NYSEARCH/Northeast Gas Association

Advanced Research Under Way On PE Pipe For Natural Gas

By **Joseph P. Mallia, Angelo Fabiano** and **Hitesh Patadia**

Modern polyethylene (PE) pipe's capabilities and characteristics have improved greatly since first installations more than 40 years ago. Interest in PE pipe has expanded widely throughout the gas distribution industry. NYSEARCH/Northeast Gas Association is conducting research that is revealing the strengths and durability of modern PE pipe with notable results. Incorporating these revelations into industry standards could result in benefits on many levels.

Research involving modern PE pipe materials applications is being performed to ensure that safe design, fabrication, installation, operation and maintenance of PE pipe can continue with confidence. PE pipe ASTM standards applied to the local distribution company (LDC) continue to be updated to reflect the modern PE pipe capabilities currently being produced for gas distribution applications. Recent revisions to ASTM D-2513 are an example of a concerted industry effort to incorporate some of these research results. This improves the industry standard to more accurately apply new known capabilities of modern PE pipe materials.

Design Limitation

Pipeline engineers design to code requirements and company engineering standards based on PE material specifications. In some cases, these requirements may be limiting due to historical empirical data, general manufacturer guidance and past experiences which may not be applicable to the better performing PE materials that are in use today.

Steel pipe properties are well-known and established, standardized through more than 100 years of application in a variety of industries beyond that of the gas industry. Early steel pipe ruptures and leaks led to stricter and more safety conscious design standards reflected in ASTM and ASME industry standards for all types of pipe. In parallel and only recently, ASTM and ASME standards have been established for PE pipe that the natural gas industry recognizes. Today, approximately 95% of LDC pipe installations in the U.S. are built with polyethylene. Over the years, steady improvements to PE materials, like PE 4710 and bimodal resins, require that industry standards be updated to reflect their superior performance over the earlier vintage PE materials.

Long-term Life

Typical practice for acceptance of PE pipe joining in the field for butt fusion joints is to visually inspect the size and shape of the pipe bead roll-back after fusing the two pipe ends together. Generally, the integrity of the overall pipe segment is confirmed with an elevated pressure air test. These examinations verify that the pipe has been assembled correctly but reveal little about its potential performance longevity and durability over time.

Design engineers assume that PE piping networks will provide safe and reliable service for more than a design targeted life of 50 years. The industry is approaching that 50-year milestone of use, in particular with the earlier vintage PE materials.

Though negative occurrences are rare, caution must be taken to identify and address PE pipe limitations and better understand their impact on in-service performance. For instance, PE pipe characteristics such as slow crack growth (SCG, Figure 1) and rapid crack propagation (RCP, Figure 2) happen infrequently. However, they are still a concern to LDCs and must be considered when designing and installing new PE pipelines. Efforts are made to reduce the risk of SCG by minimizing external stress risers on the pipe. The potential for RCP failure can be reduced by limiting factors that influence critical RCP pressure.

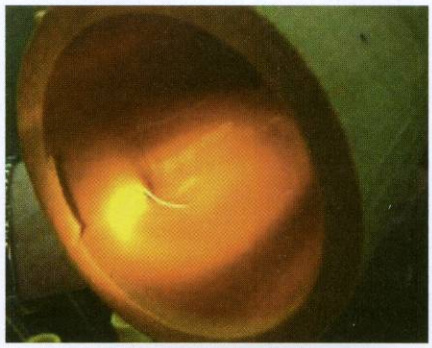

Figure 1: Slow Crack Growth.

Figure 2: Results of Rapid Crack Propagation.

Ongoing research results that evaluate the SCG and RCP in modern PE pipe have identified great conservatism in the established industry standards. For example, for modern PE pipe RCP critical pressure limitations, using formulas in the current standards, are underestimated by 1.5 to 2 times. Although actual RCP type failures are rare, operating pressures in PE systems are unnecessarily being reduced, thereby negatively impacting gas flow and design requirements.

Pipe Joining Inspection

Typically, there are two methods for joining PE pipe: 1) electrofusion (EF) couplings and 2) butt fusion. Although LDCs use both methods, butt fusion is currently the one most commonly performed. It is recognized that there is a need to obtain a better understanding of variables impacting joint integrity and to develop methods of field examination to verify good quality joints. Currently butt fusion joints are visually inspected by examining the resulting exterior bead for certain size and shape characteristics (typical butt fusion bead, Figure 3). Visual inspection is primarily the basis of acceptance of a fusion joint. This visual inspection is only a general observation of the butt fusion's condition but reveals nothing about the volumetric cohesion of

the face-to-face contact and integrity of the fused material throughout the pipe wall.

Some utilities have had success with field inspection instruments, such as the UltraMac. However, this equipment was limited in use and eventually was no longer supported by the manufacturer. Recently a resurgence of interest has evolved to improve methods of field inspection for fusion joints, both butt fusion and EF. Research is ongoing to determine the effectiveness of ultrasonic — including time-of-flight-diffraction (TOFD) and phased array (PA) -microwave and digital x-ray non-destructive techniques (NDE) and their ability to discern defects that are typically encountered in the field.

Although statistics show that butt fusion joint failures are uncommon events, there is still a need to reduce failures and verify joint quality in the field. An improved field non-destructive examination (NDE) technique involving volumetric inspection is needed for LDCs, especially with the advent of new and stronger materials leading the way to larger diameter and higher pressure PE systems. Examining the volume of the pipe wall, from external wall through to the internal wall, is much more revealing of the integrity of the fusion than simply visually inspecting the bead size and roll-back.

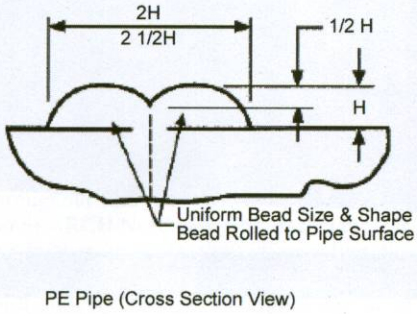

Figure 3: ASTM PE fusion joint bead.

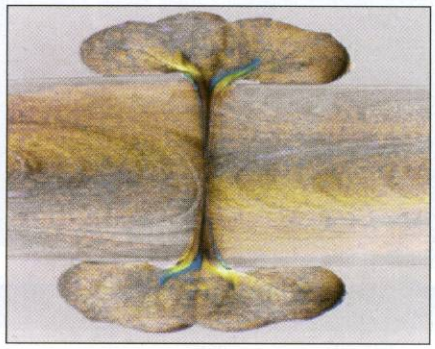

Figure 4: PE fusion pipe wall cross section.

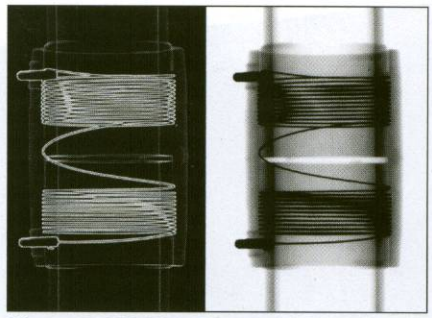

Figure 5: PE Pipe EF coupling NDE Digital x-rays (reversed images).

Volumetric examination reveals much more of the overall joint fusion (Figure 4) or the complete fusion examination of an electrofusion coupling (PE pipe EF coupling NDE digital x-rays, Figure 5).

Rapidly evolving NDE techniques to evaluate the volume of pipe butt fusion and EF joints are getting the industry closer to having a means to actually distinguishing good quality joints from weak ones.

Research on NDE techniques is being evaluated based on analytic modeling and new empirical test methods to detect implanted defects and varied fusion parameters in PE pipe samples. A robust statistical analysis approach based on a "Design of Experiment" (DOE) methodology has been incorporated

into test programs. This approach ensures that the proper number of samples and their resulting correlations will provide the maximum information relative to complex interactions at the joint interface in a repeatable and defensible manner.

Acceptance Criteria Determination

As NDE techniques improve and instruments are developed for field applications, LDCs will be better able to detect defects and better poised to identify anomalies that were not seen before. As more anomalies are detected, an understanding and acceptance of anomalies must be understood. Research is under way to determine a threshold of acceptable and unacceptable anomalies impacting joint fusion integrity. Ultimately these NDE instruments will provide a better understanding of the impact of an anomaly's type, size, shape and position which will be the basis for establishing acceptance criteria.

Updating Industry Standards

Ongoing industry committees are taking lead roles in cautiously revising the material standards, such as the AGA Plastic Materials Committee and the ASTM D-2513 working group. Industry experts and peer review committees ultimately lead to improvements that allow the overall industry to benefit. This will provide a better and expanding use of PE material, improved system designs and a safe pipeline infrastructure.

NYSEARCH and expert review committees have recently initiated research to determine the effect of outdoor stored PE pipe exposed directly to ultraviolet (UV) rays. The recently revised ASTM D-2513 allows for extended periods of outdoor storage of PE pipe directly exposed to UV rays. Although the storage time period has been extended from the previous ASTM revision, it remains a "time-based" criterion rather than a "performance-based" criterion. Research has begun to determine how a functional material test may be used to determine whether PE pipe is acceptable for use. The main concern related to outdoor storage of PE pipe is the oxidation layer that results from continuous UV exposure. When the oxidized outer surface of the pipe is scraped away, the remaining PE material may be acceptable for use at an age beyond the pipe's print line manufactured date.

Future Involvement

Today, LDCs confidently install systems made with modern PE pipe. This is a result of continued industry attention and education involving better materials and a better understanding of the performance of these materials, for both immediate and long term system integrity. Research leads to better designs, optimized overall cost and safer more predictable pipeline infrastructure. Continued evaluation and questions to better understand PE pipe behavior leads to an overall industry benefit.

Active research is ongoing with the NYSEARCH voluntary R & D organization in the areas of PE pipe butt and EF fusion integrity, improved NDE methods, more insightful understanding of SCG and RCP, and — collectively — a cohesive industry support standards process. The results of this research will bring a better understanding of and improved PE pipe design and applications.

Authors: Joseph P. Mallia, *NYSEARCH/NGA 20 Waterview Blvd., Parsippany, NY 07054, Ph: 973-265-1900, jmallia@northeastgas.org.*

Angelo Fabiano, *NYSEARCH/NGA 20 Waterview Blvd., Parsippany, NY 07054, Ph: 973-265-1900, afabiano@northeastgas.org.*

Hitesh Patadia, *Tej Group, 1521 Rolling Hills Dr., Crystal Lake, IL 60014, Ph: 847-873-3139, hitesh@tejgroupinc.com.*