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Investigation of Fiberglass-Reinforced Plastic (FRP) Condensate Return Carrier Piping

by
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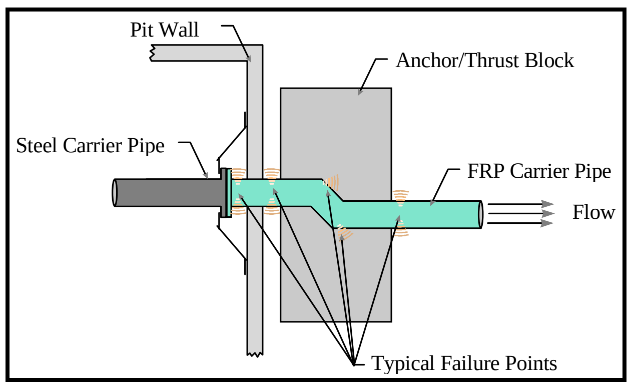

Typical failure points around manholes.

The Army operates approximately 2700 miles of heat distribution system piping, a large portion of which are used for steam and condensate return piping. The use of fiberglass-reinforced plastic (FRP) carrier piping for the return of hot condensate to the boiler plant was allowed. The failure of this piping results in considerable extra expense. This report presents results of a survey that evaluated the performance of FRP condensate carrier piping on Federal installations, especially the performance of systems that have in-line cooling devices installed according to recent criteria. The survey indicated that most Federal agencies that have used FRP pipe for condensate carrier return are not satisfied with its performance because of its general failure to achieve design performance. This study concluded that, overall, the problems with FRP pipe in condensate return service and associated maintenance to correct them far outweigh the benefits derived from using FRP pipe.

Foreword

This project was conducted for the Federal Agency Committee on Underground Heat Distribution Systems under Military Interdepartmental Purchase Request (MIPR) No. E87950329, Work Unit No. JN5, "Investigation of Fiberglass-Reinforced Plastic (FRP) Condensate Return Carrier Piping"; funding provided by the Office of the Chief of Engineers. The technical monitor was Dale Otterness, CEMP-ET.

The work was done by the Materials Science and Technology Division (FL-M) of the Facilities Technology Laboratory (FL), U.S. Army Construction Engineering Research Laboratories (USACERL). The USACERL principal investigator was Charles P. Marsh and the associate investigator was Orange S. Marshall, Jr. Base personnel were consistently helpful during the surveys and their efforts served to greatly improve the quality and scope of this study. Dr. Ilker R. Adiguzel is Chief, CECER-FL-M, and Larry M. Windingland is Acting Operations Chief, CECER-FL. The USACERL technical editor was William J. Wolfe, Technical Resources.

COL James A. Walter is Commander and Dr. Michael J. O'Connor is Director of USACERL.

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1 Introduction

Background

The Army operates approximately 2700 miles of heat distribution system piping (*Directorate of Public Works Annual Summary of Operations* 1995). A large portion of these systems are used for steam and condensate return piping. Allowed at the time of the survey (in conjunction with a condensate cooling device) was fiberglass-reinforced plastic (FRP) carrier piping for the return of hot (150 to 200 °F)* condensate to the boiler plant. The failure of condensate return piping resulting in the addition of a large percentage of "make up" water results in a considerable and avoidable extra expense. Condensate piping failures also releases boiler water treatment chemicals to the environment.

Interviews during a recent series of site visits revealed a unanimous dissatisfaction with FRP carrier piping for this application. Aberdeen Proving Grounds, MD has experienced numerous failures. Personnel at Fort Lewis, WA indicated that their experience was negative and that they intend never to use FRP condensate carrier piping again. Grissom Air Force Base, IN has instituted a policy to replace each section with a steel carrier pipe as it fails. Furthermore, previous related work has also shown the use of FRP materials for the less demanding service of direct buried conduit casings to be inadequate (Marsh, Demetroulis, and Carnaham 1996).

Objective

The objective of this work was to evaluate the performance of FRP condensate carrier piping on Army facilities, especially the performance of systems that have in-line cooling devices installed according to Department of Defense (DOD) specifications.

* °F = (°C × 1.8) + 32.

Approach

1. An extensive listing of Federal installations that have installed FRP condensate carrier piping based on information supplied by FRP pipe manufacturers was developed.
2. A telephone survey was conducted to ascertain: (a) the perceived performance of the FRP condensate carrier systems, (b) if the cooling devices were installed, where they were installed and their performance, (c) problems with the systems, and (d) the opinions of engineering and maintenance staffs on the FRP pipeline's general performance.
3. Federal installations that had FRP carrier pipe still in use and that had cooling devices installed in them, and those that had FRP carrier pipe still in use, but were not sure if they had cooling devices, were selected for field visits to interview staff and to visually evaluate the systems.
4. A follow-up telephone survey was done to ascertain the performance of steel condensate piping to compare the two piping systems based on different materials systems.
5. Results of the surveys were gathered and analyzed, conclusions were drawn, and recommendations were made.

Scope

This study is limited to FRP and steel condensate piping systems at U.S. Government agency installations, with an emphasis on DOD facilities. It includes FRP and steel pipe systems installed since 1982. Manufacturer's data on FRP condensate carrier systems installed before 1982 were not available.

2 Fiberglass-Reinforced Plastic Condensate Carrier Piping

Fiberglass piping first became a viable alternative to protected steel, stainless steel, and other more exotic materials in 1950 when centrifugally cast fiberglass pipe was first used by the oil industry as a solution to corrosion problems (Fiberglass Pipe Institute 1989). From that time, FRP piping systems have played a major role in chemical processing, in oil and gas transmission, in municipal wastewater drainage and treatment, and in numerous industrial applications including condensate return carrier piping for underground heat distribution systems.

In addition to conventional corrosion resistance, a major advantage to fiberglass pipe is its strength-to-weight ratio, meaning that, pound for pound, FRP pipe is stronger than steel or stainless steel pipe. A typical FRP pipe weighs one fourth to one sixteenth that of steel pipe and has an equal hoop strength. Weight considerations with respect to pipe are critical, for these translate directly into cost savings via reduced transportation costs, as well as speed and ease of installation. Still another important attribute of FRP pipe is the improved hydraulic and flow factors that are achieved by the smooth interior surfaces fiberglass affords.

Two different processes are commonly used to fabricate fiberglass pipe of interest in this survey: filament winding and centrifugal casting. Filament winding and centrifugal casting are used to make pipe with diameters up to approximately 12 in. (1 in. = 25.4 mm). Of the two production processes, filament winding is the more common method.

In filament winding, continuous fiberglass filaments, called “rovings,” are saturated with catalyzed liquid resin and helically wound around a polished steel mandrel. Typically, the fibers are fed through a mechanical device that moves up and down the length of the rotating mandrel. The resin is then cured at elevated temperatures and the finished pipe is removed from the mandrel. Filament winding results in the higher fiber-to-resin ratio than centrifugal casting and consequently offers the higher strength-to-weight ratio.

The centrifugal casting process involves layering glass cloth on the inside walls of a tubular mold rotated at high speed. Catalyzed liquid resin is then injected into the rotating mold. Centrifugal force ensures that the reinforcing fibers are thoroughly saturated with resin and serves to drive out air bubbles that might compromise the physical properties of the pipe. The mold continues to rotate while the resin cures. Centrifugal casting typically results in a 100-percent resin liner, which is an excellent chemical barrier. Because the resin liner also resists abrasion, it offers protection of the fiber reinforcement.

The same corrosion-resistant resin formulations used in other fiberglass systems are used in FRP piping: isophthalic polyesters, vinylester, and epoxy. To add other desirable properties to the pipe, thermoplastic linings of polyvinyl chloride (PVC), nylon, or polyethylene are sometimes used on both inner and/or outside surfaces (Margolos 1986).

3 Installation Survey Data

Telephone Surveys

A total of 24 Federal agency installations were contacted by telephone consisting of 11 Army installations, four Air Force installations, six Navy installations, one Marine Corps installation, and one Veterans Administration hospital. Tables 1 through 5 show the installations surveyed broken down by service and Federal agency. To identify the appropriate individual or individuals to survey, the public works director or head of civil engineering for the Air Force was initially contacted. Those contacts recommended individuals at each installation who were knowledgeable about the performance of the installed condensate carrier systems, sometimes the foreman of the heat plant or a designer/engineer who had designed the heating systems. Often these individuals would recommend a pipe crew foreman or pipe fitter to respond to the survey questions. At installations where several individuals were interviewed, their basic opinions on the performance of the FRP pipe were consistent, even though some were able to provide different details or experiences than others.

Table 1. Army installations surveyed.

Installation	Total FRP Carrier Piping (ft)	Construction Date	Cooling Devices Installed	% In Service
Fort Devins, MA	5060	1984-85	Yes	0
Fort Lewis, WA	4610	1984	No	0
Fort Meyer, VA	4370	1984	Yes	60
Fort Lee, VA	4300	1984	No	0
Aberdeen Proving Ground, MD	3610	1986	No	20
Toole Army Depot, UT	2250	1986	Yes	100
Fort Greely, AK	1800	1985	Yes	100
Sierra Army Depot, CA	4320	1989	Yes	31
Military Ocean Terminal, NJ	1250	1991	Yes	100
Umatilla Army Depot, OR	320	1986	No	0 - Abandoned
Fort Richardson, AK	680	1984	Yes	100
U.S. Military Academy, West Point, NY	360	1993	Yes (on one loop only)	100

Table 2. Air Force installations surveyed.

Installation	Total FRP Carrier Piping (ft)	Construction Date	Cooling Devices Installed	% Service
Moody AFB, GA	1150	1982-83	No	0
Grissom AFB, IN	900	1985	Yes	0
Griffis AFB, NY	760	1985-86	Yes	0 - BRAC
Hill AFB, UT	420	1984	No	0

Table 3. Navy installations surveyed.

Installation	Total FRP Carrier Piping (ft)	Construction Date	Cooling Devices Installed	% In Service
Corpus Christi NAS, TX	2520	1985	No	0
Patuxent NAS, MD	1800	1989	Yes	0 - Abandoned
Lakehurst NAS, NJ	400	1984	No	0
Naval Submarine Base Hospital, CT	240	1987	Yes	0
Naval Fleet Training Center, CA	234	1985	Yes	0
Navy Station, Long Beach, CA	160	1987	N/A	0

Table 4. Marine Corps installations surveyed.

Installation	Total FRP Carrier Piping (ft)	Construction Date	Cooling Devices Installed	% in Service
Recruit Depot, San Diego, CA	210	1985	Yes	100

Table 5. Veterans Administration facilities surveyed.

Installation	Total FRP Carrier Piping (ft)	Construction Date	Cooling Devices Installed	% In Service
VA Hospital, Vancouver, WA	2950	1984 1990	No Yes	100

A typical survey consisted of the following questions:

1. Information provided to USACERL by the FRP manufacturers indicated that the facility had FRP condensate carrier piping installed. Are they using FRP pipe for a condensate carrier?
2. If it was installed, how is it performing?
3. Have they had to perform any maintenance on the carrier pipe?
4. What was the cause of the problems (if any) they have had in using the FRP carrier pipe?
5. At what pressure/temperature do they run their steam?
6. What is the typical condensate temperature?
7. Do they have cooling devices installed on the line?

8. Are the cooling devices performing properly?
9. If they are not performing as designed, what is the cause of the poor performance?
10. Have they done anything to correct system deficiencies?

A follow-up survey was conducted to get a better comparison between the performance of the FRP carrier piping with steel carrier pipes. The following questions were asked:

1. How is the steel carrier piping performing?
2. Have they had to perform any maintenance on the steel carrier pipes?
3. What was the cause of the problems (if any) they have had in using the steel carrier pipe?
4. How long was the steel pipe in the ground before they began experiencing the problems?
5. Are they using cathodic protection on the pipe line?

Site Visits

In addition to the telephone surveys, nine installations were selected for site visits to discuss the performance of the FRP carrier piping performance with engineers and technicians working with the systems and also to inspect the systems. Table 6 lists the installations visited. The first criterion for site visit selection was whether the installation used diffusers in conjunction with their condensate return systems. Those installations that no longer have FRP pipe in place and those that do not have diffusers in use were eliminated from consideration for site visits. Because of the travel time and expense involved, installations in Alaska were also dropped from the list. Of the remaining installations, Griffis Air Force Base was eliminated because it had closed and Sierra Army Depot was also eliminated because of its remote location. The remaining installations were visited. Grissom Air Force Base was also visited because of its close proximity to USACERL. Information from the first visit was used as an initial indicator of what to look for and discuss for subsequent site visits. In essence, systems that should perform best were selected for closer evaluation through site visits.

Table 6. Field visit sites.

Installation	Number of Man Holes Inspected	For or Against Use of FRP	Cooling Device Operation	Site Visit Date
Grissom AFB, IN	2	Against	Didn't Work	9 Jul 96
Toole Army Depot, UT	8	Undecided	Didn't Work	24 Jul 96
VA Hospital, Vancouver, WA	2	For	Worked	30 Jul 96
Fort Myer, VA	3	Against	Didn't Work	14 Aug 96
Patuxent NAS, MD	2	For	Worked	15 Aug 96
Fort Devins, MA	0*	Against	Didn't Work	20 Aug 96
USMA, NY	2	For	Didn't Work	21 Aug 96
Military Ocean Terminal, NJ	0**	For	N/A	22 Aug 96
APG, MD	0***	Against	N/A	5 Sep 96

*All FRP pipe removed prior to site visit
**FRP pipe either in shallow trenches, outside buildings) or suspended from ceilings (inside buildings).
***Distribution lines run through tunnels. Tunnels connected to FRP lines visited and inspected. One loop had steel inserted inside FRP pipe.

Site visits consisted of face-to-face interviews with engineers and technicians who designed the installed pipelines and maintained them, followed by inspection of manholes along the FRP pipeline. The interviews focused on maintenance and repair (M&R) experiences, and solutions to problems at the installations. The number of manholes that were inspected at each site varied. A minimum of one manhole was inspected for each run with FRP condensate carrier piping. In some cases, all manholes were inspected.

4 Survey Findings

This chapter summarizes the installations' responses to the telephone survey questions and the discussion that took place during site visits.

Satisfaction

Of the engineers and technicians surveyed who were knowledgeable about the performance of FRP condensate carrier pipe systems at their respective installations, 16. 7 percent said they liked FRP carrier piping. This corresponds to 11.7 percent of the total FRP condensate carrier piping by length used by the Federal agencies surveyed. Of those remaining, 70.8 percent of the installations surveyed (82.0 percent by length of pipe) said that they hated FRP pipe and would never willingly specify it again. The remaining 12.5 percent (6.2 percent by pipe length) were undecided. Those who stated that they liked FRP pipe for condensate return cited the following advantages of using that type of pipe over steel: (1) ease of installation, (2) ease of maintenance, and (3) the freedom from the requirement to join the pipe with welds (Figure 1). The overall ratio of dissatisfied installations to installations satisfied with the performance of FRP condensate pipes is 4.2:1 (6.9:1 by pipe length).

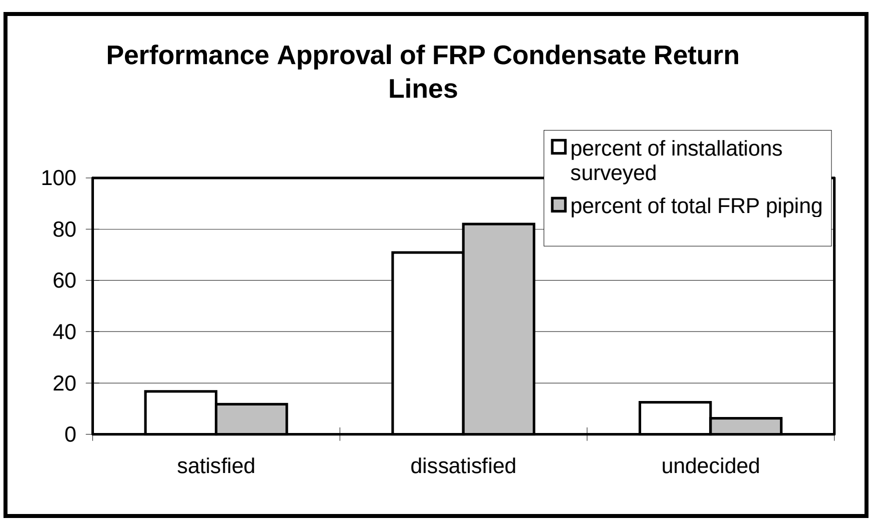

Figure 1. Performance approval of FRP condensate return carrier lines.

Percent of Installed FRP in Use

Many of the surveyed installations stated that all or part of the installed FRP condensate carrier pipe had been either removed or abandoned. Two installations (4.7 percent of the installed pipe) had abandoned the facilities that the FRP carrier pipe serviced and, as a result, the associated carrier pipe as well. Of the other 22 Federal agencies surveyed, only 43.5 percent were still using the installed FRP carrier pipe. This corresponds to 33.4 percent of the installed carrier pipe still being used and 61.9 percent removed, either replaced with steel piping or abandoned in place (Figure 2). Some agencies (13.0 percent) had replaced the FRP pipe with steel pipe in shallow trenches, and 17.4 percent had installed individual unit boilers in buildings previously serviced by FRP pipe.

Use of Diffusers

When asked whether diffusers had been used in conjunction with their FRP systems, 54.2 percent responded “Yes,” 41. 7 percent responded “No” and the remaining 4.1 percent responded that they did not know (65.1 percent, 25.3 percent, and 9.6 percent, respectively, of the length of pipe installed).

Many of the engineers and technicians surveyed at agencies using diffusers stated that, even though the diffusers had been installed according to specifications, they did not work properly. Interviewees indicated that the diffusers did not work properly at 69.2 percent of those installations (56.4 percent by pipe length); that they *did* work properly at only 15.4 percent of the agencies (21.0 percent of the pipe), and that, at 15.4 percent of the installations, they simply did not know.

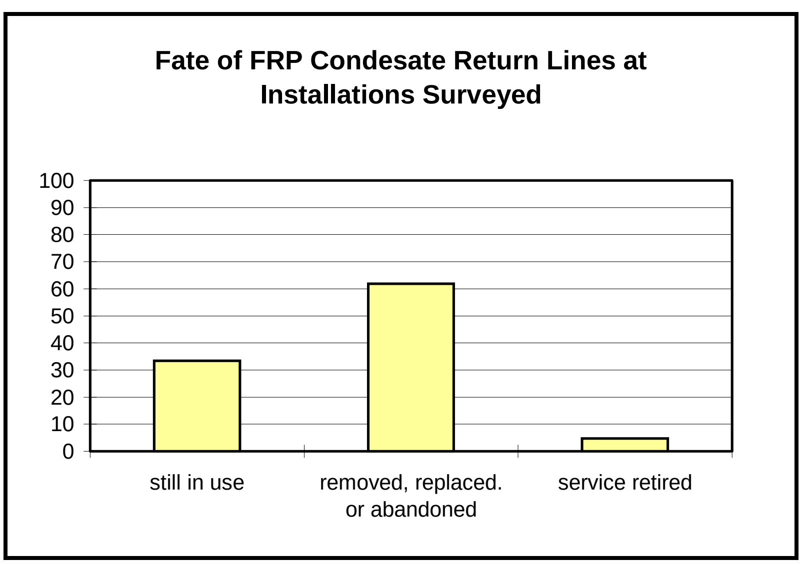

Figure 2. Fate of FRP condensate return lines.

Maintenance and Repair Problems

When asked if they had had maintenance and repair problems associated with the use of FRP condensate carrier pipe, 69.6 percent replied "Yes" (81.2 percent by pipe length). None of those who claimed to like FRP pipe for condensate return (all of those constructed since 1990) stated that they had any problems with using it, while 94.1 percent of those who dislike the application reported that they did have M&R problems with it. Two-thirds of those undecided also reported that they have had problems with it. Table 7 lists the problems cited during the survey associated with using FRP pipe for condensate return. It also lists the percent of Federal agencies that experienced each problem and the percent of the total length of FRP pipe installed associated with those agencies.

Table 7. Problems associated with using FRP for condensate return.

Problem	Percent Agencies Affected	Percent Pipe at Agencies
Ground movement breaks the FRP pipe	20.8	28.2
settling of manholes and anchors	16.6	26.5
heave from freeze-thaw	8.3	2.5
Heat	75.0	83.8
pipe deteriorates when steam traps blow releasing live steam into system	66.7	81.3
steam impingement from leaking adjacent steam pipes	12.5	13.9
sags too much	8.3	2.5
Pipe is too fragile	45.8	55.8
shipping and installation	4.2	22.9
overhead loading	12.5	0.9
thermal shock	4.2	2.8
water hammer	8.3	8.4
thermal expansion and contraction	25.0	32.6
susceptibility to sabotage and vandalism damage	4.2	4.0
erosion	4.2	10.3
Difficult to repair	41.7	53.3
repair kits too difficult to use	29.2	41.1
repair kits won't work all year round	4.2	11.3
requires special tools to join	8.3	12.6
joining pipe from different manufacturers difficult	8.3	12.6
pipe difficult to locate to repair	12.5	12.2
excessive excavation to find sound pipe	4.2	9.8
Contractor workmanship errors	33.3	44.8
Engineering design problems	8.3	13.7
Pipe is too expensive	12.5	7.7
Condensate water chemistry	12.5	14.4
Joint and seal packing failure/deterioration	37.5	39.9

Low Resistance to Heat

By far, the biggest problem with using FRP condensate carrier piping is related to its low resistance to heat in the form of live steam in the lines. There is a saying that “a chain is only as strong as its weakest link.” The weakest link in a condensate return carrier piping system is the steam traps. Steam traps are the largest single maintenance problem in any of the underground heat distribution systems surveyed. When a steam trap fails, the live steam quickly decomposes the resin in the pipe leaving only the fiberglass reinforcing starting at the first tee or elbow encountered. Since the fibers alone cannot contain the condensate, a leak occurs. If a steam trap fails, it may be months before it is discovered and even then, depending on its location, it may be weeks or months before maintenance crews can gain access to repair or replace the trap or the leak. No currently available FRP condensate return carrier pipe is capable of surviving live steam for any extended period of time. Figure 3 shows a typical failure mechanism from live steam in an FRP pipeline.

The latest design criteria requires the installation of a heat diffusion device between the steam trap and the FRP condensate carrier piping. These are designed to prevent live steam from a blown trap from getting to the FRP pipe. In most cases, the diffusers have not worked properly. Installations have modified and redesigned the Federal agency designed diffuser to get it to work, but have still achieved mixed results. One installation where the FRP pipe was still holding up well had put two diffusers in line, a second one backing up the first in case it failed. The major reported problem with the diffuser devices is that the valves and thermostats freeze up.

Other heat-related problems cited include damage to the condensate return lines when a leak in the adjacent steam line occurs. As stated previously, the resin in the FRP pipe decomposes when subjected to live steam causing a leak in the condensate line. The other heat-related problem is sagging of the FRP pipe if it becomes necessary to excavate under the condensate return piping. The stiffness of the pipe is directly related to the reinforcement and the temperature of the condensate in the pipe. The hotter the water is in the pipe, the more flexible the pipe becomes. Any excavation to be done below the pipe requires

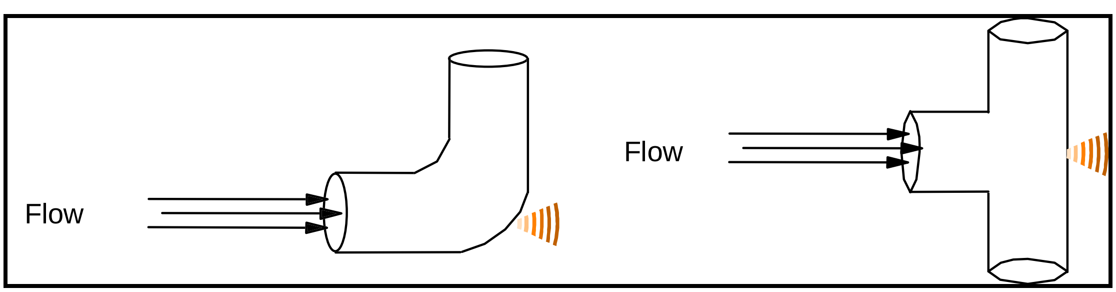

Figure 3. Typical FRP pipe deterioration at fittings from steam flow.

extensive shoring or supporting the pipe to prevent potential pipe separation at a nearby joint.

Difficulty of Damage Repair

The second largest problem cited dealt with the difficulty of repairing the damaged FRP pipe. From the maintenance personnel's viewpoint, the pipe manufacturer's repair kits are difficult to use. Typically, when repairs are required, it is during the heating season when outside temperatures are very low and in northern climates, the ground is frozen. Repair kits require drying the pipe surface to be repaired, removing surface contaminants and preparing the surface, mixing polymer resins for the repair and applying them. The speed and degree of cure are very temperature dependent. To get the resin to cure properly, the repair area must be heated for the curing cycle time.

A problem with any kind of buried plastic/polymeric pipe line is locating it once it has been in place for a while. If as-built drawings at an installation are not kept up to date or are not accurate in their exact location of the plastic pipe, locating the pipe in the ground is a major task. The pipe density is not too different from the surrounding soil and there is no metal in them so normal pipe-locating techniques do not work. The only alternative is to start digging and continue until it is located. Attaching a metallic tape or wire to the pipe before burying it has been successful in many, but not all, instances for locating buried FRP pipe. It is worthwhile to add one surveyed individual's comment on the general performance of FRP in certain applications: "If it is on a rack above ground like in a chemical plant, you can't come close to it's performance, but once you take it and directly bury it in the ground and expose it there to live steam you are asking for problems."

Another repair problem is that the pipe requires special tools to join them. Each pipe manufacturer has unique specifications for manufacturing its pipe. Each manufacturer has different joining tool requirements so that pipe from different manufacturers cannot be easily joined.

When the FRP pipe breaks, it is typically either in or within a few inches of the manholes or the concrete anchors (Figure 4). This may have several causes, including: (1) settling of the manholes and anchors over time, (2) settling of the anchor and not the manhole, or vice versa, (3) ground heave from freeze-thaw in cold climates, (4) thermal expansion and contraction of the pipe, or (5) a combination of two or more of any of these. When the pipe breaks, a significant

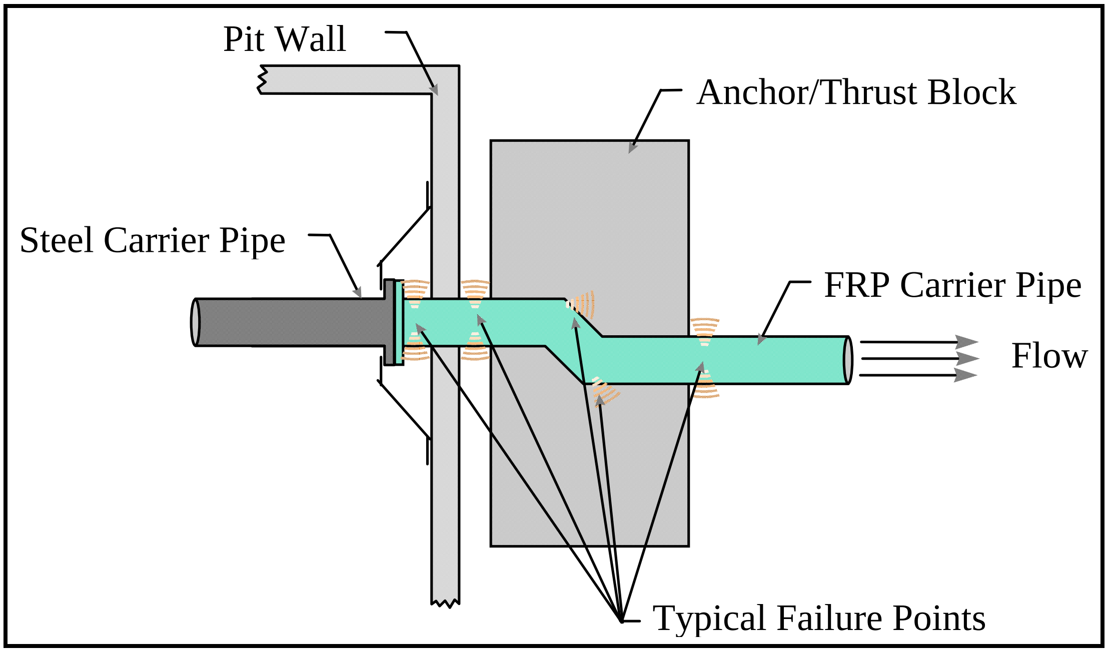

Figure 4. Typical failure points around manholes.

length of adjacent pipe is also damaged, requiring additional excavation and testing to find sound pipe to attach a repair section of pipe to.

Fragility

The third largest problem with using FRP pipe that was cited was that the pipe is too fragile to use for underground applications. Special care and handling is required during shipping and installation to prevent damage from impact. During installation, the pipe is susceptible to thermal shock. A contact at one installation stated that, while installing the pipe in cold weather, they had to warm the pipe before cutting it to prevent the inner liner from shattering. In cold weather, the liner became too brittle. Shattering was not localized, but affected the entire piece of pipe. Overhead loading was also cited as a problem, even under 6 in. of concrete. The weight of vehicles and aircraft crossing over the pipe damages it. In addition, the FRP pipe cannot withstand the forces of water hammer. The installations stated that it was only a problem if the water temperature in the pipe got too high.

Other problems cited with the use of FRP pipe include joint and seal packing failure/deterioration, contractor workmanship errors, engineer design errors, the cost of FRP pipe in relation to steel pipe, and deterioration of the pipe due to condensate water chemistry. In fact, the damage classified here as erosion and condensate water attack is probably the result of live steam in the line that no one knew about. Nonabrasive erosion or chemical degradation of a properly cured pipe is not likely.

Lifespan

When asked about the lifespan of the FRP condensate carrier pipes installed at the Federal agencies, the responses varied from less than a day at one installation to 30 years for one pipe run at another. Survey responses show the average pipe life span to be 4.8 years, with a standard deviation of ± 3.33 years, and a median of 5 years.

Comparison to Steel Pipe

When asked if they had problems with the use of steel pipe, the installations responded “Yes” at 45.5 percent of the installations. The reported major problem was corrosion of the steel (31.8 percent). When asked if they used any form of cathodic protection on their pipelines, 50 percent of them said “Yes” and 50 percent said “No.”

Problems cited by the installations associated with the use of steel pipe other than corrosion were trap maintenance, deterioration of seals and packing, asbestos insulation removal and disposal, leaks at the connections, and workmanship errors by contractors. Note that problems of wet insulation, thin walled outer pipe, and concrete-steel interface corrosion are all causes of corrosion-related leaks.

Of those who like FRP, 50 percent said they have had problems with steel pipe. Installations with 60.5 percent of the FRP pipe installed stated that they did not have problems with steel pipe. Of those who are dissatisfied with FRP pipe, 41.176 percent have had problems with steel pipe also. One-third (33.3 percent) of those who are undecided have had problems with steel condensate carrier pipe, 66.6 percent have not.

The life of steel pipe cited by the installations for carrying boiler condensate water had a mean of 30.6 years, with a standard deviation of ± 9.44 years, and a median of 31 years. The range of life span cited varied from 10 to 50 years. Figure 5 shows the results of a comparison, based on the survey, of the life of FRP and steel condensate carrier pipes. Figure 6 shows the differences in service life between the two types if piping by installation for those installations who provided this type of data. (Note that Installation 1 has highly acidic soil.)

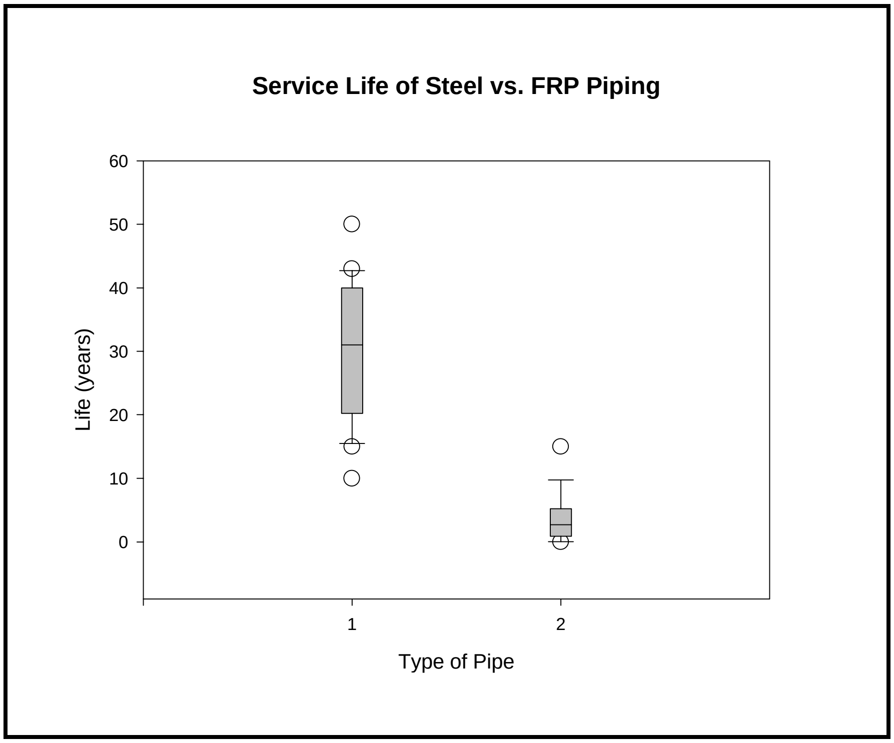

Figure 5. Life comparison between FRP and steel condensate carrier pipes.

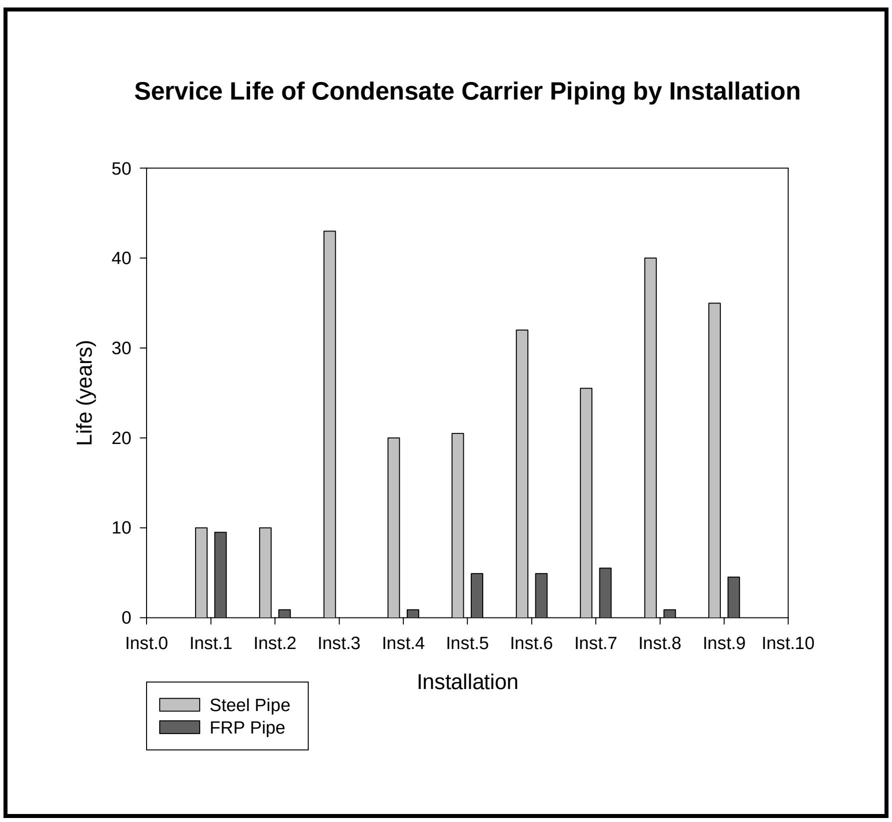

Figure 6. Service life comparison of steel vs. FRP piping by installation.

Advantages of FRP Pipe

Advantages of using FRP pipe cited in the survey include: (1) ease of installation (since it weighs much less than steel), (2) ease of maintenance (since special kits requiring minimal labor are available from the pipe manufacturers), and (3) freedom from the requirement to weld, especially in locations where there is a fire or explosion hazard. Cited advantages in using steel pipe included that: (1) steel pipe is repairable year-round by welding, (2) steel pipe is not susceptible to ground movement from freeze-thaw, (3) steel pipe is not susceptible to deterioration if a steam trap blows, and (4) steel pipe can withstand higher levels of water hammer.

Repair Costs

A typical repair takes two or three men, a backhoe operator, a laborer, and a mechanic 8 to 10 hours to complete. This type of repair at or near a manhole consists of the following steps:

1. Turning the system off (and waiting for it to cool down)
2. Unbolting the flange in the manhole
3. Cutting out the concrete thrust block
4. Excavating the FRP pipe back to a point where it is round, and cutting it off there
5. Reaming the end and adding a flange to the FRP pipe
6. Running steel pipe for cut out portion of FRP pipe
7. Flanging both ends of the steel replacement
8. Bolting up the flanges
9. Turning the system on and checking it for leaks
10. Replacing the dirt fill (and doing any landscaping).

A recent repair at Fort Myer, VA required 2 days just to remove the concrete placed over the pipe. Typical repair costs between $2000 and $3000.

5 Conclusions and Recommendations

Conclusions

The survey conducted for this study indicates that most Federal agencies' installations that have used FRP pipe for condensate carrier return report that they are not satisfied with its performance. This study concludes that, overall, the problems and associated maintenance to correct them far outweigh the benefits derived from the FRP pipe.

The major advantage of using the FRP pipe is its resistance to internal corrosion and the elimination of the need for cathodic protection to prevent its corrosion. Its other advantage is its comparably lower weight. This weight difference results in lower shipping, installation labor, and equipment costs compared to that of steel.

Since the FRP pipe will not corrode, it has the potential to outlast iron and steel pipe in underground applications. Whenever metal contacts boiler water that is not correctly chemically treated, accelerated corrosion and fouling will occur. However other factors quickly overcome the life expectancy of the FRP. The major factor is the unreliability of steam traps in the system. The industry has attempted to alleviate that problem by recommending the installation of diffusers, but experience has shown that diffusers are also unreliable. In addition, the FRP pipe cannot withstand the forces applied to it from manhole and anchor movement caused by settling or freeze-thaw thrusting, nor can it withstand the forces of expansion and contraction as the thermal loading inside the pipe varies.

Most of the FRP pipe that was included in this survey has been replaced by steel pipe. At two installations, the FRP pipe was abandoned because the buildings they serviced were abandoned. Only about a third of the FRP pipe included in this survey is still in use. Since very little FRP pipe included in the survey was older than 12 years, this suggests that the average life span may be biased on the low side. However considering that two-thirds of the FRP pipe had been replaced or abandoned within this short time, the estimation of useful life span is still very likely valid. Even with its inherent corrosion problems, steel pipe provides over six times the useful life of FRP pipe at Federal agencies.

Recommendations

1. This study recommends that FRP pipe *not* be allowed for condensate return systems. One individual surveyed summarized the performance of FRP well when he said that FRP pipe has its place in certain applications where it will work well: “If it is on a rack above ground like in a chemical plant, you can’t come close to it’s performance, but once you take it and directly bury it in the ground and expose it there to live steam you are asking for problems.”

2. It is strongly recommended that extra care (beyond the currently approved designs) be taken to ensure that no live steam ever enters FRP piping. The currently approved designs to prevent it from occurring are ineffective.

3. It is recommended that steel or stainless steel pipe be specified for condensate return carrier applications unless there are special circumstances where welding or the dead load of steel pipe may present a structural or safety problem.

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