, when values on the order of 0.07 MPa were typical. The improved stiffness is likely a result of the use of continuous fibers in combination with chopped fibers which give additional axial support.

Unresolved issues associated with inspection, specification, performance testing, and installation remain and will need to be addressed as Reclamation moves forward with the use of fiberglass pipe. Minimum stiffness requirements should be raised from 0.12 MPa to 0.25 MPa in future specifications for buried fiberglass as higher stiffness could reduce the need for high-cost controlled low strength material (CLSM) backfill. Higher stiffness will also improve operational safety, functionality, and service life duration of buried pipelines. Several other issues need to be addressed, particularly inspection and maintenance of the piping after installation. Nondestructive evaluation (NDE) methods for inspection of piping during shipping, handling, and installation will also need to be developed and implemented.

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Introduction

Fiberglass pipe has been promoted as a light-weight and corrosion-resistant alternative to pipe made of concrete, steel, and other materials. The use of fiberglass pipe obviates the need for cathodic protection and protective coatings, even in corrosive soil environments. Fiberglass pipe can be more expensive than other pipe options, but its higher strength and excellent chemical resistance make it cost competitive in large-diameter, high-pressure applications. In addition, fiberglass pipe's low relative weight can reduce installation costs and increase installation rates.

Between 1967 and 1984, Reclamation installed approximately 100 miles of "Techite" brand reinforced plastic mortar (RPM) fiberglass pressure pipe in diameters ranging from 6 to 72 inches. During this period, RPM pipe was made by hand-wrapping fibers around a steel mandrel and then alternating layers of resin and sand filler. Using this manufacturing technique, the quality of the finished product depended on the skill of the manufacturing technician. The hand lay-up process resulted in resin voids within the pipe wall profile. Voids made the RPM pipe more sensitive than other pipe types to construction impact damage [1].

Some of RPM pipe used by Reclamation failed within 10 years of installation; some pipe used by users failed within the first 5 years of service. The greater time-to-failure observed in Reclamation projects can likely be attributed to Reclamation's stringent pipe inspection and quality assurance practices during both manufacturing and installation. Preliminary pipe failure investigations revealed several inherent weaknesses in the design, manufacturing, and installation practices of the pipe. Techite brand RPM pipe was withdrawn from the market following several lawsuits in the mid-1980s [1].

In most cases of failure, the RPM pipes had been buried in the "right-of-way" space along rural roads and had failed "catastrophically" (i.e., experienced sudden and unexpected burst). These factors raised concerns for public safety. In March of 1990, Reclamation placed a moratorium on the use of RPM pipe on Reclamation projects and then initiated an investigation to determine the causes of premature pipe failure (see Appendix A). Reclamation ultimately concluded that the RPM pipe manufacturing process control was subject to high variability and that the pipe was thus unsuitable for future use.

RPM pipe manufacturers worked to improve pipe design and eventually offered substantially improved products with designs tailored to project-specific operational requirements. The improved composite pipe is centrifugally-cast using chopped or continuous fibers. The centrifugal casting process results in a dense pipe wall with complete resin saturation of the glass and sand filler. Manufacturing operations are computer-controlled.

In 1997, Reclamation lifted the moratorium on the use of RPM pipe after determining that the deficiencies in earlier pipe had been adequately resolved. New pipe was required to meet the newly developed American Water Works Association (AWWA) C950-95 Fiberglass Pipe Standard [2] and the guidelines of the AWWA M45-95 Fiberglass Pipe Design Manual [3]. Regardless of the lifted moratorium, Reclamation clients retained ultimate authority in pipe selection and typically preferred to use RPM pipe only in smaller jobs.

Reclamation Science & Technology Program Project ID 9940 [4] evaluated applications for engineered composites during FY 2015. Results of that project indicated that Reclamation could benefit from further investigation of composite pipe materials. The present study was implemented to investigate current RPM pipe design practices, manufacturing methods, and quality control techniques. This investigation included an in-depth literature review, RPM pipe manufacturer site visits and interviews, field structure performance evaluations, and in-house laboratory testing.

Note that while this research focused primarily on fiberglass pipe, some of the findings might be applicable to other fiberglass composite structures (e.g., tanks, vaults) and components (e.g., manholes, pipe fittings).

Literature sources including databases, field reports, research reports, memoranda, design manuals, and original ASTM International (ASTM) standards were reviewed so that design, manufacturing, and installation deficiencies of early fiberglass pipe (i.e., late 1960s-early 1980s) could be clarified. The literature review was published as ST-2016-9777-01 in April 2016 and is included in the present report as Appendix A. The review effectively: 1) documented the history of RPM pipe use at Reclamation, 2) described current manufacturing methods and quality control test, 3) detailed the progress made in regards to the past RPM design and manufacture, and 4) identified key issues that still need to be addressed.

The review also included a survey of the capabilities of current fiberglass pipe manufacturers. The study revealed that most manufacturers make low-stiffness RPM fiberglass pipe, but two manufacturers, Hobas and Flowtite, produce pipe with sand filler and the higher stiffness needed for buried applications. The Flowtite pipe uses continuous glass fibers which yield greater pipe strength, desirable in typical Reclamation projects. Accordingly, Flowtite was selected as a destination for a site visit.

Manufacturer and Field Site Visits

Researchers from Reclamation and the U.S. Army Corps of Engineers (a research partner for this project) visited Flowtite, one of the two RPM pipe manufacturers identified during the literature review phase [1]. This visit provided the opportunity to witness, discuss, and evaluate both the manufacturing and testing capabilities of Flowtite.

Flowtite’s current manufacturing technique is a filament-winding manufacturing process that uses a steel wrap, fiberglass wrap, chopped glass fibers, sand, thermoset resin, and heat. The pipe-forming mandrel is covered with a Mylar® wrap that is removed and replaced after each pipe section is fabricated.

All Flowtite pipe sections are pressure tested with water according to ASTM D2922 [5]. Each section is pressurized and held at a value equal to approximately twice the rated pressure. Maximum pressure is maintained for two minutes; loss of pressure is cause for pipe rejection, as it is indicative of a possible future pipe failure.

Researchers also visited the Leadville Mine Drainage Tunnel Water Treatment Plant and the Navajo Gallup project site to inspect two in-service fiberglass composite structures.

Additional notes and several photographs related to both the manufacturer and field site visits were compiled in travel reports, attached to this report as Appendices B and C.

Reclamation Laboratory Testing

Given inherent flexibility, fiberglass pipe relies primarily on the strength of the pipe bedding material to support overburden. Pipe stiffness is nonetheless an important parameter and is used in combination with soil modulus to evaluate pipe deflection.

Reclamation has the capability to perform stiffness testing (ASTM D-2412) [6], *Split D Tensile Strength* (ASTM D2290) [7], *Erosion-Abrasion Resistance* (no universally accepted standard), and *Impact Resistance* (pendulum: ASTM D256 [8] and falling weight: ASTM D2444 [9]). These tests are described in greater detail in the Literature Review, Appendix A.

To determine whether or not the Flowtite fiberglass pipe is capable of meeting the AWWA standard of 0.25 megapascals (MPa) stiffness for RPM pipe, Reclamation conducted stiffness testing according to ASTM D-2412 [6].

Method

ASTM D-2412 [6] dictates measuring pipe deflection while a compressive load is applied at a constant rate to a short section of pipe via two parallel plates (see Figure 1). Deflection of the pipe diameter is recorded throughout the test. Pipe stiffness is determined by measuring the force per unit length to compress a section of pipe to 5% deflection. The pipe must then withstand further loading to 20% deflection without structural failure. Pipe stiffness is reported in pounds per square inch (psi) at 5% deflection and converted to MPa for comparison to the required stiffness value.

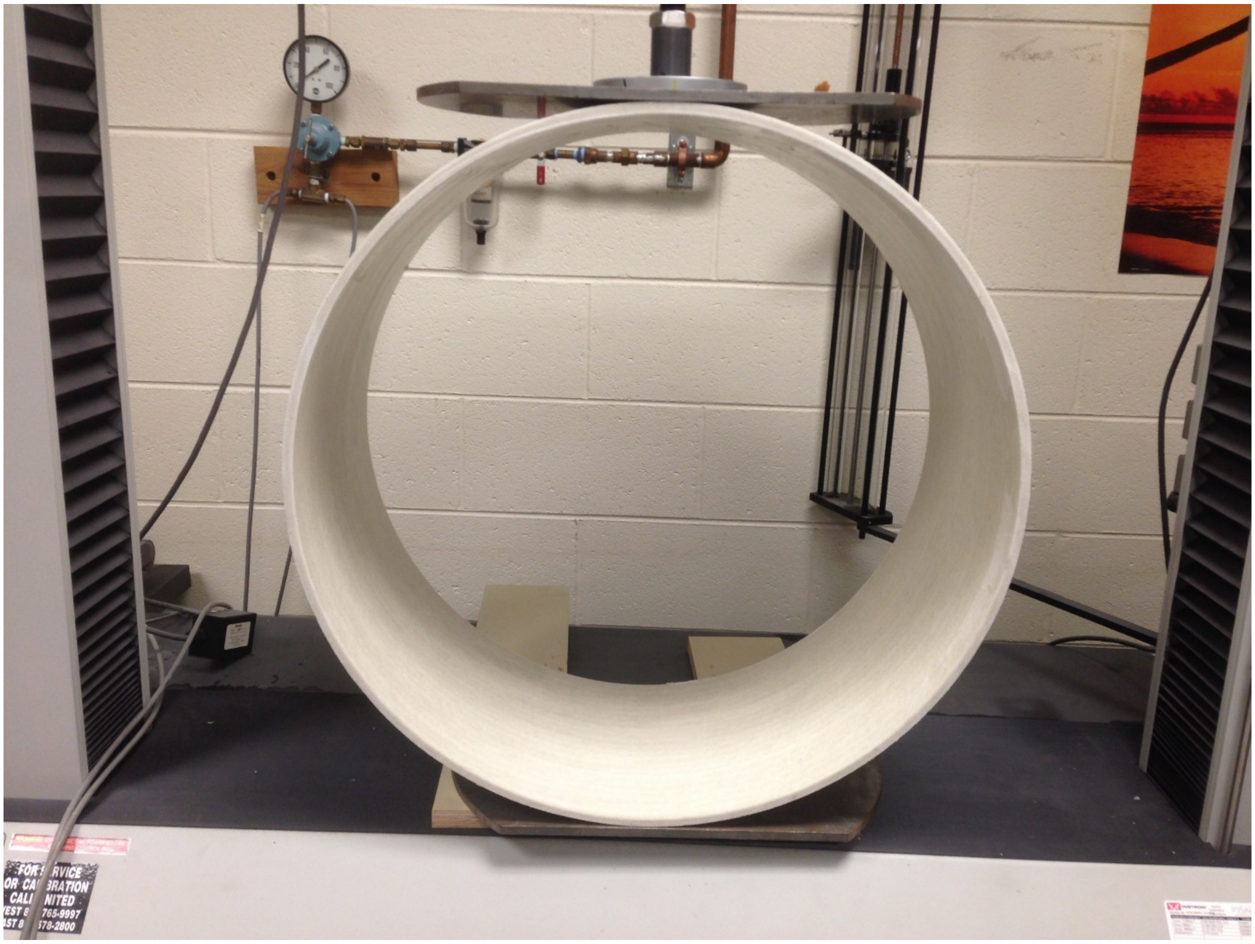


Figure 1 - Stiffness testing Flowtite 24-inch RPM pipe at the Reclamation laboratory.

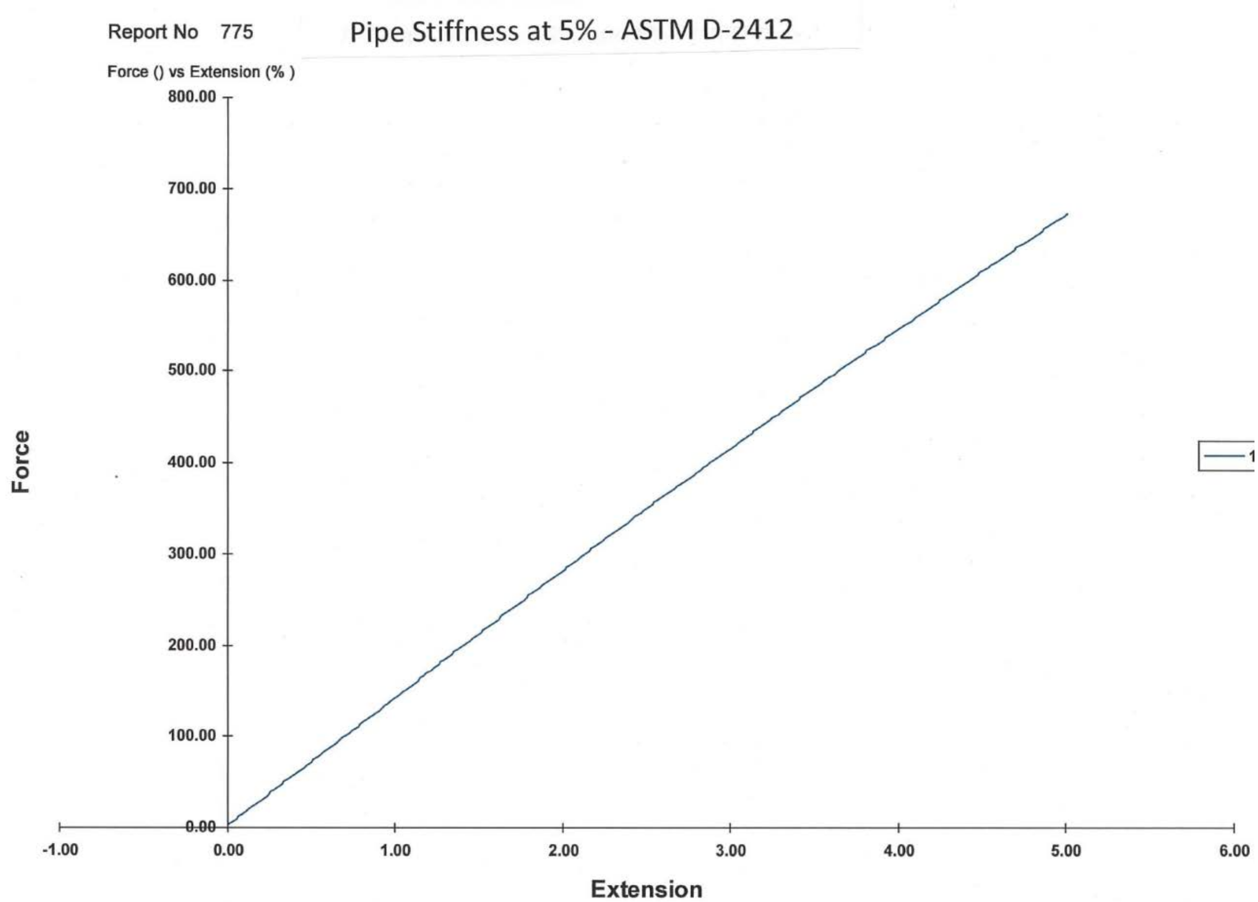
Results

Reclamation evaluated pipe stiffness of a short section of 25-inch diameter RPM pipe manufactured by Flowtite. The tested pipe had stiffness of 0.31 MPa (45 psi) at 5% deflection (see Table 1 and Figure 2). This stiffness value represents a significant improvement over stiffness values of pipe made during the 1970s, when values on the order of 0.07 MPa were typical. The observed enhanced performance can be attributed to Flowtite's use of continuous fibers in combination with chopped fibers which give additional axial support.

Table 1 - Pipe stiffness testing results from testing performed in Reclamation's laboratory.

	Pipe Diameter (inches)	Length (inches)	Force at 5% (psi)	Pipe Stiffness at 5% (psi)
Flowtite	25.1	11.75	672	45.58

Figure 2 - Pipe stiffness testing results from Reclamation's laboratory.



Conclusion

RPM fiberglass pipe design and manufacturing technology have improved significantly since the 1960s. Industry standards have improved as a result of more-stringent production and installation requirements. Stiffness of current-production fiberglass pipe manufactured by companies such as Hobas and Flowtite is much higher than that of pipes made before and during the Reclamation moratorium period. Accordingly, modern RPM pipe is much more suitable for buried applications. Current-production pipes are also less likely to fail catastrophically in high operating pressure applications because of the higher factors of safety applied during the design process.

The minimum pipe stiffness requirement should be raised from 0.125 MPa (18 psi) to 0.25 MPa (36 psi) in future specifications for buried fiberglass pipe. Higher stiffness will, in some instances, obviate the need for the use of high-cost CLSM backfill. Higher stiffness will also improve operational safety, functionality, and service life duration of buried pipelines.

Unresolved issues associated with inspection, maintenance, specification, performance testing, and installation remain and will need to be addressed as Reclamation moves forward with the use of fiberglass pipe. Nondestructive evaluation (NDE) methods for inspection of piping during shipping, handling, and installation will also need to be developed and implemented. Several specific areas of needed research were discussed in the Literature Review (see Appendix A).

References

[1] United States Department of the Interior, Bureau of Reclamation, "Fiberglass Pipe Literature Review", Interim Report ST-2016-9777-01, Denver CO, 2016.

[2] American Water Works Association, Standard for Fiberglass Pressure Pipe, Denver CO, 2013.

[3] American Water Works Association, M45 - Manual for Fiberglass Pipe Design, Denver CO, 2014.

[4] United States Department of the Interior, Bureau of Reclamation, "Composite Materials for Reclamation Infrastructure", ST-2015-9940-01, Denver CO, 2015.

[5] ASTM International, D2922 - Standard Test Methods for Density of Soil and Soil-Aggregate in Place by Nuclear Methods (Shallow Depth), 2005.

[6] ASTM International, D2412 - Standard for Determination of External Loading Characteristics for Plastic Pipe by Parallel-Plate Loading, 2002.

[7] ASTM International, D2290 - Standard Test Method for Apparent Hoop Tensile Strength of Plastic or Reinforced Plastic Pipe, 2016.

[8] ASTM International, D256 - Standard Test Methods for Determining the Izod Pendulum Impact Resistance of Plastics, 2010.

[9] ASTM International, D2444 - Standard Practice for Determination of the Impact Resistance of Thermoplastic Pipe and Fittings by Means of a Tup (Falling Weight), 2017.

Appendix A – Fiberglass Pipe Literature Review

RECLAMATION
Managing Water in the West

Fiberglass Pipe Literature Review

Research and Development Office
Science and Technology Program
Interim Report ST-2016-9777-01

U.S. Department of the Interior
Bureau of Reclamation
Research and Development Office

April 22, 2016

Mission Statements

The U.S. Department of the Interior protects America's natural resources and heritage, honors our cultures and tribal communities, and supplies the energy to power our future.

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.

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14. ABSTRACT *(Maximum 200 words)* This report documents Reclamation's history with RPM fiberglass pipe, reviews the available literature for recent developments, and identifies additional research needs. Between 1967 and 1984, Reclamation installed about 100 miles of Techite RPM pipe. Reclamation began experiencing RPM pipe failures within 10 years, while other users experienced failures within 5 years. The main difference was more stringent inspection and quality assurance both at the factory and at the jobsite. Investigations identified several inherent weaknesses in the design, manufacturing, and installation of RPM pipe. After several lawsuits, Techite RPM pipe was removed from the market in the mid 1980's. In 1990, Reclamation formally discontinued use of all fiberglass pipes while known deficiencies were addressed. In 1997, Reclamation lifted the ban on all fiberglass pipe meeting the newly established AWWA C950-95 "Fiberglass Pipe Standard" and AWWA M45-95 "Fiberglass Pipe Design Manual". However, each client retained the ultimate authority to select the pipe options best suited for their needs. Therefore over the last 30 years, fiberglass pipe options were rarely (if ever) included in Reclamation specifications. Recently, Reclamation began including the RPM fiberglass pipe option on large jobs such as Navajo-Gallup (NM) and East Low (WA). This report identifies key issues that still need to be addressed.						
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Peer Reviewer; I have reviewed the assigned items/sections(s) noted for the above document and believe them to be in accordance with the project requirements, standards of the profession, and Reclamation policy.

Reviewer Dave Tordonato Date Reviewed 8/11/2016
(Signature)

Acronyms and Abbreviations

ASTM	American Society of Testing and Materials
AWWA	American Water Works Association
BOR	Bureau of Reclamation
CLSM	Controlled Low Strength Material
FRC	Fiber Reinforced Composite
FRP	Fiber Reinforced Plastic or- Fiber Reinforced Polymer
FS	Factor of Safety
ft	feet
ft-lb	foot-pounds (energy)
GRP	Glass Reinforced Plastic
HDB	Hydrostatic Design Basis
PMC	Polymer Matrix Composites
psi	pounds per square inch (pressure)
RPM	Reinforced Plastic Mortar
RTR	Reinforced Thermosetting Resin
USBR	United States Bureau of Reclamation
UTC	United Technology Corporation

Executive Summary

Reclamation has a long history using RPM fiberglass pipe with mixed results. This report documents Reclamation's history with RPM pipe, reviews the available literature for recent developments, and identifies additional research needs.

Fiberglass is a light-weight, corrosion-resistant, cost-competitive alternative for concrete, steel and other plastic pipe, especially in large-diameter, high-pressure applications. Fiberglass pipe is highly corrosion resistant eliminating the expense of cathodic protection needed with steel and reinforced concrete pipe in corrosive soils. Fiberglass pipe weighs less than other pipe alternatives, which can reduce installation costs and increase installation speeds.

Between 1967 and 1984, Reclamation installed about 100 miles of "Techite" brand RPM pressure pipe in diameters from 6 to 72 inches. Reclamation began seeing RPM pipe failures within 10 years of installation, while other pipe users saw failures within 5 years. The main difference between Reclamation practice and that of others was more stringent inspection and quality assurance during manufacturing and installation. Pipe failure investigations identified several inherent weaknesses in the design, manufacturing, and installation of RPM pipe.

After several lawsuits, Techite brand RPM pipe was removed from the market in the mid 1980's. In 1990, Reclamation formally discontinued use of all fiberglass pipes while known deficiencies were being addressed. In 1997, Reclamation determined that the deficiencies with earlier RPM pipe had been adequately addressed and lifted the ban on all fiberglass pipe meeting the newly developed AWWA C950-95 Fiberglass Pipe Standard and AWWA M45-95 Fiberglass Pipe Design Manual. However, each client retained the ultimate authority to select the pipe options which best met their specific needs. Also, each contractor would select which pipe option to install – based on lowest installed cost. Therefore even with the ban lifted, the fiberglass pipe option was rarely included in Reclamation specifications (typically only on smaller regional jobs). Reclamation installed very little (if any) fiberglass pipe during this time period.

Recently, Reclamation has once again been including the RPM fiberglass pipe option on several large jobs including Navajo-Gallup (NM) and East Low (WA). This report documents Reclamation's history with RPM pipe and identifies key issues that still need to be addressed.

Contents

Fiberglass Pipe Literature Review

Introduction

Fiberglass pipe is an alternative for concrete, coated-steel and other plastic pipe. Fiberglass is a light-weight, corrosion-resistant, cost-competitive piping alternative especially in large-diameter, high-pressure applications. Fiberglass pipe is highly corrosion resistant eliminating the expense of cathodic protection needed with steel and reinforced concrete pipe in corrosive soils. Fiberglass pipe weighs less than other pipe alternatives, which can reduce installation costs and increase installation speeds.

Fiberglass Composition

Fiberglass pipe was introduced in 1948 in the oil industry [1]. Fiberglass is the generic name for Glass Reinforced Plastic (GRP), consisting of glass fiber reinforcement in a polyester plastic matrix. Reinforced Plastic Mortar (RPM) pipe incorporates a sand filler (silicate) to economically increase wall thickness and pipe stiffness for large-diameter, buried applications (typically greater than 12 inches). RPM pipe is also manufactured for non-pressure applications such as sewers and gravity-flow drains.

Fiberglass is a sub-set of FRP (fiber reinforced plastic or fiber reinforced polymer) which consists of a fiber reinforcement used in a polymer (plastic) matrix. The fibers provide tensile strength while the polymer resin (plastic) matrix provides structural rigidity (shape) and compressive strength. In other parts of the world, FRP is called Fiber Reinforced Composite (FRC), Reinforced Thermosetting Resin (RTR), and Polymer Matrix Composites (PMC). Several types of resins and fiber reinforcement are used commercially.

<u>Resin</u> – Several polymers (resins) are used commercially in FRP pipe. Polyester resin is commonly used in FRP pipe for domestic and irrigation water applications. Other resins include vinyl-ester and epoxy, which are more expensive and are used when FRP pipe is exposed to highly corrosive liquids.

<u>Fibers</u> – Reinforcing fibers include glass fibers (most commonly E-glass), polyester fibers, carbon fibers, and aramid fibers. Glass fibers are susceptible to attack by chlorides and humidity; therefore, the glass fibers must be completely encapsulated in the polymer matrix. A surfacing mat (veil) is used to provide a smooth, resin-rich surface finish. Reinforcing mats are made from continuous strands or from chopped fibers. These reinforcing mats are incorporated into the pipe wall and are also used in hand lay-up operations.

Reclamation History with Fiberglass Pipe

Reclamation has a long history of using "Techite" RPM fiberglass pipe with mixed results. This report includes review of the literature as well as information gathered from current and retired Reclamation pipe experts.

In 1966, UTC (United Technology Corporation) developed the first RPM pipe under the tradename "Techite" in response to interest expressed by Reclamation for a high-quality plastic pipe to compete with steel and concrete pipe. Other companies including J-M (Johns-Mansville) and Amoco produced RPM pipe under the Techite brand, while Owens Corning manufactured RPM pipe for other users, but not for Reclamation. From 1967 to 1971, Reclamation installed three test sections of RPM pipe.

Table 1 – Reclamation Experimental RPM Pipe Installations.

Date	Spec Number	Location	Diameter	Length
1967	DC-6514	Westlands Water District (CA)	15 inch	0.5 miles (2600 feet)
1968		Lower Yellowstone Project	39 inch	0.2 miles (1200 feet)
1970-71		Yuma Project (AZ)	30 inch	0.2 miles (1200 feet)

Based on positive short-term results from these three test sections, Reclamation installed about 100 miles of RPM pipe on Bureau projects between 1973 and 1984 in diameters ranging from 6 to 72 inches. The following list of Reclamation RPM pipe installations was gathered primarily from the "Reclamation Pipe Database" [2]. Other sources cite slightly different installed lengths of RPM pipe (see table footnotes). Excerpts (print-outs) from the Reclamation's internal computer database of jobs using RPM pipe are included in Appendix A.

Table 2 – Reclamation RPM Pipe Installations.

Date	Spec Number	Location	Diameter (inches)	Head Class (feet) [a]	Length (miles)
1967-1978	DC-6550	Westlands Water District (CA)	30 to 36	25 to 150	5.0
1973	DC-6880	Westlands Water District (CA)	10 to 27	100 to 275	1.6
1974	DC-6949	Manson Pumping Plants (WA) Lake Chelan - Chief Joseph Dam	27 to 45	50 to 450	2.8
1972-1973	DC-6972	Vernal Mesa Ditch (CO)	48	25	0.3
1974-1975	DC-6977	Minot Extension (ND)	24 to 48	50 to 125	7.0
1976	DC-7066	Westlands Water District (CA)	24 to 54	25 to 450	20.3 [b]
1976	DC-7098	Pleasant Oak Main (CA)	27 to 30	25 to 450	4.0
1975-1976	DC-7110	Westlands Water District (CA)	30 to 33 30 to 39	25 to 150	5.0 [b]
1976	DC-7184	Westlands Water District (CA)	24 to 54	25 to 300	20.9
1978	DC-7238	El Dorado Irrigation District Main No. 2, Pipeline, and Reservoir 2a	27 to 30	175 to 500	1.9
1979	DC-7318	Navajo Indian Irrigation - Pipe Lateral & Pumping Plant, Block 4	24 to 30	25 to 500	0.3
	DC-7450	Dunnigan Water District (CA)	42 to 48	25 to 150	0.9
1981-1984	DC-7466	Grand Valley Water Users Association (CO)	27 to 42	25 to 150	4.5
1982	DC-7473	Colusa County Water District - Contract 2A	27 to 30	50 to 175	2.3
1984	DC-7508	Oroville-Tonasket Irrigation District – Ellisford Pumping Plant Discharge Line	24 to 30	50 to 500	2.9
1984	DC-7510	Yuma Desalting Plant – Pretreatment 11	6 to 72	50 to 550	2.7
				Total	82.4

[a] While some of the literature reports Head Class (ft), others report Pressure Class (psi). For consistency, all pressures are listed as Head Class (ft). Conversion: 100 ft of head = 43.3 psi

[b] The 1977 RPM Study Team [3] reported lengths for DC-7066 as 37.1 miles, and DC-7110 as 10.0 miles

In addition, a lesser but unknown amount of RPM pipe was installed on smaller regional projects and on small loan projects where Reclamation had the responsibility of design review, while construction and inspection (factory and jobsite) were handled by the owner. These projects are not included in the Reclamation computer database. Furthermore, Amoco reports that over 750 miles of RPM pressure pipe, in all sizes and pressure classes, were installed on other (non-Bureau) projects. A partial list of these installations with limited project data is shown below.

Table 3 – Partial List of Small Loans and Regional RPM Pipe Installations.

Date	Location	Diameter (inches)	Distance
1972	Haights Creek Irrigation District (UT)	18 to 27	3.0 miles
	Nevada Irrigation District (CA)		6.3 miles
1975-1976	Roy Irrigation District (UT)	10 to 24	2.8 miles
1975	Tualatin Project (OR)	45	
	Buttonwillow Improvement District (CA)	45	
	Cawelo Water District (CA)		

The 1977 Reclamation Study Team [3] evaluated the performance of RPM pipe and recommended the continued use of RPM pipe up to 54 inch diameter. The recommendation was based on failure rates comparable to other pipe types. The report recognized that other agencies (including small loan projects) were experiencing significantly higher RPM pipe failure rates. The main difference between Reclamation practice and that of others (including small loans) was more stringent inspection and quality assurance during manufacturing and installation. The report recommended that RPM pipe only be included as an allowable pipe option for small loan projects when the district requests the option in writing. In 1984, Reclamation approved use of Techite RPM pipe up to 108 inches diameter, but very little of the larger sizes were installed.

Because of numerous lawsuits over pipe failures, the manufacturers stopped producing Techite RPM pipe in the mid 1980's. Reclamation provided expert testimony, but was not a litigant in any of these lawsuits. Reclamation began seeing RPM pipe failures within 10 years of installation, while other pipe users saw failures within 5 years. The failures were catastrophic (pipe burst) leading to significant concerns regarding public safety. In 1990, Reclamation formally discontinued use of all fiberglass pipe [4] while the reasons for premature pipe failure were investigated. The memorandum temporarily banning the use of fiberglass pipe is included in Appendix B. Investigations identified several inherent weaknesses in the design, manufacturing, and installation of Techite RPM pipe [3] [5]:

1. Voids in the pipe wall because of incomplete resin saturation of the sand filler,
2. Blisters in the pipe wall because of osmosis.
3. Manufacturing defects at the bell and spigot.
4. Variability and structural defects in the pipe wall because of the amount of hand labor and lack of automation during manufacturing,

5. Structural damage during shipping, handling and installation because of low impact strength, oversized aggregate, and equipment damage,
6. Changes in the manufacturing process such as the liner material:
    a. 1967 – Resin-rich mortar (sand-filled liner)
    b. 1973 – Aluminum silicate filled – Type I
    c. 1976 – Ashland liner
7. Pipe mismarked at the factory and damaged during factory proof testing or service,
8. Excessive deflection because of low pipe stiffness (10 psi)
9. Failure to measure pipe deflection after installation – Lack of a requirement for maximum allowable deflection in the specifications.
10. Stress concentrations caused by bulges in the pipe wall because of bedding issues, non-uniform backfill (embedment) and insufficient haunch support.
11. Circumferential cracks caused by low longitudinal strength.
12. Design Factors of Safety (FS) were lower than Reclamation was led to understand. Instead of a FS of 2.0 at 100-year service for hydrostatic pressure, the actual FS used by the manufacturer was 1.6 at 100-year service. Soil loading further reduced the FS.

Industry Standards – Working through AWWA and ASTM, Reclamation has had a long and productive partnership with pipe manufacturers. In 1988, AWWA first published the AWWA Standard on Fiberglass Pressure Pipe (C950-88) [6]. In that same year, ASTM published standards on Fiberglass Pressure Pipe (D3517) [7] and Fiberglass Sewer Pipe (D3262) [8]. The ASTM Fiberglass Pressure Pipe Standard closely paralleled Reclamation Specifications [3]. In 1995, AWWA revised C950 and moved the design of fiberglass pipe to a separate Fiberglass Pipe Design Manual (AWWA M45) [1]. These state-of-the-practice standards have been updated repeatedly and remain the industry standards.

Table 4 – Industry Standards for RPM Pipe.

Standard	Title	Year Adopted	Current Version
AWWA C-950	AWWA Standard for Fiberglass Pressure Pipe	1988	2013
AWWA M-45	AWWA Manual for Fiberglass Pipe Design	1995	2014
ASTM D3262	Standard Specification for Fiberglass (Glass-Fiber-Reinforced Thermosetting-Resin) Sewer Pipe	1988	2011
ASTM D3517	Standard Specification for Fiberglass (Glass-Fiber-Reinforced Thermosetting-Resin) Pressure Pipe	1988	2014

In 1991 [9], Reclamation partially lifted the ban on fiberglass pipe to allow HOBAS brand centrifugally-cast RPM pipe which has a much denser wall and addressed many of the earlier deficiencies. The memorandum is included in Appendix B. The Hobas pipe uses chopped glass fibers in a centrifugally casting process and is still manufactured commercially.

In 1997, Reclamation lifted the fiberglass pipe ban [10] to allow the use of fiberglass pipe meeting the newly developed AWWA C950-95 "Fiberglass Pipe Standard" and AWWA M45-95 "Fiberglass Pipe Design Manual". The memorandum is included in Appendix B. However, each client retained the ultimate authority to select the pipe options which best met their specific needs. Also, each contractor would select which pipe option to install – based on lowest installed cost. Therefore even with the ban lifted, fiberglass pipe options were rarely included in specifications (perhaps for some smaller regional jobs), much less actually installed.

Recently Reclamation resumed including the RPM pipe option on several large jobs shown in Table 5 below. This decision was based on the client's wishes, market forces, and unique engineering challenges.

Table 5. Recent Reclamation Specifications including the RPM Pipe Option.

Specification	Pipe Diameter (inches)	Head Class (feet)
East Low Canal Siphon [c] Columbia Basin Project (WA)	156	75
San Juan Lateral – Reach 12B [12] Navajo-Gallup Water Supply Project (NM)	24 to 36	475
Cutter Lateral – Reach 22B [13] Navajo-Gallup Water Supply Project (NM)	24 to 36	375

[c] The East Low owner ultimately decided not to include the RPM pipe option in the final specifications

The specifications include special design and installation requirements for pipe stiffness, embedment (backfill), and deflection to address some of the previous concerns with RPM pipe. Fiberglass fittings up to 24-inch diameter are covered under ASTM D5685, but larger diameters currently require steel fittings. Reclamation is working with ASTM Committee D20 to expand ASTM D5685 to cover larger diameter fiberglass fittings. To date, the RPM pipe option has not been selected on any of these jobs. Upcoming specifications for Navajo-Gallup Reach 12.1 and 12.2, and Blocks 9 thru 11 will again include the RPM pipe option for 24- to 48-inch diameters.

<u>Pipe Manufacturers</u> - Previous Reclamation reports [11] have identified several manufacturers of fiberglass pipe, including:

- Flowtite
- Hobas
- Smith Fiberglass
- RPS Composites
- Enduro Composites
- Fiberglass Systems
- Beetle Plastics
- Ershigs
- Superlit
- ACWAPIPE (Arabian Company for Water Pipes)
- Watani Composites

Most of these pipes are GRP fiberglass pipe with low pipe stiffness. Hobas and Flowtite produce RPM fiberglass pipe with sand filler and the higher pipe stiffness needed for buried applications. The Hobas pipe is more often used for low head and no head (gravity flow) applications because of the chopped glass fibers used with the centrifugally casting process. The Flowtite pipe is more often used for pressure applications because of the strength provided by the continuous glass fibers. The two products are compared in Table 6.

Table 6 - Current RPM Pipe Manufacturers

	Flowtite	Hobas
Diameters (DN)	12" – 156" [d]	18" – 120"
Pressure Class (PN)	50 psi – 250 psi [e]	25 psi – 250 psi [e]
Pipe Stiffness (SN)	18 psi – 72 psi	18 psi – 72 psi
Pipe Lengths	10 ft, 20 ft, 40 ft	10 ft, 20 ft
Resin	Polyester, Vinyl Ester	Polyester
Glass	Continuous rovings plus chopped fibers	Chopped fiber
Sand Filler (RPM)	Yes	Yes
Manufacturing Process	Continuously Advancing Mandrel	Centrifugally Cast
Joints	Double Bell, Gasketed	Low-Profile Bell & Spigot, Gasketed

[d] Flowtite proposed to produce 156-inch diameter pipe for East Low Canal

[e] Larger diameters are typically not available in the highest pressure classes.

Laboratory Testing Capabilities

Reclamation has not performed any laboratory testing on the newer versions of RPM fiberglass pipe. The following tests are routinely used to evaluate RPM pipe. Pressure tests (HDB, quick burst, proof, and offset joint) are performed by the pipe manufacturer, while the Pipe Stiffness, Split-D, Impact Resistance, and Abrasion tests can be performed in the Reclamation Laboratory.

<u>HDB (Hydrostatic Design Basis)</u> – Each manufacturer performs in-house testing per ASTM D2992 to determine the rated operating pressure (psi) for their product. The rated operating pressure is determined by the HDB plot (see figure 1) of burst strength vs. time on log-log scale, extrapolated to 50 year service with an appropriate Factor of Safety (FS) (typically 1.8). The quick burst strength of fiberglass pipe is typically 10 to 12 times the long term burst strength. The loss of strength over time is believed to be caused by stress corrosion of the E-glass fibers in the presence of water. The HDB Factor of Safety does not account for stresses due to soil burial. HDB testing is to be repeated whenever the pipe materials, formulation or design are changed.

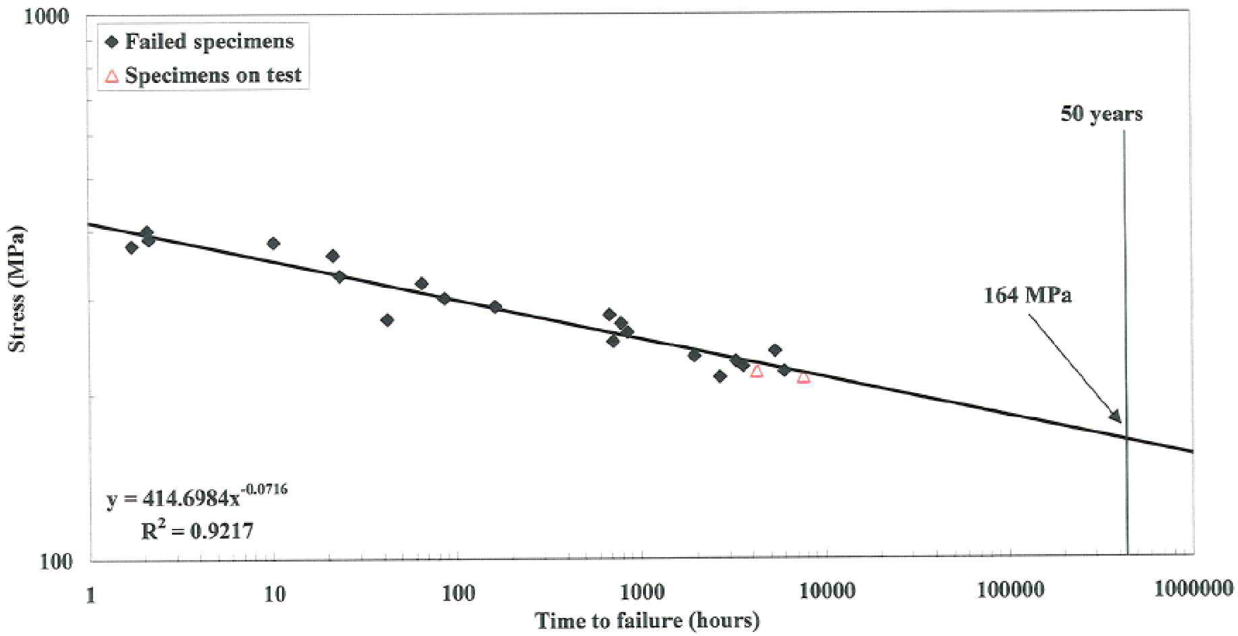

Figure 1 – Typical stress regression curve extrapolated to 50 years [14] .

For comparison, thermoplastic pipe is also designed by the HDB method. Instead of stress corrosion, creep is responsible for the reduction in strength over time. The quick burst strength of thermoplastic pipe is typically 5 to 10 times greater than the long term burst strength.

<u>Quick Burst Test</u> - ASTM D1599 requires a specimen length of 3 to 5 pipe diameters to eliminate end effects. For small pipe (6-inch diameter and less) the minimum sample length is five diameters, while larger pipe require a minimum sample length of three diameters. Specimen lengths less than the minimums demonstrate erroneous higher burst strengths because of the support provided by the end restraints. The quick burst test is used for manufacturing quality control, and provides the initial reference point for long-term HDB testing.

Proof Testing – Each section of fiberglass pipe is proof tested at the factory to twice the rated pressure. This QC test identifies pipe pinholes and joint defects.

Pipe Stiffness (PS) – ASTM D2412 – Fiberglass is a flexible pipe and therefore relies primarily on the strength of the pipe bedding material to support the overburden. The Pipe Stiffness is used in combination with Soil Modulus in pipe deflection calculations. Therefore both Pipe Stiffness and Soil Modulus have units of stress or pressure (psi). Pipe stiffness is determined by measuring the force per unit length to compress a section of pipe to 5 percent deflection between two parallel plates. The pipe must then withstand further loading to 20 percent deflection without structural failure. Pipe stiffness is reported in psi at 5 percent deflection and is calculated as follows:

$$PS = \frac{\text{Force}}{\text{Length x deflection}}$$

Split D Tensile – ASTM D2290 - Two hemispherical grips (D shaped), matching the pipe inside diameter fit inside the pipe and produce tensile stresses that simulate internal burst pressure. The test specimen is a short length of pipe where the pipe cross section is machined to produce a reduced cross section at the point of maximum stress. The split D test is easier to run than the quick burst, but only tests a small portion of the pipe profile, not the entire specimen.

Offset Joint Testing – Once per lot, a pipe joint is assembled with the maximum allowable offset (typically 2.5 degrees to 5 degrees depending on pipe diameter). The pipe joint specimen is then proof tested to 1.5 times rated pressure per AWWA C950.

Erosion-Abrasion Resistance - Fiberglass pipe is manufactured with a resin-rich inner liner to keep water away from the glass fibers. In addition, various additives are added to the inner liner to improve erosion resistance from sediment-laden water. Limited data exists in manufacturer literature, and there is no universally accepted test standard for pipe abrasion [11]. Reclamation's in-house test calls for an aggregate-slurry to be placed in a 12-inch length of sealed pipe. The pipe is then placed on a mill and rotated 10,000 revolutions at a speed to simulate flow velocities. The pipe liner thickness is measured before and after the test.

Impact Resistance – The impact energy (ft-lb) is defined as the falling height (ft) multiplied by the weight (lb). Impact damage typically occurs during construction either from large aggregate falling from a height or from equipment impacts during handling and installation. ASTM D256 (Pendulum) and ASTM D2444 (Falling Weight) are used to deliver and quantify the impact energy.

RPM Pipe Design and Construction Issues

Impact Strength – The pipe manufacturers have taken steps to address the previous issues with impact resistance.

A 2003 Flowtite report [14] documents a 40 joule (30 ft-lb) impact on a 32-inch Flowtite pipe that caused no visible damage or cracking on the inner face. Short term flexural modulus, peak stress, and peak strain were reduced 1.1 %, 6.1 %, and 3.6 % respectively (all within the limits of experimental error). The report compares laboratory tests with a proposed United Utilities specification that allows a reduction up to 20 % in each property following a 40 joule impact. According to the report, stress regression tests and long-term flexural tests indicate that the predicted 50-year values for modulus are unchanged (within experimental error).

Flowtite has produced several videos that present anecdotal evidence of the impact resistance of their pipe. Four of the Flowtite videos (with screenshots) are discussed below.

1. Flowtite video (www.youtube.com/watch?v=G2Z__S2rhTU) [15] shows a backhoe bucket repeatedly impacting a 30-inch fiberglass pipe pressurized to 232 psi (1600 kPa). After about a dozen blows, the impacts from the backhoe cause structural damage to the pipe wall and the pipe begins to leak significantly at the impact site. The pipe leaks but does not fail catastrophically. The impact demonstration is impressive, but not readily quantifiable.

Figure 2 – Screenshot of Backhoe Impacting RPM Pipe

2. Flowtite video www.youtube.com/watch?v=C6EvpeARCC4 [16] shows a 28.6 lb (13 kg) rock dropped from a height of 6.6 feet (2 meters) onto the crown of an unrestrained section of Flowtite pipe on a jobsite in Sweden during the winter months. Impact energy calculates to 190 ft-lb. The same pipe is later burst tested at the factory (see below).

Figure 3 – Screenshot of Rock Dropped onto the RPM Pipe.

3. After the field impact (190 ft-lb), the pipe is factory burst tested and fails catastrophically www.youtube.com/watch?v=eLj7Ukzt8ck [17] at a pressure of 1812 psi (125 bars). The 32-inch pipe is rated for 232 psi (16 bars) operating pressure. The burst pressure test is 7.8 times the rated pressure. The original FS for burst of an undamaged pipe is somewhere between 8 and 10 (based on conversations with the pipe manufacturer).

Figure 4 – A split-second prior to failure, a crack appears at the location of the rock impact.

Figure 5 – Pipe failure is catastrophic at 1812 psi (125 bars).

4. Flowtite video www.youtube.com/watch?v=nQ4xSn4A0iw [18] shows a burst of 1375 psi on a 150 psi 24-inch FRP Flowtite pipe, demonstrating a ratio of 9.2 (1375/150) between quick burst and rated pipe pressure. In the video, the failure appears to initiate at the left-hand seal, suggesting the true burst strength is higher than the demonstrated 1375 psi.

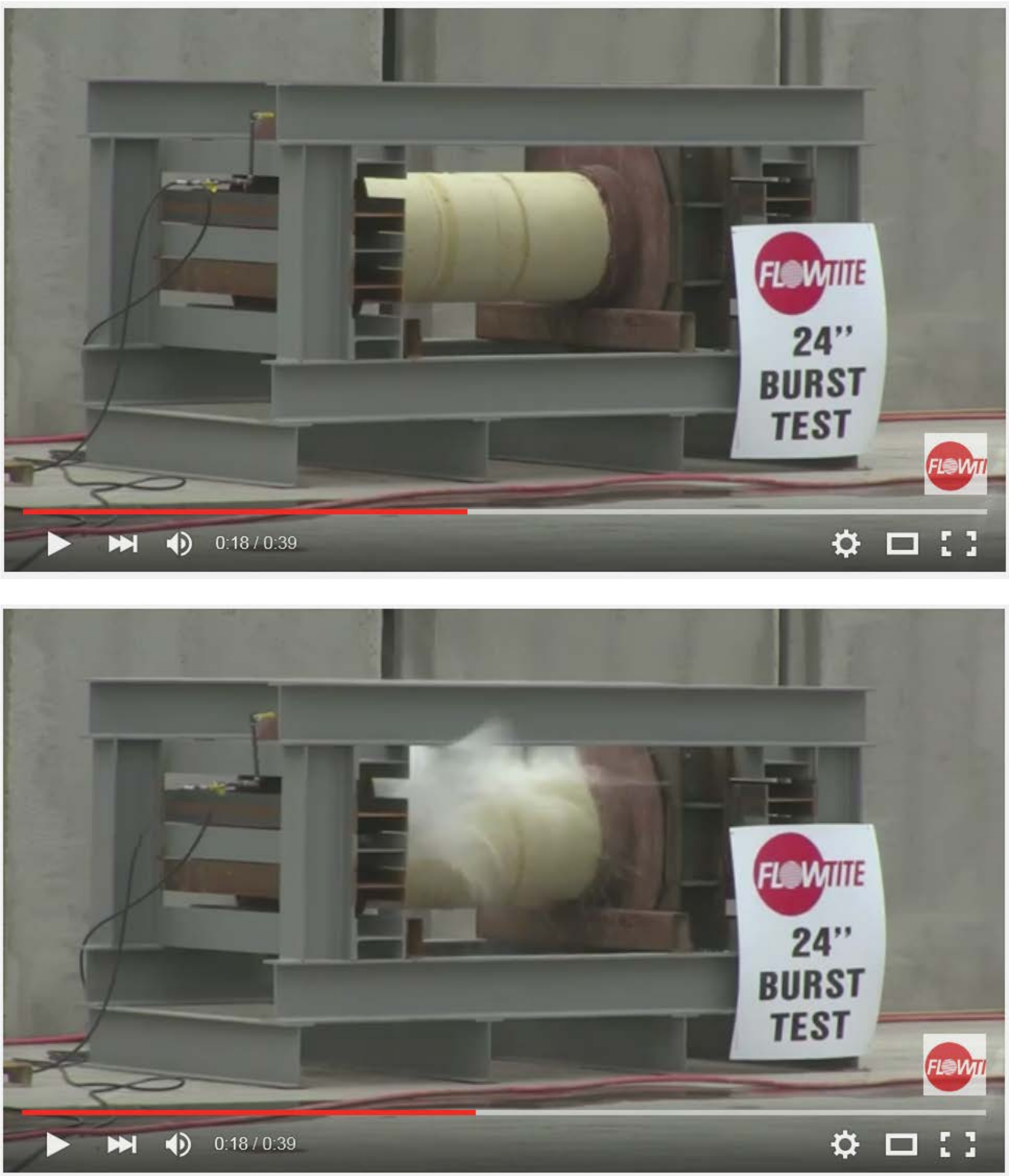

Figure 6 –Laboratory burst test on 24-inch RPM Pipe. Failure initiates at left end cap.

Deflection – Fiberglass pipe design limits the allowable long-term deflection (change in diameter) to 5% maximum for long-term stability. To limit the long term deflection to 5 percent, short-term deflection after backfill is limited to 3 percent. Maximum deflection can occur in any direction, but is most often found in the vertical direction. On larger pipe, deflection is checked with a probe during walk-thru (crawl-thru) inspection. On smaller pipe, a pipe pig (3% smaller than pipe diameter) is pulled thru the pipe for a "Go/No Go" deflection test. Better deflection measurements techniques are needed, such as photographic methods or instrumented pipe pigs that can be pulled or self-propelled thru the pipe to check deflection.

Bulges – localized deflection – Bulges most often occur at the invert when pipe is resting on hard subgrade. Poor compaction in the pipe haunch (i.e. below the springline) can also lead to invert flattening (bulge). Over-compaction can lead to bulges in any location (haunches, springline, crown). These bulges cause high stress and strain concentrations. New techniques such as photogrammetry are needed to quickly identify bulges and assess pipe shape during inspection. Numerical methods can be used to calculate stresses and strains based on pipe shape.

Pipe Stiffness – The Techite RPM pipe used in the 1970's had pipe stiffness of about 10 psi [5]. The current generation of RPM pipe is much stiffer and is available in pipe stiffness of 18 psi, 36 psi, 46 psi, and 72 psi. Reclamation current design calls for 18 psi pipe stiffness, determined on a case-by-case basis depending on depth of burial and trench design (side support). For direct burial, Hobas literature recommends PS of 36, 46, and 72 psi depending on cover depth and embedment conditions. Flowtite installation guidelines allow all pipe stiffness classes with proper backfill. Deflection and performance on new RPM pipe installations should be monitored to determine if current pipe stiffness requirements are adequate for direct burial applications.

Embedment (backfill) – Adequate soil support is critical for thin-walled, flexible pipe such as fiberglass. The area of the pipe haunch is notoriously difficult to compact and was a problem with earlier RPM pipes. Therefore, current Reclamation specifications require the use of CLSM (Controlled Low Strength Material) - also known as flowable fill - for backfill either up to 25% or up to 75% of pipe diameter, followed by select compacted backfill to 12 inches above the pipe crown. This requirement is modelled after steel pipe which is also a thin-walled, flexible pipe. Based on cost, contractors typically choose to backfill with CLSM up to 25% of diameter. However because of the low pipe stiffness (18 psi) and the stress-corrosion sensitivity of fiberglass pipe, the more conservative backfill requirement of CLSM up to 75% of pipe diameter may be warranted. While CLSM is more expensive than traditional backfill, use of CLSM in the haunch and embedment offers superior pipe support and may also offer significant savings in quality testing and faster installation rates.

Research Needs - This report identifies the following research needs:

1. Evaluate manufacturer's methods to assess and repair factory defects such as voids and sand pockets in the pipe wall.

2. Develop or identify quality assurance and inspection criteria for joints and fittings which are common failure points for composite pipe system.

3. Verify impact resistance to dropped stone simulating field installation (worst case). Verify strength retention by Quick Burst or Split-D Tensile.

4. Develop techniques to detect and assess field damage to RPM pipe.

5. Evaluate techniques to repair field damage to RPM pipe.

6. Develop methods to evaluate repairs of damaged RPM pipe.

7. Develop field techniques to assess deflection of RPM pipe (especially for small diameter pipes that are not man-accessible).

8. The 1977 Study Team report [3] recommended updating the 1971 "Guide for Visual Inspection of RPM Pressure Pipe" [19]. This inspection guide needs to be updated for use on current Reclamation projects such as Navajo-Gallup.

9. Develop inspection techniques to assess remaining life of older pipe (ie after 20 years).

10. Develop techniques to detect and evaluate point loads (bulges) on RPM pipe.

11. Numerical methods to calculate strains based on pipe shape. Photographic techniques (photogrammetry) to quickly assess pipe shape for use in numerical analysis.

12. Develop or evaluate improved backfill techniques for flexible pipe that requires significant soil support.

13. Develop or evaluate ways to monitor deflection and performance of new RPM installations to determine if Pipe Stiffness requirements are adequate for direct burial.

14. Conduct a cost-benefit comparison of CLSM (flowable fill) to 25% of pipe diameter vs CLSM to 75% of pipe diameter. Also compare use of CLSM with imported backfill vs CLSM using native soils.

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[17] "Youtube - RPM Burst after Rock Impact," [Online]. Available: www.youtube.com/watch?v=eLj7Ukzt8ck .

[18] "YouTube - Burst on 24-inch RPM Pipe," [Online]. Available: www.youtube.com/watch?v=nQ4xSn4A0iw.

[19] BOR - Bureau of Reclamation, Guide for Visual Inspection of Reinforced Plastic Mortar Pressure Pipe, Denver CO, 1971.

Appendix A

“Reclamation Pipe Database”

Jobs using RPM Pipe

PIPE LENGTH SUMMARY

Water Conveyance

PIPE	LENGTH (ft)	LENGTH (mi)
REINFORCED PLASTIC MORTAR	437921	82.94

qryRPM 3/15/2016

SPECNO	PIPE_ACRO	LENGTH
DC-6951	OPTIONS(RCP,RPM,PT,AC,ST)	2808
DC-6514	RPM	2587
DC-6550	RPM	26585
DC-6880	RPM	8419
DC-6949	RPM	14995
DC-6972	RPM	1470
DC-6977	RPM	36775
DC-7066	RPM	107273
DC-7098	RPM	21120
DC-7110	RPM	26307
DC-7184	RPM	110450
DC-7238	RPM	10185
DC-7318	RPM	1494
DC-7450(2)	RPM	4670
DC-7466	RPM	23685
DC-7473	RPM	12185
DC-7508(1) -	RPM	15311
DC-7510	RPM	14410

PIPE LENGTH SUMMARY

Water Conveyance

PIPE	LENGTH (ft)	LENGTH (mi)
ASBESTOS-CEMENT	11804705	2235.74
DUCTILE IRON	148122	28.05
EMBEDDED CYLINDER PRESTRESSED CONCRETE	419407	79.43
LINED CYLINDER PRESTRESSED CONCRETE	193880	36.72
MONOLITHIC CAST-IN-PLACE	34174	6.47
NON-CYLINDER PRESTRESSED CONCRETE	315385	59.73
OPTIONS (AC, ST)	24520	4.64
OPTIONS (AC,RCP,PT,ST)	9760	1.85
OPTIONS (NCP,PT,ST)	93740	17.75
OPTIONS (PT,ST,RCP,AC)	8242	1.56
OPTIONS (PVC,AC)	5420	1.03
OPTIONS (RCP,PT,AC)	60810	11.52
OPTIONS(AC,PT,NPC,RCP,ST)	33158	6.28
OPTIONS(AC,RCP,PT,ST)	218115	41.31
OPTIONS(RCP,RPM,PT,AC,ST)	2808	0.53
POLYVINYL CHLORIDE	1108856	210.01
PRETENSIONED CONCRETE CYLINDER	1551200	293.79
REINFORCED CONCRETE CYLINDER	191070	36.19
REINFORCED CONCRETE PRESSURE	5195726	984.04
REINFORCED PLASTIC MORTAR	437921	82.94
STEEL	1697851	321.56
UNKNOWN		

Select: DC-6951

SPECNO: DC-6951

TITLE: EARTHWORK & STRUCTURES FOR GOULD CANAL

REGION: UPPER COLORADO - UC

PROJECT: FRUITLAND MESA

INDICATOR:	1	METHCOMP:	
PIPE_ACRO:	OPTIONS/RCP,RP	DEGREECOMP:	
LENGTH:	2808	PERCCOMEX:	
MINDIA:	30	PERCROCKEX:	
MAXDIA:	42	TRENCHTYPE:	
MINHEAD:	25	GROUNDWATE:	0
MAXHEAD:	150	SOILCLASS:	
MINCOVER:	5	CATHOPROT:	
MAXCOVER:	10	CORROMONIT:	
LINING:		MAXFLOW:	
COATING:		MINFLOW:	
SUPPLLOC:		PUMPEDGRAV:	GRAVITY
COST:		SYSTEMTYPE:	SIPHON
PIPEFAIL:		WATER:	
INSPEDATES:		WATERSOURC:	GOULD CANAL
PROBMEMO:		WATERSTORG:	CANAL
		ADJUSTSPEE:	0
		NUMDELIV:	
ROADCROSS:		PUMPHEADS:	
TYPEBED:			

View Pipe Data

View Spec Info

View Cost Info

View Water District Info

Return to Switchboard

Select: DC-6951

SPECNO: DC-6951

TITLE: EARTHWORK & STRUCTURES FOR GOULD CANAL

REGION: UPPER COLORADO - UC

PROJECT: FRUITLAND MESA

DIVISION:		CONTRACTOR:	TIAGO CONSTRUC
STATE:	COLORADO	CONTRTYPE:	
COUNTY:	MONTROSE	AWARDDATE:	6/6/1972
NEARTOWN:	CRAWFORD	COMPDATE:	7/11/1973

View Pipe Data

View Spec Info

View Cost Info

View Water District Info

Return to Switchboard

SPECNO:	TITLE:
DC-6514	WESTLANDS WATER DISTRICT DISTRIBUTION SYSTEM, LATERAL 7 - 9.5S
	REGION: MID-PACIFIC - MP
	PROJECT: CENTRAL VALLEY

INDICATOR:	1	METHCOMP:		View Pipe Data
PIPE_ACRO:	RPM	DEGREECOMP:	0	View Spec Info
LENGTH:	2587	PERCCOMEX:	0	View Cost Info
MINDIA:	15	PERCROCKEX:	0	View Water District Info
MAXDIA:	15	TRENCHTYPE:		Return to Switchboard
MINHEAD:	325	GROUNDWATE:	0	
MAXHEAD:	325	SOILCLASS:		
MINCOVER:	5	CATHOPROT:		
MAXCOVER:	5	CORROMONIT:		
LINING:	0.00	MAXFLOW:	7	
COATING:	0.00	MINFLOW:	0	
SUPPLLOC:		PUMPEDGRAV:		
COST:	1285	SYSTEMTYPE:		
PIPEFAIL:		WATER:		
INSPEDATES:		WATERSOURC:	SAN LUIS CANAL	
PROBMEMO:		WATERSTORG:		
		ADJUSTSPEE:	0	
		NUMDELIV:	0	
ROADCROSS:		PUMPHEADS:	0	
TYPEBED:				

SPECNO:	TITLE:
DC-6514	WESTLANDS WATER DISTRICT DISTRIBUTION SYSTEM, LATERAL 7 - 9.5S
	REGION: MID-PACIFIC - MP
	PROJECT: CENTRAL VALLEY

DIVISION:	WEST SAN JOAQU	CONTRACTOR:	D.J. HALLGREN (R	View Pipe Data
STATE:	CALIFORNIA	CONTRTYPE:		View Spec Info
COUNTY:		AWARDDATE:	4/25/1967	View Cost Info
NEARTOWN:	MENDOTA	COMPDATE:	1/1/1978	View Water District Info
				Return to Switchboard

SPECNO:	DC-6550
TITLE:	WESTLANDS WATER DISTRICT DISTRIBUTION SYSTEM. LATERALS 6. 7. 8. 9. 10. 11 AND 12
REGION:	MID-PACIFIC - MP
PROJECT:	CENTRAL VALLEY

INDICATOR:	3	METHCOMP:	
PIPE_ACRO:	RPM	DEGREECOMP:	0
LENGTH:	26585	PERCCOMEX:	0
MINDIA:	30	PERCROCKEX:	0
MAXDIA:	36	TRENCHTYPE:	
MINHEAD:	25	GROUNDWATE:	0
MAXHEAD:	150	SOILCLASS:	
MINCOVER:	5	CATHOPROT:	
MAXCOVER:	20	CORROMONIT:	
LINING:	0.00	MAXFLOW:	0
COATING:	0.00	MINFLOW:	0
SUPPLLOC:		PUMPEDGRAV:	
COST:	0	SYSTEMTYPE:	
PIPEFAIL:		WATER:	
INSPEDATES:		WATERSOURC:	
PROBMEMO:		WATERSTORG:	
		ADJUSTSPEE:	0
		NUMDELIV:	0
ROADCROSS:		PUMPHEADS:	0
TYPEBED:			

SPECNO:	DC-6550
TITLE:	WESTLANDS WATER DISTRICT DISTRIBUTION SYSTEM. LATERALS 6. 7. 8. 9. 10. 11 AND 12
REGION:	MID-PACIFIC - MP
PROJECT:	CENTRAL VALLEY

DIVISION:	WEST SAN JOAOU	CONTRACTOR:	LENTZ CONSTRUC
STATE:	CALIFORNIA	CONTRTYPE:	
COUNTY:		AWARDDATE:	9/7/1967
NEARTOWN:	MENDOTA	COMPDATE:	1/1/1978

View Pipe Data

View Spec Info

View Cost Info

View Water District Info

Return to Switchboard

SPECNO: DC-6880

TITLE: WESTLANDS WATER DISTRICT DISTRIBUTION SYSTEM. LATERAL 7R

REGION: MID-PACIFIC - MP

PROJECT: CENTAL VALLEY

INDICATOR:	4	METHCOMP:	
PIPE_ACRO:	RPM	DEGREECOMP:	0
LENGTH:	8419	PERCCOMEX:	0
MINDIA:	10	PERCROCKEX:	0
MAXDIA:	27	TRENCHTYPE:	
MINHEAD:	100	GROUNDWATE:	0
MAXHEAD:	275	SOILCLASS:	
MINCOVER:	0	CATHOPROT:	
MAXCOVER:	0	CORROMONIT:	
LINING:	0.00	MAXFLOW:	70
COATING:	0.00	MINFLOW:	0
SUPPLLOC:		PUMPEDGRAV:	
COST:	0	SYSTEMTYPE:	
PIPEFAIL:		WATER:	
INSPEDATES:		WATERSOURC:	SAN LUIS CANAL
PROBMEMO:	-	WATERSTORG:	
		ADJUSTSPEE:	0
		NUMDELIV:	0
ROADCROSS:		PUMPHEADS:	0
TYPEBED:			

Select: DC-6880

SPECNO: DC-6880

TITLE: WESTLANDS WATER DISTRICT DISTRIBUTION SYSTEM. LATERAL 7R

REGION: MID-PACIFIC - MP

PROJECT: CENTAL VALLEY

DIVISION:	WEST SAN JOAOU	CONTRACTOR:	C.R. FEDRICK AND
STATE:	CALIFORNIA	CONTRTYPE:	
COUNTY:		AWARDDATE:	5/19/1971
NEARTOWN:	PANOCHE	COMPDATE:	11/19/1973

View Pipe Data

View Spec Info

View Cost Info

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Return to Switchboard

SPECNO: DC-6949

TITLE: LAKE CHELAN LATERALS, MANSON UNIT

REGION: PACIFIC NORTHWEST - PN

PROJECT: CHIEF JOSEPH DAM

INDICATOR:	2	METHCOMP:	
PIPE_ACRO:	RPM	DEGREECOMP:	0
LENGTH:	14995	PERCCOMEX:	0
MINDIA:	27	PERCROCKEX:	0
MAXDIA:	45	TRENCHTYPE:	
MINHEAD:	50	GROUNDWATE:	0
MAXHEAD:	450	SOILCLASS:	
MINCOVER:	5	CATHOPROT:	NONE
MAXCOVER:	15	CORROMONIT:	NONE
LINING:	0.00	MAXFLOW:	0
COATING:	0.00	MINFLOW:	0
SUPPLLOC:		PUMPEDGRAV:	PUMPED
COST:	0	SYSTEMTYPE:	IRRIGATION
PIPEFAIL:	YES - 5 FAILURES	WATER:	CLEAR
INSPEDATES:		WATERSOURC:	LAKE CHELAN
PROBMEMO:	RPM PIPE FAILURES June 1986	WATERSTORG:	
		ADJUSTSPEE:	0
		NUMDELIV:	0
ROADCROSS:		PUMPHEADS:	0
TYPEBED:			

DIVISION:	CHELAN	CONTRACTOR:	MOUNTAIN STATE
STATE:	WASHINGTON	CONTRTYPE:	SEALED BID
COUNTY:	DOUGLAS	AWARDDATE:	6/29/1972
NEARTOWN:	MANSON	COMPDATE:	5/30/1974

View Pipe Data

View Spec Info

View Cost Info

View Water District Info

Return to Switchboard

Select: DC-6972

SPECNO: DC-6972

TITLE: EARTHWORK & STRUCTURES FOR VERNAL MESA DITCH

REGION: UPPER COLORADO - UC

PROJECT: BOSTWICK PARK

INDICATOR:	1	METHCOMP:	
PIPE_ACRO:	RPM	DEGREECOMP:	
LENGTH:	1470	PERCCOMEX:	
MINDIA:	48	PERCROCKEX:	
MAXDIA:	48	TRENCHTYPE:	
MINHEAD:	25	GROUNDWATE:	0
MAXHEAD:	25	SOILCLASS:	
MINCOVER:	10	CATHOPROT:	
MAXCOVER:	10	CORROMONIT:	
LINING:		MAXFLOW:	
COATING:		MINFLOW:	
SUPPLLOC:		PUMPEDGRAV:	GRAVITY
COST:		SYSTEMTYPE:	SIPHON
PIPEFAIL:		WATER:	
INSPEDATES:		WATERSOURC:	
PROBMEMO:		WATERSTORG:	
		ADJUSTSPEE:	0
		NUMDELIV:	
ROADCROSS:		PUMPHEADS:	
TYPEBED:			

View Pipe Data
View Spec Info
View Cost Info
View Water District Info
Return to Switchboard

SPECNO: DC-6972

TITLE: EARTHWORK & STRUCTURES FOR VERNAL MESA DITCH

REGION: UPPER COLORADO - UC

PROJECT: BOSTWICK PARK

DIVISION:		CONTRACTOR:	MCSTAIN CORPOR
STATE:	COLORADO	CONTRTYPE:	
COUNTY:		AWARDDATE:	10/27/1972
NEARTOWN:	VERNAL	COMPDATE:	10/27/1972

View Pipe Data
View Spec Info
View Cost Info
View Water District Info
Return to Switchboard

SPECNO:	TITLE:
DC-6977	MINOT EXTENSION. MINOT AND PIPELINES

REGION: GREAT PLAINS - GP / MISSOURI BASIN - MB / UPPER MISSOURI - UM

PROJECT: PICK-SLOAN MISSOURI BASIN PROGRAM

INDICATOR:	2	METHCOMP:	
PIPE_ACRO:	RPM	DEGREECOMP:	0
LENGTH:	36775	PERCCOMEX:	0
MINDIA:	24	PERCROCKEX:	0
MAXDIA:	48	TRENCHTYPE:	
MINHEAD:	50	GROUNDWATE:	0
MAXHEAD:	125	SOILCLASS:	
MINCOVER:	0	CATHOPROT:	
MAXCOVER:	0	CORROMONIT:	
LINING:	0.00	MAXFLOW:	18.6
COATING:	0.00	MINFLOW:	0
SUPPLLOC:		PUMPEDGRAV:	
COST:	0	SYSTEMTYPE:	
PIPEFAIL:		WATER:	
INSPEDATES:		WATERSOURC:	
PROBMEMO:		WATERSTORG:	
		ADJUSTSPEE:	0
		NUMDELIV:	0
ROADCROSS:		PUMPHEADS:	0
TYPEBED:			

DIVISION:	NORTH DAKOTA G	CONTRACTOR:	ABBOT AND HAGG
STATE:	NORTH DAKOTA	CONTRTYPE:	
COUNTY:		AWARDDATE:	11/15/1972
NEARTOWN:	MINOT	COMPDATE:	11/5/1974

View Pipe Data

View Spec Info

View Cost Info

View Water District Info

Return to Switchboard

SPECNO: DC-7066

TITLE: WESTLANDS WATER DISTRICT DISTRIBUTION SYSTEM. LATERALS 21R. 22R. 24R. 25R. 26R. 27R. 2

REGION: MID-PACIFIC - MP

PROJECT: CENTRAL VALLEY

INDICATOR:	4	METHCOMP:	
PIPE_ACRO:	RPM	DEGREECOMP:	0
LENGTH:	107273	PERCCOMEX:	0
MINDIA:	24	PERCROCKEX:	0
MAXDIA:	54	TRENCHTYPE:	
MINHEAD:	25	GROUNDWATE:	0
MAXHEAD:	450	SOILCLASS:	
MINCOVER:	5	CATHOPROT:	
MAXCOVER:	20	CORROMONIT:	
LINING:	0.00	MAXFLOW:	0
COATING:	0.00	MINFLOW:	0
SUPPLLOC:		PUMPEDGRAV:	PUMPED
COST:	0	SYSTEMTYPE:	IRRIGATION
PIPEFAIL:		WATER:	
INSPEDATES:		WATERSOURC:	SAN LUIS CANAL
PROBMEMO:		WATERSTORG:	TANK
		ADJUSTSPEE:	0
		NUMDELIV:	0
ROADCROSS:		PUMPHEADS:	0
TYPEBED:			

Select: DC-7066

SPECNO: DC-7066

TITLE: WESTLANDS WATER DISTRICT DISTRIBUTION SYSTEM. LATERALS 21R. 22R. 24R. 25R. 26R. 27R. 2

REGION: MID-PACIFIC - MP

PROJECT: CENTRAL VALLEY

DIVISION:	WEST SAN JOAQU	CONTRACTOR:	C.R. FEDRICK. INC
STATE:	CALIFORNIA	CONTRTYPE:	SEALED BID
COUNTY:	FRESNO AND KIN	AWARDDATE:	7/9/1974
NEARTOWN:	HURON	COMPDATE:	6/8/1976

View Pipe Data

View Spec Info

View Cost Info

View Water District Info

Return to Switchboard

SPECNO: DC-7098

TITLE: PLEASANT OAK MAIN. PIPELINE 7 AND RESERVOIRS B AND C

REGION: MID-PACIFIC - MP

PROJECT: CENTRAL VALLEY

INDICATOR:	2	METHCOMP:	
PIPE_ACRO:	RPM	DEGREECOMP:	0
LENGTH:	21120	PERCCOMEX:	0
MINDIA:	27	PERCROCKEX:	0
MAXDIA:	30	TRENCHTYPE:	
MINHEAD:	25	GROUNDWATE:	0
MAXHEAD:	450	SOILCLASS:	
MINCOVER:	0	CATHOPROT:	
MAXCOVER:	0	CORROMONIT:	
LINING:	0.00	MAXFLOW:	0
COATING:	0.00	MINFLOW:	0
SUPPLLOC:		PUMPEDGRAV:	GRAVITY
COST:	0	SYSTEMTYPE:	IRRIGATION
PIPEFAIL:		WATER:	
INSPEDATES:		WATERSOURC:	RESERVOIR A
PROBMEMO:		WATERSTORG:	
		ADJUSTSPEE:	0
		NUMDELIV:	0
ROADCROSS:		PUMPHEADS:	0
TYPEBED:			

DIVISION:	AMERICAN RIVER	CONTRACTOR:	H.M. BYARS CONS
STATE:	CALIFORNIA	CONTRTYPE:	
COUNTY:	EL DORADO	AWARDDATE:	3/14/1975
NEARTOWN:	PLACERVILLE	COMPDATE:	2/11/1977

View Pipe Data

View Spec Info

View Cost Info

View Water District Info

Return to Switchboard

Select: DC-7110

SPECNO:	TITLE:
DC-7110	WESTLANDS WATER DISTRICT DISTRIBUTION SYSTEM. LATERALS 4. 7. 13. 14. 32. 33. 34. 35. 36. 3
	REGION: MID-PACIFIC - MP
	PROJECT: CENTRAL VALLEY

INDICATOR:	3	METHCOMP:	.
PIPE_ACRO:	RPM	DEGREECOMP:	0
LENGTH:	26307	PERCCOMEX:	0
MINDIA:	30	PERCROCKEX:	0
MAXDIA:	33	TRENCHTYPE:	
MINHEAD:	25	GROUNDWATE:	0
MAXHEAD:	150	SOILCLASS:	
MINCOVER:	5	CATHOPROT:	
MAXCOVER:	20	CORROMONIT:	
LINING:	0.00	MAXFLOW:	0
COATING:	0.00	MINFLOW:	0
SUPPLLOC:		PUMPEDGRAV:	PUMPED
COST:	0	SYSTEMTYPE:	IRRIGATION
PIPEFAIL:		WATER:	
INSPEDATES:		WATERSOURC:	SAN LUIS CANAL
PROBMEMO:		WATERSTORG:	
		ADJUSTSPEE:	0
		NUMDELIV:	13700
ROADCROSS:		PUMPHEADS:	0
TYPEBED:			

Select: DC-7110

SPECNO:	TITLE:
DC-7110	WESTLANDS WATER DISTRICT DISTRIBUTION SYSTEM. LATERALS 4. 7. 13. 14. 32. 33. 34. 35. 36. 3
	REGION: MID-PACIFIC - MP
	PROJECT: CENTRAL VALLEY

DIVISION:	WEST SAN JOAQU	CONTRACTOR:	GRANITE CONSTR
STATE:	CALIFORNIA	CONTRTYPE:	
COUNTY:	FRESNO AND KIN	AWARDDATE:	5/13/1975
NEARTOWN:	MENDOTA	COMPDATE:	4/17/1977

View Pipe Data

View Spec Info

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View Water District Info

Return to Switchboard

Select: DC-7184

SPECNO: DC-7184

TITLE: WESTLANDS WATER DISTRICT DISTRIBUTION SYSTEM. LATERALS 1R. 3R AND 4R. CONTRACT 13B

REGION: MID-PACIFIC - MP

PROJECT: CENTRAL VALLEY

INDICATOR:	3	METHCOMP:	
PIPE_ACRO:	RPM	DEGREECOMP:	0
LENGTH:	110450	PERCCOMEX:	0
MINDIA:	24	PERCROCKEX:	0
MAXDIA:	54	TRENCHTYPE:	
MINHEAD:	25	GROUNDWATE:	0
MAXHEAD:	300	SOILCLASS:	
MINCOVER:	5	CATHOPROT:	
MAXCOVER:	20	CORROMONIT:	
LINING:	0.00	MAXFLOW:	0
COATING:	0.00	MINFLOW:	0
SUPPLLOC:		PUMPEDGRAV:	PUMPED
COST:	0	SYSTEMTYPE:	IRRIGATION
PIPEFAIL:		WATER:	
INSPEDATES:		WATERSOURC:	SAN LUIS CANAL
PROBMEMO:		WATERSTORG:	RESERVOIRS
		ADJUSTSPEE:	0
		NUMDELIV:	17880
ROADCROSS:		PUMPHEADS:	0
TYPEBED:			

Select: DC-7184

SPECNO: DC-7184

TITLE: WESTLANDS WATER DISTRICT DISTRIBUTION SYSTEM. LATERALS 1R. 3R AND 4R. CONTRACT 13B

REGION: MID-PACIFIC - MP

PROJECT: CENTRAL VALLEY

DIVISION:	WEST SAN JOAOU	CONTRACTOR:	MCGUIRE AND HE
STATE:	CALIFORNIA	CONTRTYPE:	
COUNTY:	FRESNO	AWARDDATE:	6/30/1976
NEARTOWN:	MENDOTA	COMPDATE:	8/29/1978

View Pipe Data

View Spec Info

View Cost Info

View Water District Info

Return to Switchboard

Select: DC-7238

SPECNO: DC-7238

TITLE: EL DORADO MAIN NO. 2, PIPELINE, AND RESERVOIR 2A

REGION: MID-PACIFIC - MP

PROJECT: CENTRAL VALLEY

INDICATOR:	2	METHCOMP:	
PIPE_ACRO:	RPM	DEGREECOMP:	0
LENGTH:	10185	PERCCOMEX:	0
MINDIA:	27	PERCROCKEX:	0
MAXDIA:	30	TRENCHTYPE:	
MINHEAD:	175	GROUNDWATE:	0
MAXHEAD:	500	SOILCLASS:	
MINCOVER:	5	CATHOPROT:	
MAXCOVER:	10	CORROMONIT:	
LINING:	0.00	MAXFLOW:	0
COATING:	0.00	MINFLOW:	0
SUPPLLOC:		PUMPEDGRAV:	GRAVITY
COST:	0	SYSTEMTYPE:	M&I
PIPEFAIL:		WATER:	
INSPEDATES:	-	WATERSOURC:	RESERVOIR 2A
PROBMEMO:		WATERSTORG:	
		ADJUSTSPEE:	0
		NUMDELIV:	0
ROADCROSS:		PUMPHEADS:	0
TYPEBED:			

DIVISION:		CONTRACTOR:	WUNSHELL AND S
STATE:	CALIFORNIA	CONTRTYPE:	
COUNTY:	EL DORADO	AWARDDATE:	1/10/1977
NEARTOWN:	PLACERVILLE	COMPDATE:	9/2/1978

View Pipe Data

View Spec Info

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Return to Switchboard

SPECNO:	TITLE:
DC-7318	PIPE LATERALS AND PUMPING PLANTS. BLOCK 4
	REGION: UPPER COLORADO - UC / GREAT PLAINS - GP / SOUTHWEST - SW
	PROJECT: NAVAJO INDIAN IRRIGATION

INDICATOR:	2	METHCOMP:	
PIPE_ACRO:	RPM	DEGREECOMP:	0
LENGTH:	1494	PERCCOMEX:	0
MINDIA:	24	PERCROCKEX:	0
MAXDIA:	30	TRENCHTYPE:	
MINHEAD:	25	GROUNDWATE:	0
MAXHEAD:	500	SOILCLASS:	
MINCOVER:	5	CATHOPROT:	
MAXCOVER:	15	CORROMONIT:	
LINING:	0.00	MAXFLOW:	0
COATING:	0.00	MINFLOW:	0
SUPPLLOC:	AMOCO/RIVERSID	PUMPEDGRAV:	
COST:	0	SYSTEMTYPE:	
PIPEFAIL:		WATER:	
INSPEDATES:		WATERSOURC:	
PROBMEMO:		WATERSTORG:	
		ADJUSTSPEE:	0
		NUMDELIV:	0
ROADCROSS:		PUMPHEADS:	0
TYPEBED:			

Select: DC-7318

SPECNO:	TITLE:
DC-7318	PIPE LATERALS AND PUMPING PLANTS. BLOCK 4
	REGION: UPPER COLORADO - UC / GREAT PLAINS - GP / SOUTHWEST - SW
	PROJECT: NAVAJO INDIAN IRRIGATION

DIVISION:		CONTRACTOR:	C.R. FEDRICK. INC
STATE:	NEW MEXICO	CONTRTYPE:	
COUNTY:	SAN JUAN	AWARDDATE:	5/9/1978
NEARTOWN:	FARMINGTON	COMPDATE:	10/15/1979

View Pipe Data

View Spec Info

View Cost Info

View Water District Info

Return to Switchboard

SPECNO: DC-7450(2)

TITLE: PIPELINE AND STRUCTURES FOR DUNNIGAN WATER DISTRICT DISTRIBUTION SYSTEM

REGION: MID-PACIFIC - MP

PROJECT: CENTRAL VALLEY

INDICATOR:	2	METHCOMP:	
PIPE_ACRO:	RPM	DEGREECOMP:	0
LENGTH:	4670	PERCCOMEX:	0
MINDIA:	42	PERCROCKEX:	0
MAXDIA:	48	TRENCHTYPE:	
MINHEAD:	25	GROUNDWATE:	0
MAXHEAD:	150	SOILCLASS:	
MINCOVER:	5	CATHOPROT:	
MAXCOVER:	15	CORROMONIT:	
LINING:	0.00	MAXFLOW:	0
COATING:	0.00	MINFLOW:	0
SUPPLLOC:	CORBAN/ARMCO.	PUMPEDGRAV:	PUMPED
COST:	0	SYSTEMTYPE:	IRRIGATION
PIPEFAIL:		WATER:	
INSPEDATES:		WATERSOURC:	TEHAMA-COLUSA
PROBMEMO:		WATERSTORG:	
		ADJUSTSPEE:	0
		NUMDELIV:	0
ROADCROSS:		PUMPHEADS:	0
TYPEBED:			

DIVISION:	SACRAMENTO RIV	CONTRACTOR:	GRANITE CONSTR
STATE:	CALIFORNIA	CONTRTYPE:	
COUNTY:	YOLO	AWARDDATE:	
NEARTOWN:	DUNNIGAN	COMPDATE:	

View Pipe Data

View Spec Info

View Cost Info

View Water District Info

Return to Switchboard

SPECNO: DC-7466

TITLE: GOVERNMENT HIGHLINE LATERALS - STAGE 1

REGION: UPPER COLORADO - UC

PROJECT: COLORADO RIVER BASIN SALINITY CONTROL

INDICATOR:	3	METHCOMP:	
PIPE_ACRO:	RPM	DEGREECOMP:	0
LENGTH:	23685	PERCCOMEX:	0
MINDIA:	27	PERCROCKEX:	0
MAXDIA:	42	TRENCHTYPE:	
MINHEAD:	25	GROUNDWATE:	0
MAXHEAD:	150	SOILCLASS:	
MINCOVER:	5	CATHOPROT:	
MAXCOVER:	10	CORROMONIT:	
LINING:	0.00	MAXFLOW:	0
COATING:	0.00	MINFLOW:	0
SUPPLLOC:	CORBAN/ARMCO.	PUMPEDGRAV:	GRAVITY
COST:	0	SYSTEMTYPE:	IRRIGATION
PIPEFAIL:		WATER:	
INSPEDATES:		WATERSOURC:	GOVERNMENT HI
PROBMEMO:		WATERSTORG:	NONE
		ADJUSTSPEE:	0
		NUMDELIV:	5590
ROADCROSS:		PUMPHEADS:	0
TYPEBED:			

Select: DC-7466

SPECNO: DC-7466

TITLE: GOVERNMENT HIGHLINE LATERALS - STAGE 1

REGION: UPPER COLORADO - UC

PROJECT: COLORADO RIVER BASIN SALINITY CONTROL

DIVISION:	GRAND VALLEY U	CONTRACTOR:	SBA ITL. (DENVER
STATE:	COLORADO	CONTRTYPE:	
COUNTY:	MESA	AWARDDATE:	9/15/1981
NEARTOWN:	FRUITA	COMPDATE:	3/3/1984

View Pipe Data

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Return to Switchboard

SPECNO:	TITLE:
DC-7473	COLUSA COUNTY CONTRACT 2A
	REGION: MID-PACIFIC - MP
	PROJECT: CENTRAL VALLEY

INDICATOR:	2	METHCOMP:	
PIPE_ACRO:	RPM	DEGREECOMP:	0
LENGTH:	12185	PERCCOMEX:	0
MINDIA:	27	PERCROCKEX:	0
MAXDIA:	30	TRENCHTYPE:	
MINHEAD:	50	GROUNDWATE:	0
MAXHEAD:	175	SOILCLASS:	
MINCOVER:	5	CATHOPROT:	
MAXCOVER:	10	CORROMONIT:	
LINING:	0.00	MAXFLOW:	0
COATING:	0.00	MINFLOW:	0
SUPPLLOC:	CORBAN/ARMCO.	PUMPEDGRAV:	PUMPED
COST:	0	SYSTEMTYPE:	IRRIGATION
PIPEFAIL:		WATER:	
INSPEDATES:		WATERSOURC:	TEHEMA COLUSA
PROBMEMO:		WATERSTORG:	
		ADJUSTSPEE:	0
		NUMDELIV:	7262
ROADCROSS:		PUMPHEADS:	0
TYPEBED:			

DIVISION:		CONTRACTOR:	COPENHAGEN UTI
STATE:	CALIFORNIA	CONTRTYPE:	
COUNTY:	COLUSA	AWARDDATE:	8/19/1981
NEARTOWN:	ARBUCKLE	COMPDATE:	6/15/1982

View Pipe Data

View Spec Info

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View Water District Info

Return to Switchboard

SPECNO:	DC-7508(1)
TITLE:	ELLISFORD. EAST TONASKET AND BONAPARTE CREEK DIST. SYS - SCHEDULE 2
REGION:	PACIFIC NORTHWEST - PN
PROJECT:	CHIEF JOSEPH DAM

INDICATOR:	3	METHCOMP:	
PIPE_ACRO:	RPM	DEGREECOMP:	0
LENGTH:	15311	PERCCOMEX:	0
MINDIA:	24	PERCROCKEX:	0
MAXDIA:	30	TRENCHTYPE:	
MINHEAD:	50	GROUNDWATE:	0
MAXHEAD:	500	SOILCLASS:	
MINCOVER:	0	CATHOPROT:	
MAXCOVER:	0	CORROMONIT:	
LINING:	0.00	MAXFLOW:	0
COATING:	0.00	MINFLOW:	0
SUPPLLOC:	CORBAN/ARMCO.	PUMPEDGRAV:	PUMPED
COST:	0	SYSTEMTYPE:	IRRIGATION
PIPEFAIL:	YES - 2 FAILURES	WATER:	SILTY
INSPEDATES:		WATERSOURC:	OKANAGON RIVER
PROBMEMO:	RPM PIPE FAILURES July 4 1990 -	WATERSTORG:	RESERVOIR
		ADJUSTSPEE:	0
		NUMDELIV:	3730
ROADCROSS:		PUMPHEADS:	0
TYPEBED:			

Select: DC-7508(1)

SPECNO:	DC-7508(1)
TITLE:	ELLISFORD. EAST TONASKET AND BONAPARTE CREEK DIST. SYS - SCHEDULE 2
REGION:	PACIFIC NORTHWEST - PN
PROJECT:	CHIEF JOSEPH DAM

DIVISION:		CONTRACTOR:	GOODFELLOW BR
STATE:	WASHINGTON	CONTRTYPE:	
COUNTY:	OKANAGON	AWARDDATE:	8/18/1982
NEARTOWN:	TONASKET AND E	COMPDATE:	2/9/1984

View Pipe Data

View Spec Info

View Cost Info

View Water District Info

Return to Switchboard

SPECNO: DC-7510

TITLE: PRETREATMENT 11 - YUMA DESALTING PLANT

REGION: LOWER COLORADO - LC

PROJECT: COLORADO RIVER BASIN SALINITY CONTROL

INDICATOR:	1	METHCOMP:	
PIPE_ACRO:	RPM	DEGREECOMP:	0
LENGTH:	14410	PERCCOMEX:	0
MINDIA:	6	PERCROCKEX:	0
MAXDIA:	72	TRENCHTYPE:	
MINHEAD:	50	GROUNDWATE:	0
MAXHEAD:	550	SOILCLASS:	
MINCOVER:	0	CATHOPROT:	
MAXCOVER:	0	CORROMONIT:	
LINING:	0.00	MAXFLOW:	0
COATING:	0.00	MINFLOW:	0
SUPPLLOC:	CORBAN/ARMCO.	PUMPEDGRAV:	PUMPED
COST:	0	SYSTEMTYPE:	DESALTING LINE
PIPEFAIL:		WATER:	
INSPEDATES:		WATERSOURC:	COLORADO RIVER
PROBMEMO:		WATERSTORG:	
		ADJUSTSPEE:	0
		NUMDELIV:	0
ROADCROSS:		PUMPHEADS:	0
TYPEBED:			

View Pipe Data

View Spec Info

View Cost Info

View Water District Info

Return to Switchboard

SPECNO: DC-7510

TITLE: PRETREATMENT 11 - YUMA DESALTING PLANT

REGION: LOWER COLORADO - LC

PROJECT: COLORADO RIVER BASIN SALINITY CONTROL

DIVISION:		CONTRACTOR:	BRINDERSON COR
STATE:	ARIZONA	CONTRTYPE:	
COUNTY:	YUMA	AWARDDATE:	8/6/1982
NEARTOWN:	YUMA	COMPDATE:	7/26/1984

View Pipe Data

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Return to Switchboard

Appendix B

Reclamation Decision Memorandums Regarding RPM Pipe

1. **1990 - Temporary Ban on all Fiberglass Pipe**
2. **1991 - Partial Lifting on Ban to Allow "HOBAS" Brand RPM Pipe**
3. **1997 – Memorandum - Lifting of Ban on all Fiberglass Pipe**

MS-884 (1
Bureau of

TES GOVERNMENT
ındum

Denver, Colorado
DATE: March 12, 1990

TO : Design Managers
Attention: D-3120 (Schoeman, Wegener, Mitchell, Fisher, Cowan)

FROM : Chief, Water Conveyance Branch

SUBJECT: Temporary Policy for Water Conveyance Branch Pipe Designs and Specifications - (Specification, Pipelines)

Due to the recent Bureau of Reclamation problems with prestressed concrete pipe and reinforced thermosetting resin pipe (fiberglass), these two pipe types until further notice will not be considered as options in our specifications. If and when the ongoing research investigations are able to identify and clear up the problems with these pipe options, they may again be used in the future. Notice will be given at that time for rescinding this policy.

Walter L. Long

cc: D-3100
D-3120 (Long)
D-3500
D-3523
D-3700

WBR:JPBaysinger/WLLong:cmm:03/12/90:236-4203
PC-WP(5.0)2:WLL3.MEM

D-3120

Mr. Larry McQueen
Area Manager
HOBAS USA Inc.
5330 Office Centre Court
Suite B-53
Bakersfield CA 93309

JUN 1 8 1991

Subject: Waiver of Moratoriums on Fiberglass Pipe for the Eastern Municipal Water District (Pipelines)

Dear Mr. McQueen:

The Bureau of Reclamation is still analyzing the data dealing with the failure of reinforced plastic mortar (RPM) pipe. We have not come to any conclusions as of this date and subsequently our moratoriums for the use of fiberglass pipe is still in effect. However, we feel that the centrifugally cast fiberglass reinforced polyester pipe produced by your company will eventually be allowed as a pipe option on Reclamation projects. Therefore, on a case by case basis, we will give approval for the use of your company's pipe with the stipulation that it meets all the requirements of the American Water Works Association (AWWA) standard for fiberglass pressure pipe C950-88.

Sincerely,

Walter L Long

Walter L. Long, Chief
Water Conveyance Branch

bc: D-3100, D-3120, D-3120 (Kinney)

WBR:DHWegener:tla:06/10/91:236-3949
PCWP:Wegener.1

DATE	PEER REVIEWER(S)	CODE
6/13/97	[signature] Signature	
	Lowell D. Pimley Printed Name	D-8140
	Signature	
	Printed Name	
Author Initials	PEER REVIEW NOT REQUIRED	

D-8140
ADM-1.10

JUN 16 1997

MEMORANDUM

To: See Attached Distribution

From: Felix W. Cook, Sr.
Director, Technical Service Center

Subject: Use of Fiberglass Pipe on Reclamation Projects

On March 12, 1990, the Assistant Commissioner Engineering and Research initiated a temporary moratorium on the use of Reinforced Thermosetting Resin (Fiberglass) Pipe for Reclamation projects. This action was prompted by unexplained ruptures of Fiberglass Pipe on several Reclamation projects. The failed pipe units on these projects were manufactured using a fabrication technique originally developed in the late 1960's under the trade name "Techite" and prior to development of the 1988 American Water Works Association (AWWA) standard for Fiberglass Pipe.

Historically, Reclamation has included as many technically viable pipe options as possible on our projects to enhance competition among pipe suppliers thus keeping pipe prices responsive to market forces. The Technical Service Center (TSC) therefore believed investigating the possibility of reinstating the use of Fiberglass Pipe for Reclamation projects was in our clients' best interest.

To that end, the TSC has worked with Fiberglass Pipe producers and users associated with AWWA since 1990. This association has allowed our engineers to better understand the AWWA Standard for Fiberglass Pressure Pipe (C950) and has provided access to other users' experience with the product. Based on discussions with other pipe users, Fiberglass Pipe manufactured to recent standards appears to have provided good service on their projects with no reported ruptures.

AWWA has recently updated the C950-88 standard. The major revisions to the 1988 standard involve removing the design portion from the C950 standard and placing these details into a separate design manual. The new AWWA standard for Fiberglass Pressure Pipe (C950-95) is a manufacturing standard only. The manufacture of Fiberglass Pipe under this new standard will remain essentially unchanged from the 1988 version.

Design of fiberglass pipe is addressed in a separate document called the Fiberglass Pipe Design Manual (AWWA Manual M45). With input from our representative on the AWWA subcommittee, the design criteria in this manual provide a more accurate procedure to determine the required pipe stiffness for a given installation. Installation and handling precautions have also been strengthened compared to earlier standards.

Given these factors, we believe that Fiberglass Pipe designed and installed in accordance with the newly released AWWA M45 Fiberglass Pipe Design Manual and manufactured in accordance with the updated AWWA C950-95 standard will produce a product with acceptable performance for Reclamation projects.

Therefore, the TSC plans to include Fiberglass Pipe (which meets the above criteria) in the list of pipe options provided to our clients for applications within its size and pressure limits. As is the case with all pipe types, however, each client has the ultimate authority to select pipe options which best meet the specific needs of their project. The pipe options which are acceptable to the client will then be included in the construction specifications for that project.

The TSC is available to provide assistance for the design of Fiberglass Pipe and to answer questions related to manufacturing processes. If you have technical questions on the use of Fiberglass Pipe, please call Mr. Leo Kinney of my staff at 303-236-3999, extension 526. If your office is interested in obtaining copies of the C950-95 standard and the M45 Fiberglass Pipe Design Manual, they are available from the American Water Works Association, 6666 West Quincy Avenue, Denver, CO 80235.

Thank you.

Attachment

bc: D-1000, D-8000, D-8100, D-8140 (Fuerst, Kinney), D-8180 (Swihart)

Appendix B – Travel Report – Flowtite (Thompson Pipe Group) Factory Visit, Zachary, Louisiana

Date: 4/4/2017

Travelers: Atousa Plaseied (8540), Jay Swihart (8540), Nick Clough (8140), and Emma Manzanares (FCCO)

Flowtite Reps: Jeff LeBlanc, Casey Wood (tour guide), and Erica Chandler

GFRP pipe evolution from 1970's designs to the current design and Flowtite pipe "recipe" were discussed. Pipe, tank, and manholes used to be manufactured in Owens Corning, but delivered to other companies including Flowtite. Research and Development is still in Owens Corning. Flowtite manufactures pipe, couplings/fittings (figure A-1), and Tee connectors (figure A-2). Pipe (with dimeter of 30 to 244 cm) is composed of the following materials:

- Resin: Polyester and vinyl ester.
- Fiber: E-CR glass (E-glass w/o Boron), both continuous and chopped (about 5 cm long)
- Filler: Sand

Note that Flowtite also manufactures flanges. Flanges are handmade, labor intensive, and all fiberglass with no sand. The quantity of glass is increased and the sand is reduced in higher pressure pipe ratings. As a result, a thinner walled pipe can be designed to withstand higher pressures than a thicker walled pipe with sand.

The fabrication process (figure A-3 to A-9) is a filament wound manufacturing process including steel wrap, Mylar wrap, fiberglass wrap, chopped glass fibers, sand, resin, and heat. Mylar acts as a liner between the mandrel and the mixture throughout the fabrication process and is removed after the pipe sections are fabricated. The mandrel is similar to the steel pipe fabrication. The chopped glass fiber provides the axial strength for the pipe and the fiberglass strands provide the hoop strength for the pipe under pressure. All pipe sections are stamped with the following identifications (figure A-10):

- Diameter
- Pressure
- Stiffness

A 0.25 MPa stiffness is standard in the U.S. No structural change is needed due to UV light because of thermoset resin used. Thermoset resins are fully cured and are UV resistant.

Figure A-1.—GFRP pipe couplings/fittings with gaskets for sealing

Figure A-2.—GFRP tee connector

Figure A-3.—Flowtite filament wound manufacturing process

Figure A-4.—Continuous fiberglass thread woven and wrapped over Mylar

Figure A-5.—Chopped glass fiber waste

Figure A-6.—Heating system to cure resin

Figure A-7—Cutting pipe to the required length

Figure A-8.—Lowering the pipe for testing

Figure A-9.—Checking the pipe and removing Mylar

Figure A-10.—Stamping the pipe identification
(diameter (24 inch or 61 cm), pressure (250 psi or 2 MPa), and stiffness
(36 psi or 0.25 MPa))

After the pipe fabrication, the pipe sections move to a calibration station: the ends are calibrated/adjusted to fit in the Flowtite couplings. Pipe sections are then forwarded to the hydro-tester station (figure A-11) for pressure testing with water. All pipe sections are tested to twice the rated pressure and held for two minutes. The setup for hydro-testing the GFRP pipe is similar to steel pipe hydro-testing. The pipe fails if it loses pressure.

Figure A-11.—Hydro-tester station

The following tests are performed in the laboratory:

Resin: initial gel time and reactive properties

Physical properties:

- Viscosity
- Solid content
- Acid number
- Flash point
- Shelf life at 25°C

Curing properties:

- Gel time at 25°C
- Reactivity test at 25°C

Fiber and sand: check grain size for sand (0.2 percent moisture or less)

Barcol Hardness: ASTM D2583

Tensile Strength: ISO 527 (figure A-12 shows the samples for mechanical testing)

Tensile Modulus: ISO 527

Stiffness tester: ASTM 2412: pipe sample deflects until breaks (figure A-13, test observed).

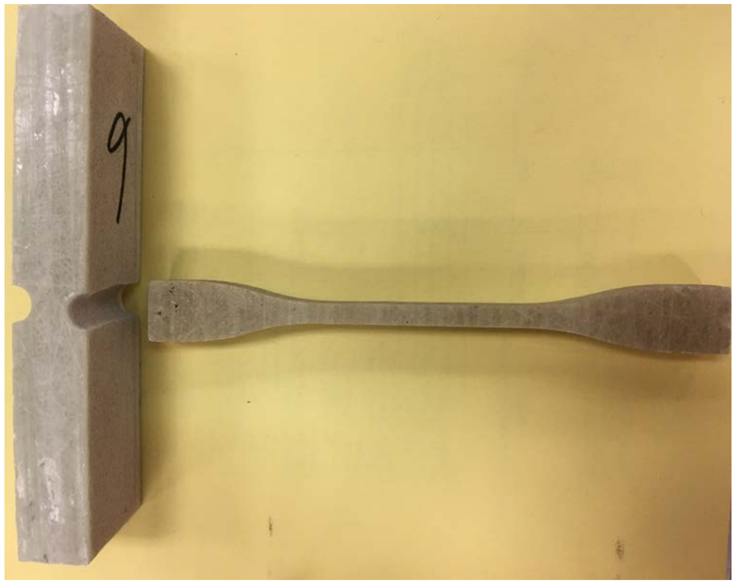

Figure A-12.—Samples for mechanical testing

Figure A-13.— Mechanical properties tester (29,000 N load at 5% deflection)

The fittings were tested similar to pipe at twice the pressure rating and held for a period of two minutes to ten minutes (figure A-14).

Figure A-14.—pressure testing of the fittings

As mentioned earlier, flanges are fabricated by hand (figure A-15). The pipe section is placed on a table. Sections of woven fiberglass cloths (figure A-16) approximately 20 cm × 30 cm are layered on a separate table and coated with resin. They are then formed to the pipe to create a flange. This process is time intensive and takes about 2 days (2 to 3 shifts per day) to complete one flange. The flange bolt holes are then drilled by hand.

Figure A-15.—Fabrication process of flanges

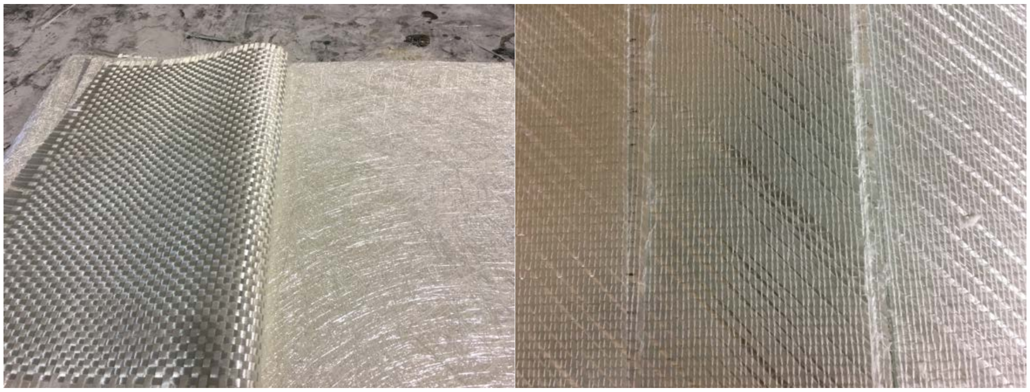

Figure A-16.—Woven fiberglass cloths

Appendix C – Travel Report – Leadville Mine Drainage Tunnel Water Treatment Plant, Leadville, Colorado

Date: 5/25/2017

Travelers: Atousa Plaseied (8540), Jay Swihart (8540), and Christine Henderson (8540)

Leadville Mine Drainage Tunnel Water Treatment Plant Rep: Jenelle Stefanic

Inspector: Ron Harris (Free Water Systems)

Visual Inspection of acid and caustic tanks were performed 5 years after 2012 inspection and 4 year after 2013 repair in May 2017. The reports from 2012 and 2017 inspections, prepared by Ron Harris, Western Underground Fiberglass Service, a division of Free Water Systems, LLC, are included in Appendix B.

Tank Inspection and Repair Protocol – Leadville Mine Drainage Tunnel Water Treatment Plant – December 2012

Inspection:

Two tanks were inspected:

1) Dilute sulphuric acid tank – Design Tanks – Dion 6631 – 3 m D x 4 m T – mfd 12/2000

This tank has a failing liner. Many deteriorated areas appear throughout the entire interior surface. The bottom cap joint and areas around all the penetrations and manway show severe deterioration. There is also a series of cracks appearing on one side, which appear to be possible shipping damage. Structurally, this tank appears intact. There is a mixer mounted on the outside top of this tank, with a platform bolted directly into the top of the tank at each end with common lag bolts. These bolts have wallowed out and allow the mixer to shake when in operation.

This tank requires relining and the addition of two support platforms on top for the mixer.

Penetrations on this tank are: 61 cm Manway

- 2 – 8 cm Flanged nozzles
- 1 – 5 cm Flanged nozzle
- 1 – 10 cm Nozzle
- 1 – 5 cm Threaded nipple – plugged

Repair Protocol:

The entire interior of this tank will need to be sanded, with particular attention to the deteriorated areas and the areas around the bottom cap and penetrations. After sanding, two thorough acetone wipes will be needed to prepare for layers of penetrating resin. Layers of penetrating resin need to be applied until there is no fiber visible on the interior surface. After letting the penetrating resin harden thoroughly, all areas treated will require an additional sanding, followed again by twice wiping down with acetone. Final application will be a layer of Derakane resin over C-veil, with the final, top layer, requiring an added surfacing agent to promote complete curing. The manway flange on this tank is also deteriorated and will require the same treatment, plus a final sanding, to insure a good seal. The manway blank appears intact, not requiring any work.

Mounting brackets for the mixer will need to be added after adding a gusset to each top corner. This gusset should "wrap" around from the horizontal top surface to the vertical side of the tank for several inches and be built up with succeeding layers of 57 g structural mat to a thickness of at least 0.6 cm. An FRP channel, 8 cm x 3 cm and 5 cm longer than the pump bracket, should then be laminated onto the gusset, giving adequate clearance underneath for the nuts on the mounting bolts. Rubber washers would be recommended between the mounting and the pump bracket to absorb vibration.

2) NaOH storage Tank – Palmer Tanks – Hetron 922 – 2 m D x 5 m T – mfd 9/23/2005

This tank shows a few small areas of deterioration around the penetrations and the manway. These areas need to be resurfaced. Structurally this tank appears sound and should provide many more years of service. Those deteriorated areas are all where hand lamination was used during production and require the same basic repair protocol as the interior of the acid tank. The manway flange shows some minor deterioration and should be resurfaced and refaced. The manway blank appears intact.

Penetrations on this tank are: 61 cm Manway

- 1 – 8 cm Nozzle
- 2 – 5 cm Nozzles

Tank Inspection and Repair Protocol – Leadville Mine Drainage Tunnel Water Treatment Plant – May 2017

1) Tank Description: Dilute Sulfuric Acid Tank AS4

Dimensions: 3 m D x 4 m T   Shape: Cylinder

Function: Dilution/Metering

Material: Fiberglass: FRP – Dion 6631

FRP Type: Helical ______ Chop Hoop: ______ Cast: X   Other: _______

Steel Type: Welded: _______ Riveted: ________ Other: ________

General Condition: Previous Repairs Relined in 2013 appear intact – no exposed fiber visible

Floor: Good

Joint: Good

Seams: N/A

Top: Not Inspected, Indoor

Fittings: Good

Notes: Recommend Follow up Inspection in five years Maximum

2) Tank Description: NaOH Storage Dilute Tank CS4

Dimensions: 2 m D x 5 m T   Shape: Cylinder

Function: Caustic Storage/Metering

Material: Fiberglass: Hetron 922

FRP Type: Helical X Chop Hoop: ______ Cast: _______ Other: _______

General Condition: Good (Tank was re-lined in 2015)

Floor: Good

Joint: Good

Seams: Good

Top: Not Inspected – Indoors

Fittings: Good

Notes: Recommend re-inspection in 3-5 years

Inspection was performed on both acid and caustic tanks (figures B-1 and B-2). These tanks are used for chemical treatment and cleaning water. Visual inspection was a reliable and easy method to detect blisters, air pockets, voids, and delamination in FRP tanks. Digital tap hammer could also be used as a tool for detecting delamination by change in the sound.

Figure B-1.—Acid and caustic tanks used for water treatment with their manufacturing information

Figure B-2.—Visual inspection of the acid tank interior

This report can be found in \\bor\do\tsc\Support\Groups\8500\Reports Database. Approximate file size: 4,270 KB.

Point of Contact:

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303-445-2390