North American Society for Trenchless Technology (NASTT)
No-Dig Show 2012

Nashville, TN
March 11-15, 2012

Paper E-1-01

Winter Wonderland Does Wonders to CIPP Renewal of a High Pressure Gas Main in NJ

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ABSTRACT: Renewing gas mains using CIPP liners continues to be an expanding trenchless solution for the gas industry in North America. The dead of winter is not the best time for applying this renewal technique when gas loads are at their peaks and supply issues can occur when mains are out of service. Yet, for circumstances beyond anyone's control the renewal of nearly 700 feet of leaking 16-inch diameter high pressure (HP) cast iron (CI) gas main needed to take place in early January, 2011. The job was well-planned in advance. A unique Carbon FRP laminate was designed and tested for this one-of-a kind application for bridging a 24-inch drip pot located under RR tracks that could not be removed. Nevertheless, many unforseen cicumstances and weather-related issues contributed to make this an extremely difficult job to successfully complete. The issues required many on-the-spot decisions, "audible" calls and field solutions that needed to be properly executed in order to get the main gas main back in service without delay. This paper will review this specific job from a planning, testing and scheduling perspective to its final installation, including various unforseen problems faced and solutions employed, including regulatory issues, and lessons learned.

1. INTRODUCTION

"Winter Wonderland Does Wonders" is a title that may conjure up thoughts in your mind, such as sipping hot cider while enjoying the warmth of your fireplace and seeing fresh new soft snow glistening like diamonds on the tree tops from the window of your home. Well… *forgetaboutit*….this paper is about a 125 year old leaking CI pipeline that needed to be rehabilitated during the harshest winter the northeast has seen in years, and all while overcoming new innovative technology challenges in one of the most heavily debris-laden gas pipelines ever encountered. The harsh weather was not the only obstacle challenging the project team, but the real challenge was in the pipeline itself.

2. BACKGROUND

In the Spring of 2010, a project team consisting of representatives from Public Service Electric and Gas Co. (PSE&G) and Progressive Pipeline Management (PPM) made a site visit to a project on Madison Ave. in Patterson, NJ to discuss the potential rehabilitation of an HP 16-inch diameter leaking CI gas pipeline. The uniqueness of the project was reviewed and the numerous challenges were discussed. The pipeline travels down Madison Ave., a major thoroughfare in the city of Patterson, onto private property near a factory building wall through an active truck dock loading/unloading area at a depth of approximately 24 feet. Then it follows under a set of railroad tracks to another private parking lot on the opposite side of the tracks, approximately 700 feet in length (Figure 1). The pipeline, according to the historic drawings circa 1900, has one 45 degree bend somewhere close to the center of the job and a drip pot that is located directly under the railroad tracks (Figure 2). The drip pot was used for collecting hydrocarbon fluids from the old gas manufacturing days and was a common fitting for that era. The 45 degree bend did not pose a problem from a lining perspective since liners are ideal for such applications/geometries, but the drip pot was a major obstacle and needed to be replaced with a section of straight pipe. This was necessary because the liner could not pass through the internal drip pot piping (standpipe) and negotiate the drip pot's 24-inch gap without adequate bearing support for the liner. The project was placed on hold until a solution for traversing the drip pot without having to excavate and remove it could be developed.

Figure 1. Overview of project area.

3. FRP LAMINATE

In the Fall of 2009, QuakeWrap, Inc. was showcasing one of its newly developed Fiber Reinforced Polymer (FRP) laminates called PipeMedic™ at a local Trenchless Technology Road Show (Ehsani, 2009). The laminates seemed promising for solving the problem of providing adequate bearing support within the drip pot. The FRP laminates (Figure 3) have several unique attribuites that would be helpful for this application: a) they are very thin and flexible so they can be coiled for insertion into pipes as small as 4 inches in diamter; b) they include carbon and/or glass fibers in both longitudinal and transverse directions, which allow them to resist stresses in both hoop direction and along the length of the pipe; c) they include a glass veil on both faces, allowing them to be installed in direct contact with the steel pipe; and d) they match the diameter of the host pipe during installation, eliminating the need for ordering to a specific size in advance.

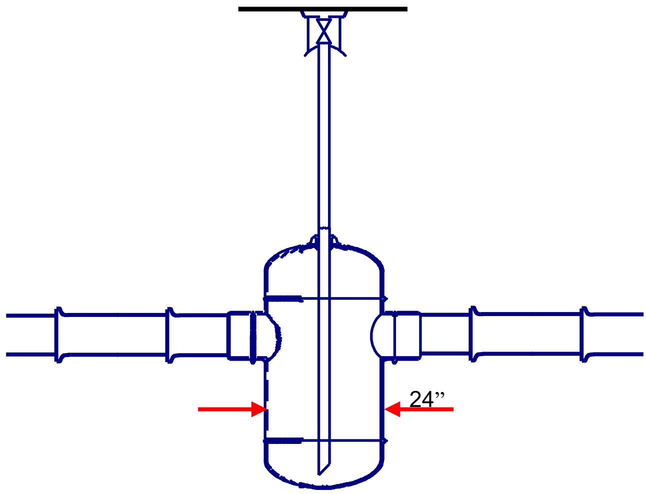

Figure 2. Drip pot schematic.

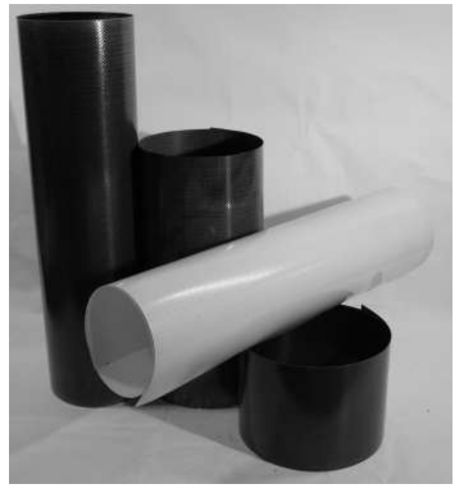

Figure 3. Samples of PipeMedic™ laminates constructed with carbon and glass fabric.

The laminate used for this project was constructed of carbon fibers sandwiched between two very thin glass scrims. Direct installation of carbon fabric on a steel pipe could result in galavanic corrosion of dissimilar metals. The common practice in repair and retrofit projects using carbon FRP is to use a layer of glass fabric as a dielectric barrier between the carbon and steel to prevent direct contact between these materials. The fact that these laminates included such a scrim on both faces eliminated any concern for long-term durabilty of the system due to corrosion. The carbon laminate is only 0.026 in. thick, with sufficient flexibility to be coiled for insertion into the 16-inch diameter pipe. It is supplied in rolls 4-ft wide x 150-ft long that can be easily cut to any size in the field. The tensile strength of the laminate is 101 ksi in the longitudinal direction and 64 ksi in the transverse direction. Other thinner laminates made of glass fiber are also available for repair of smaller diameter pipes.

At the trade show, this specific product was reviewed along with the problems associated with traversing the drip pot. In effect, the concept involved using the FRP laminate to provide a free-span section of pipe across the 24-inch diameter liquid–seperator drip pot in the pipeline. Since the CIPP liner system relies on the structural integrity of the host pipe, the laminate section is installed to perform as a stand-alone pressure-carrier section and interacts with the CIPP similar to the original carrier pipe. At that time, it was felt that the FRP laminate could potentially provide the necessary bearing support through the drip pot, which would then eventually be lined with the remainder of the 700-foot pipe segment. This would completely avoid the need to deal with the railroad authorites to replace that segment of the pipe containing the drip pot. This apporach would avoid the time and cost with getting the necessary railroad authority approvals, permits, railroad flag people, etc., including PSE&G crew time to replace the fitting with straight pipe.

To ensure the feasibility of this concept, a meeting was held at PPM’s facility in NJ along with a demonstration of the FRP laminate in a simulated drip pot. This consisted of two 16-inch diameter pipes with a 24-inch wide gap between the pipes representing the unsupported span or gap within the drip pot. Considering that the 18 inch pipe has a circumference of 4.2 feet, a 13.5 ft. long, 4 ft wide piece of laminate was required to provide a 3-ply liner with a 12-inch extension. The successful demonstration affirmed the concept that the FRP laminate could be used to act as a bridge over the gap in the drip pot. The major steps for installation include the following:

1. Applying adhesive to the one side of the laminate (Figure 4).
2. Rolling laminate onto the inflatable pig (Figure 5).
3. Inserting the pig into the pipe (Figure 6).
4. Inflating the pig to expand laminate at simulated drip pot gap (Figure 7).
5. FRP laminate section bridging 24-inch gap and curing (Figure 8).

Figure 4. Adhesive application.

Figure 5. Laminate installed onto inflatable pig.

Figure 6. Insertion into pipe section.

Figure 7. Laminate in position and pig being inflated.

Figure 8. Final installation in simulated drip pot.

4. FRP LAMINATE TESTING

Before the laminate could be used on this pipeline renewal job, the material's strength and stiffness and its suitability for such an application had to be tested and confirmed, preferably by a third party independent testing laboratory. The Gas Technology Institute (GTI) was selected by PSE&G to develop a test protocol that would satisfy the requirements of ASTM F2207 and manage the overall testing program of using the FRP laminate for rehabilitation of gas pipelines. GTI's work included providing and installing the necessary instrumentation, overseeing and conducting the testing, analyzing the test data and presenting the results of this work in the form of a final report with appropriate recommendations (Farrag 2011).

Testing was performed at PPM's facility in NJ by PPM personnel working jointly with representatives from PSE&G and GTI. The testing program included testing three sizes of steel pipe sections in 6, 12 and 16-inch diameters. Each test section included a 24-inch free-standing laminate section, which extended an additional 12 inches into each side of the pipe. The laminate-steel system was lined with CIPP, capped at both ends, thrust-restrained and connected to a hydraulic pressure system to apply controlled test pressures. Strain gages and displacement sensors were installed as shown in Figure 9 in the free-standing sections to monitor circumferential and longitudinal strains during the application of pressures up to 250 psig. The test was monitored for any movement or fractures in the laminates as well as leaks in the liner. The tests included the following:

1. Simulate the free-span or gap of a drip pot by separating 2 section of pipe by a distance of 24 inches (Figure 8). This is a worst case scenario, since drip pot sizes are generally one or two pipe diameters larger than the pipe itself. For example, a typical 12-inch diameter pipeline would utilize a drip pot 16 inches in diameter, but sometimes it may have a drip pot as large as 24-inches in diameter. A 6-inch diameter pipeline would typically use an 8-inch diameter drip pot. For sake of consistency, it was decided to simulate a 24-inch diameter drip pot for all three different piping diameters tested by GTI. This span also acts as the worst case scenario for abandoned laterals which also would need to be cut–out and replaced with straight pipe.
2. Weld all external anchorage fittings in preparation for hydrostatic testing as shown in to Figure 10.
3. Prepare the interior of the pipeline for lining by abrasive sand blasting.
4. Install the FRP laminate according to the manufacturer's installation procedures and allow the adhesive to cure overnight. (Figure 11)
5. Install Starline-2000 lining material over the laminate and allow curing overnight. (Figure 12)
6. Install weld-end caps, thread-o-lets and threaded rods for thrust restraint (Figure 13).
7. Fill with water and pressure test in stepped increments to 250 psig.

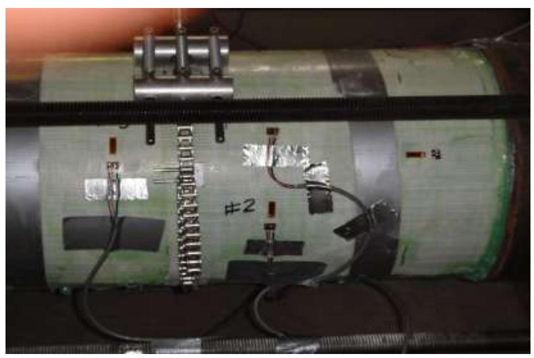

Figure 9. Typical Instrumented test specimen

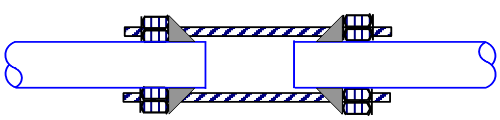

Figure 10. External anchorage for thrust restraint.

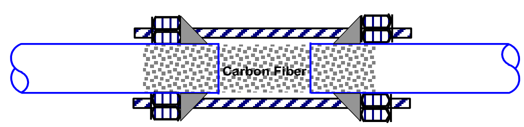

Figure 11. Laminate bridge installed.

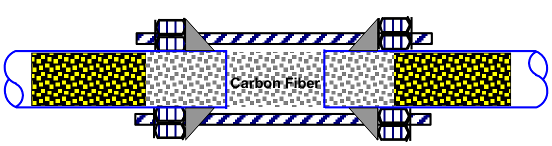

Figure 12. Liner installed over laminate.

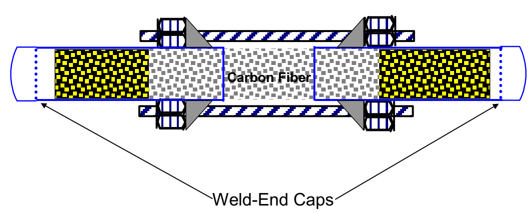

Figure 13. Ends caped for pressure testing.

The pipe sections were all tested the same and under stepped hydrostatic pressures. The pressure was increased every 2 hours in 50 psig increments up to a maximum of 250 psig. The test results demonstrated that the liner–composite sections could stand the applied pressure without leakage.

The requirements for the CIPP system as specified in ASTM F-2207 include performing test at a pressure not less than twice the certified maximum allowable operating pressure (MAOP) of the pipeline for a minimum of one hour without leakage. For gas mains operating at a pressure of up to 60 psig, the hydrostatic tests exceeded this requirement and showed that the liner-composite sections could withstand pressures up to four times the operating pressure without leakage.

The stress-strain measurements indicated that the 24-inch long free-span PipeMedic ™ laminate, with additional 12 inches in each side of the adjacent pipes, can be effectively used to carry the hydrostatic pressure of spanning gaps in liquid separator drip pots, abandoned tees or other fittings in gas pipelines. The testing program satisfied the pressure requirements of the liner-composite section as per ASTM F-2207. It is important to note that the composite section is not commonly subjected to external surface loads since these loads are still carried by the in-line fittings (i.e. drip pot, abandoned, tee, etc.), so long-term strength and its performance under external loads did not require testing.

In summary, the testing confirmed the FRP laminate's ability to perform as a stand-alone pressure-carrier section that interacts with the liner similar to the original carrier pipe.

5. INTERNAL ROBOTICS

The FRP laminate bridges the gap introduced by the drip pot. The plan was to install it from one end of the pipe approximately 85 feet from the cut using an inflatable pig. The pig was modified by adding a sled extending its length allowing it to traverse the drip pot so the packer pig could successfully be centered. This sled allowed the front or nose of the pig to be pulled to the opposite edge of the drip pot preventing the pig from falling into the pot.

The remaining major challenge was to develop a means for removing the ¾-inch diameter internal steel standpipe robotically working from inside the pipe. Several ideas were considered, but required access to the top of the standpipe as a minimum, which was prohibited by virtue of its location under the active railroad tracks. The final design included the internal cutting of the standpipe by a support bridge which had the ability to scaffold/sled across the opening or gap of the drip pot. The scaffold or sled was designed to straddle the opening close enough to the standpipe allowing the existing camera/cutter assembly access to the standpipe, making it possible for the cutaway. (Figure14)

Figure 14. Simulated drip pot with standpipe laboratory test set-up.

Figure 15. Heavily debris-laden pipe ID.

After several design iterations and shop trials, the sled resembled a two-tiered bridge and proved to work as intended. The camera/cutter combination, located one above the other, and the bi-level bridge is pulled into the pipe simultaneously up to the drip standpipe. The cutting assembly first cuts the standpipe below the invert of the pipe and then makes a second cut above the crown of the pipe. All done robotically from inside the pipe without any excavation or external pipe access required. The cut pipe sections fall into the pot section of the fitting allowing the CF to have clear access across the simulated drip pot gap (shown in Figure 14).

6. ON-SITE PROJECT CHALLENGES/ OBSTACLES

Having successfully completed a comprehensive independent third party laboratory testing program for the use of FRP laminates in this type of application, and having successfully completed all the necessary design, development, fabrication and testing of the robotics package, there was clearly a confident feeling that the renewal project could now be successfully undertaken and completed.

The original schedule called for this main to be out of service for 7 days. Due to many unforeseen scheduling problems combined with the holiday/vacation season, the pipeline was not abandoned until early January, 2011. The first step was for PPM to CCTV the abandoned segment of the pipe. As it turned out, the location of the gas main was approximately one mile from an old gas manufacturing plant (GMP), and because of the pipeline's close proximity to this plant an extremely heavy build-up of gas residue, including heavy tars, resins, oxides and oils along with heavy deposits of debris was discovered. The internal debris was so heavy and thick that an 8-inch diameter foam pig was unable to negotiate through the 16-inch diameter CI pipe (Figure 15) to enable a tag line to be installed for starting the cleaning process.

Before any work could be performed , a tag line had to be installed which could be used to pull-through a heavier cable for pulling-through the sand blasting equipment to begin cleaning the interior of the pipe. After many unsuccessful attempts trying to get the tag line through using standard procedures, techniques and equipment, a parachute-type concept was developed on site to successfully get the tag line through from one end of the pipe to the opposite end.

Conventional internal sandblasting tooling was tried but was ineffective in adequately removing the heavy debris. The sandblasting tool head was modified on-site to deflect the majority of the grit towards the bottom of the main in an effort to remove the excessive debris. This equipment modification included the successful adaptation of using a camera to view the sandblasting operation simultaneously - something that had never been done before. While being somewhat successful, the modified tooling still provided insufficient cleaning power to open-up the main to its full 16-inch diameter.

Additional cleaning was required and high pressure water jet blasting equipment was the next logical step. (Figure 16) This equipment uses water at 15,000 psig and is capable of cleaning–out the heavy debris. However, this now posed an additional set of unique problems involving equipment freeze-ups, working in the dead of winter, water supply/removal/disposal, hazardous material collection trucks, and heaters with associated project time delays. Before water jetting could be implemented, PSE&G's Environmental Department needed to be involved to oversee and manage the collection of all the waste-water material to ensure compliance with applicable environmental regulations using the vacuum collection tanker (Figure 17).

The water jetting was followed by removal of the water using foam pigs and then an extensive period of time was spent on drying the inside of the pipe using hot air injected into the pipeline. Once dry, the normal sandblasting operation was started and successfully brought the ID of the pipe down to a bright white metal finish (Figure 18) in preparation for cutting the drip pot standpipe internally, installing the FRP laminate and then lining through the entire 700-foot segment of pipe.

Figure 16. Equipment utilized for water jetting operation.

Figure 17. Vacuum tanker collection truck.

Figure 18. Pipeline ID fully cleaned.

Figure 19. Inflatable pig/laminate being inserted.

After the final sand-blast cleaning was completed, groundwater was noticed seeping into the line. Closer inspection using CCTV revealed a complete circumferential break in the line located under the set of railroad tracks which was probably the major source of gas leakage, in addition to the leaking cast iron joints. The water infiltration was not significant due to the frozen ground, but it needed to be completely eliminated prior to lining because it would create adhesion problems with the polyurethane-based resins used to adhere the liner to the host pipe. The solution was to modify the robotics equipment package tool-head on site to lay down and trowel cement over the cracked pipe to completely stop the water entry. This was the final major obstacle that was overcome prior to lining.

7. LINER INSTALLATION

The ¾-inch diameter steel drip pot standpipe was successfully cut-off in two cuts as planned using the specially designed and built robotics platform. This cleared the way for installing the FRP laminate internal sleeve/bridge as the final step before lining the entire abandoned segment of pipe. With the help of QuakeWraps's technicians, the FRP laminate installation went smoothly. Figure 19 depicts the inflatable pig with the FRP laminate sleeve installed onto it being ready to be pulled out to the drip pot. The adhesives used for the FRP laminate normally cure over one night, but due to the extremely bitter cold weather it took three nights. After the third night, the inflatable pig was deflated and removed with the FRP laminate bridge in final place spanning the drip pot gap (Figure 20).

Figure 20. Final drip pot bridge laminate assembly.

Continuing the process of pipeline renewal, the final phase of the project involved installing the Starline-2000 liner, which would internally seal the entire main, including the FRP laminate bridge installed through the drip pot. At this point, the project finally became routine and PPM took a straightforward approach of installing the liner. The Starline product also requires an adhesive to bond to the existing host pipe and like all exothermic adhesives, ambient temperatures have a direct effect on the curing time. The ambient temperatures during this project were in the low teens during the day and close to zero at night. These low temperatures caused the adhesive to significantly slow down its curing rate and resulted in a 63 hour cure despite the use of accelerants, as compared with a typical 24 hour cure.

The pipeline ends were trimmed of liner for facilitating connections to the existing piping (Figure 21) and final internal CCTV inspection was performed as a part of the acceptance criteria. This inspection confirmed a perfect lining job from end-to-end of the pipeline right through the FRP laminate bridge (Figure 22) creating a gas tight condition and resolving the nagging leaks in the area.

Figure 21. Excess liner being trimmed at pipe-ends.

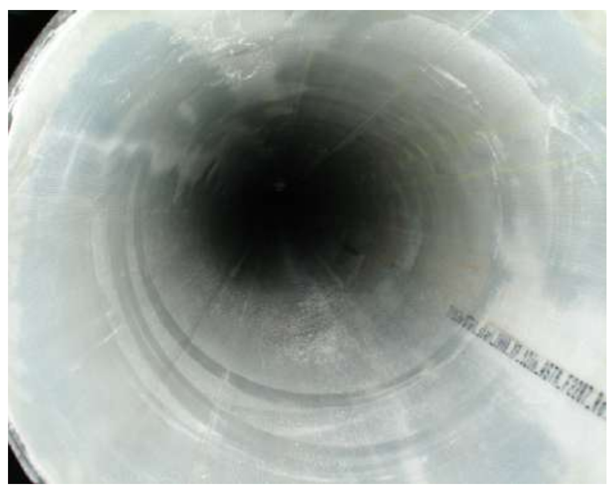

Figure 22. Completed liner installation with the FRP laminate

8. CONCLUSIONS

The renewal of this 16-inch diameter high-pressure cast iron gas main offered numerous challenges. A newly-developed carbon FRP laminate was selected to bridge the 24-inch gap caused by an abandoned drip pot. After a successful simulated installation at the contractor's yard, an extensive independent testing by GTI demonstrated that the FRP laminate was suitable for this application. Field installation challenges included modification and developments of robots to clean the pipe, cut and remove the standpipe, and install the laminate. All of these activities were further complicated by the construction schedule which coincided with one of the coldest recorded winters in the area. A truly cooperative team effort to seek creative solution by the owner, contractor and manufacturer resulted in successful completion of one of the most challenging trenchless renewal projects.

9. REFERENCES

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