INEOS
Olefins & Polymers USA

THE INTRODUCTION OF PE-100 AT WASHINGTON GAS

Abstract By: Karl M. Gunther
Washington Gas
Text By: Steve D. Sandstrum *

ABSTRACT:

Washington Gas has been researching a number of innovative methods for the repair and replacement of older large diameter cast iron mains. We considered direct burial, rolldown, U Lining, PIM, and guided boring. The ideal replacement technique would allow for a fully rated (64 psi or 5 bar) system which would have a low installation cost, a minimum 50 year life, rapid and easy installation, and provide a safe, secure, all-fused system. Trenchless technology is very attractive due to the low cost and minimal disruption to our customers. We wanted to replace an older 24" cast iron pipe operating at 20 psi (1.4 bar) with an inserted 16" IPS plastic main rated for 64 psi.
Washington Gas would require the following performance criteria:

1) The polyethylene (PE) pipe must be rated at 64 psi and yet have the maximum internal diameter. Thus high density Standard Dimension Ratio (SDR) 17 was chosen.
2) The PE pipe must have a very high resistance to slow crack growth because of the potential stresses and damage that would be inherent in insertion.
3) The pipe must have the highest resistance to rapid crack propagation since it would be unrestricted inside several sections of a 24" cast main. Furthermore, it would be possible to have dramatic swings in pipe temperature, and if the pipe were to be impacted with enough force to break through the casing rapid crack propagation (RCP) could, in theory, initiate.
4) Controlling the gas flow is also critical; therefore a 16" squeeze off tool was developed and tested by Mustang Manufacturing. Ideally, the PE pipe would have to be able to be squeezed to 100% shutoff with no damage or reduction in usable life.
5) Joining the PE pipe was also an important consideration. It was imperative to develop and test plastic-to-steel transition fittings as well as complying with the requirements of the Plastic Pipe Institute (PPI) universal procedure (PPI TR – 33/99)

We selected a material that would meet all of these criteria and that is PE–100. It is impervious to RCP because it has a critical temperature of zero degrees Fahrenheit (-18

* Formerly of INEOS Olefins & Polymers

degrees Celsius), and has a slow crack growth resistance of over 2000 hours in the PENT test. PE-100 can withstand substantial backhoe hits and mechanically induced damage that would cause failures in other piping systems. The PE-100 material we chose was Phillips 8300 pipe made from Solvay TUB 121 resin.

On August 21, 2000 Washington Gas installed the first 16" IPS PE-100 material in the United States. We will monitor its performance closely over the next 10 years.

INTRODUCTION:

Since the 1850's, Washington Gas has provided natural gas service to the mid-Atlantic seaboard region of the United States. Today, the Washington Gas distribution network includes over 800,000 residential, commercial and industrial services extending from Baltimore, Maryland to the mid-Virginia region of the US. Brown's Directory ranks Washington Gas as one of the largest natural gas distribution companies in the US based on number of services and geographic region served. (1)

The high visibility of this natural gas system which includes our nation's capitol combined with sustained demographic growth of the region has resulted in significant engineering challenges associated with the construction and maintenance of this vast distribution network. This paper shall examine one such case history. In the paragraphs which follow, we shall explore the engineering considerations involved in the rehabilitation of a 24" cast iron natural gas line in the Greater Washington DC area using the PE100 quality of HDPE gas pipe. Through an examination of a project such as this we can gather insight into Washington Gas' commitment to utilize the latest technological developments in HDPE pipe materials and construction techniques to safely improve distribution efficiencies to its customer base.

THE M STREET CAST IRON RENEWAL PROJECT:

In early 1999, Washington Gas analyzed the growing demand for gas in the southern District of Columbia and northern Virginia region of its system. Based on information available at the time, Washington Gas determined that the increasing need for gas in this region would be difficult to service through the existing series of older caste iron mains and the existing service network. A critical element of the plan that was developed to improve service to this area was the use of a 24" OD cast iron line that was originally installed in the mid 1940's. This line was intended to serve as a major transfer link within the system.

Concerns over the use of the older cast iron line arose as plans developed and it was soon determined that by rehabilitating the line with butt fused HDPE that the pressure capability of the line could be gradually increased over time as demand necessitated higher gas flow. The use of butt fused HDPE would circumvent any concerns regarding joint integrity or corrosion of the older cast iron line that may have occurred since its original installation. Utilizing the performance capability of modern HDPE pipe combined with the latest in trenchless installation techniques, Washington Gas would be able to place into service a new high performance HDPE gas line in a cost effective manner with minimal remediation cost and minimal disruption to local traffic and services. Furthermore, the use of a butt-fused HDPE liner would allow Washington Gas to gradually increase the operating pressure for this line up to 64 psi thereby continuing to meet the increasing need for gas to this region in a safe and economical fashion.

Figure 1 provides an indication of the location of the original 24" cast iron main. As can be seen from this figure, it is clear that job site planning would prove extremely important. Traffic and service disruption in this south central portion of the District of Columbia had to be kept to a minimum. Similarly, the costs of a complete cut and bury replacement of this line would prove prohibitive. For these reasons, Washington Gas engineering staff researched a variety of trenchless techniques which could be employed to rehabilitate the cast iron system. Insertion renewal with modern HDPE pipe was determined to be the most attractive alternative based on total placement costs and long term gas flow capacity of the liner size selected.

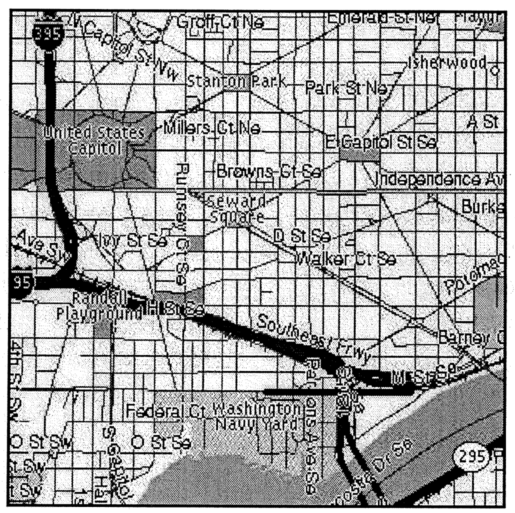

Figure 1: M Street Renewal Project Overview

Table 1: M-Street Renewal Project Statistics

Property	Value
Host Pipe	24" Cast Iron
Age of Pipe	1940's
Length of Renewal	
Phase I	700'
Phase II	1000'
Phase III	3000'
Depth of Burial	5' to 8'
Operating Pressure	
Initial	20 psi
Ultimate	64 psi

In March, 2000, the contract for construction was awarded to D.A. Foster of Springfield, Virginia. Materials were placed on order with a target for construction start-up in August, 2000. Access pits were dug initially along the east end of M Avenue and insertion of the 16" HDPE liner was started in August, 2000. The size differential between the 24" cast iron main and the 16" liner combined with the rather limited number of connections that were required on this project provided for a very quick placement of the liner. As a result, the liner was tested in accordance with the guidelines established by the Department of Transportation, CFR, Part 192 and placed into service in November, 2000.(2)

The initial placement of the 16" PE100 liner involved approximately 700' and tie-ins to 24" coat and wrap steel. A second phase of the overall cast iron renewal project involving another 1000' of 16" SDR 17 PE100 was undertaken in May, 2001. As shown in Table 1, a third phase is planned for construction in 2002.

A SERIES OF INNOVATIONS:

The M Street cast iron gas main renewal project can best be characterized as an achievement in innovation. Some of the more notable points credited to the innovation and creativity of the Washington Gas engineering staff include the following.

1) This project represents the first documented project involving the use of the PE100 quality of HDPE in a gas distribution project in the United States.
2) The pipe produced for this project by Phillips Driscopipe (now Performance Pipe) is the first major large diameter (> 12" OD) PE100 extrusion run documented in North America.
3) The Plastics Pipe Institute (PPI) generic butt fusion procedures were used to join the PE100 pipe and were proven to qualify under the requirements of the US Department of Transportation, CFR, Part 192.
4) Transition fittings in this size range have been fairly well established on an international level. However, this project marked the first major US gas project for 16" electrofusion transition fittings manufactured by Friatec, Inc.
5) Finally, a unique 16" squeeze-off tool was developed to specifically meet the needs of Washington Gas. Mustang Manufacturing produced a new, large diameter tool capable of producing complete shut-off of gas flow through compression of the HDPE liner.

Each of these achievements represents a unique engineering accomplishment in their own right. While a thorough analysis of each is clearly beyond the scope of this writing, a brief discussion on each point will follow. From this the reader can garner an appreciation for the truly unique nature of this project and the progressive approach taken by Washington Gas in meeting the needs of its customer base.

Selection of the HDPE Liner Material:

The engineering analysis of this insertion renewal project revealed the specifics detailed in Table 1. From this assessment, several key performance requirements for the HDPE liner were determined. First and foremost, the liner would have to be extremely resistant to slow crack growth. While the cast iron main would obviously be cleaned and scraped prior to insertion of the liner, it was clearly felt that the liner would be subjected to some degree of abrasion during the insertion process. For this reason, an extremely durable material would have to be specified to compensate for any gouging or scraping that would occur during placement of the liner.

Next, it was determined that the liner would have to provide the long term pressure capability required to service the growing demand for gas distribution in the region. As indicated in Table I, the plan was to start the line up at approximately 20 psi. However, it was anticipated that the operating pressure for this line could go as high as 64 psi to meet the distribution needs of the region. As such, the pipeline design should allow for increasing the operating pressure of the system to this higher level in accordance with DOT and Washington Gas operating standards.

Finally, the 16" liner would be free floating within the cast iron line and the original line did vary significantly in burial depth along the right of way. This combined with the maximum projected operating pressure and the climatic extremes that could be realized in this region, led designers to conclude that the new HDPE liner must be extremely resistant to the potential for rapid crack propagation.

Designers and engineers at Washington Gas concluded that a PE100 quality of HDPE pipe would provide the performance capabilities to safely meet these specific long-term needs while allowing for an economical installation. The piping material selected for this project was Driscopipe 8300 produced from Solvay's TuB 121 HDPE pipe. This material was specified based on its technical performance, long-standing recognition within the international gas distribution community, and availability on an import basis into the United States. Table 2 provides an overview of the technical qualities of the HDPE piping material selected for the project.

Table 2: Typical Physical Properties of Driscopipe 8300
Produced from Solvay TuB 121

Property	Test Method	Value
Melt Index	ISO 1133, MI5	0.30 gr/10 minutes
Density Natural Pigmented	ISO 1183A ISO 1183A	948.5 kg/m(3) 959.0 kg/m(3)
Tensile at Yield	ISO 6259 ASTM D638	25 Mpa 3600 psi
Long Term Hydrostatic Strength Rating	ISO 9080 ASTM D2837	MRS 10 1600 psi HDB
Slow Crack Growth	ISO 4437 Notched Pipe ASTM D1238 ASTM F1473 (PENT)	> 2000 hours > 5000 hours > 2000 hours
Rapid Crack Resistance	ISO 4437 – S4 Test	> 24 bar @ 0 deg C

A key consideration in the selection of the Solvay product was the fact that it had been well established on an international level as a material capable of producing the PE100 quality of gas pipe as defined within ISO 4437.(3) Equally important was the fact that this same material had also been designated as a PE3408 by the PPI and maintains an active listing in PPI's TR-4.(4) These two facts combined allowed Washington Gas to use the PE100 pipe produced from the Solvay TuB 121 resin as a PE3408 gas pipe under the requirements of ASTM D2513 and the US DOT requirements.(5) In this way, Washington Gas could utilize the performance capabilities of the PE100 quality to meet the project needs as specified yet still meet the requirements for HDPE gas piping under the prevailing systems of standards in the US.

First Major Large Diameter PE100 Gas Pipe Extrusion in US:

As previously indicated, the 16" SDR 17 pipe produced for this project was produced by Phillips Driscopipe (now Performance Pipe) of Richardson, Texas at their plant in Hagerstown, Maryland. Upon award of the contract to supply, logistics were arranged between Phillips Driscopipe and the Solvay Group to export the HDPE resin from Europe to the United States. The PE100 resin was loaded into supersacks, containerized and placed on ocean going freighters to the US were it was then trucked to the Hagerstown production facility. The precompounded black HDPE resin was then off-loaded at Hagerstown and inventoried for extrusion into pipe for the Washington Gas renewal project.

While the logistics involved in exporting the HDPE to the US were not without challenge, a suitable supply of material was soon on-site at Hagerstown. The full 5200' of Driscopipe 8300 was produced and prepared for shipment in 12 days. Sources at Phillips Driscopipe reported that extrusion of the 8300 product from the PE100 HDPE proved relatively trouble-free. The HDPE pipe was produced on typical US extrusion and vacuum sizing equipment with some relatively minor adjustments of the standard operating conditions.

Driscopipe personnel did report that extra time was required to dry the precompounded black resin as it did tend to pick-up excess moisture due to the extremely long transit time involved in the importation process. Standard resin hopper dryers proved capable of removing the moisture. However, the residence time in these dryers did have to be increased. Quality assurance procedures were in place to insure that a uniformly clean and dry supply of resin was available on demand to the extruder.

<u>Butt Fusion of the Driscopipe 8300 PE100:</u>

US regulations require that all HDPE pipe used in the distribution of natural gas meet the requirements of the Department of Transportation, Code of Federal Regulations, Part 192. Part 192 requires that the fusion joining procedure used for HDPE gas pipe must be qualified to meet specific requirements for tensile strength, bend back and side wall fusion.

Given that the Driscopipe 8300 was being produced for the first time for the Washington Gas renewal project, fusion procedures for this piping product were developed and qualified in accordance with industry regulations and Washington Gas requirements. The fusion procedure chosen was the PPI Generic Butt Fusion Protocol detailed in PPI TR-33/99.(6) The basic fusion parameters of TR-33/99 are presented in Table 3.

The 8300 PE100/PE3408 HDPE pipe was qualified using the PPI generic butt fusion procedure by personnel at Phillips Driscopipe. Test results verifying compliance to DOT CFR Part 192 were then supplied to Washington Gas and approved. These procedures were subsequently used to join the pipe at the job site by D.A. Foster using a McElroy 618 butt fusion apparatus as shown in Figures 2 and 3.

Table 3: PPI TR-33/99 Fusion Parameters

Property	Units	Value
Interfacial Pressure	Psi	60-90
	Bar	4.14-6.21
Heater Plate Temperature	Deg F	400-450
	Deg C	204-232

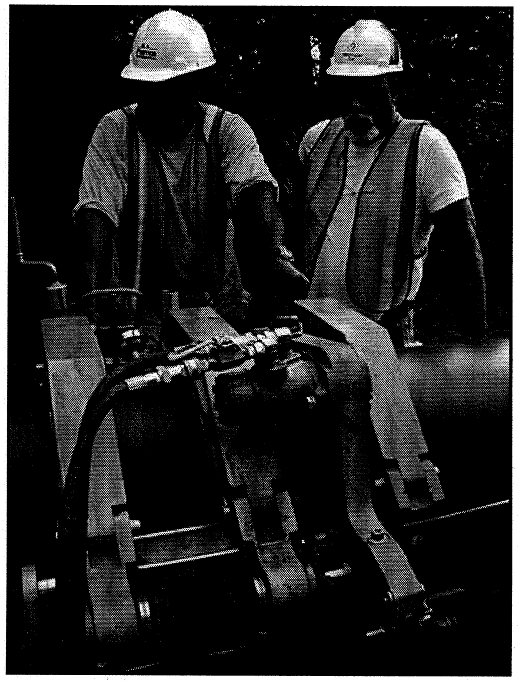

Figure 2: Fusing Driscopipe 8300 Using McElroy No. 618 Fusion Machine

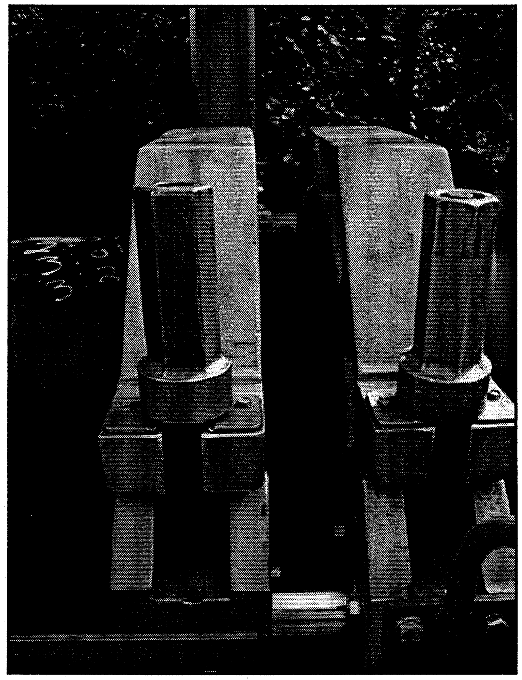

Figure 3: Butt Fusion Bead Formation

16" Electro-fusion Transition Fittings:

The 16" liner used in the insertion renewal project was connected to 24" coat and wrap steel pipe. To facilitate these transitions, 16" electro-fusion fittings were designed and supplied by Friatec, Inc. US regulations require that molded HDPE fittings used in gas distribution be manufactured from a stress-rated material. To that end, the Friatec transition fittings were molded from the same TuB 121 HDPE resin as was used for the liner itself and were subsequently qualified to meet the requirements established in DOT, CFR Part 192.

These fittings were then used to make transition connections to the 24" coat and wrap steel lines. While fittings such as these are readily available on the international market, the Washington Gas project marked the first time electro-fusion technology had been utilized for a transition connection in a major large diameter PE100 gas line renewal project in the US.