

Technical Note PP-838-TN Preventing Rapid Crack Propagation In Fused Water Pipelines

Introduction

The need for reliable, corrosion resistant pipe to rehabilitate existing pipelines and for new pipeline installation by horizontal directional drilling methodology led to the emergence of polyethylene (PE) pipe as the standard bearer for thermoplastic pipe in the trenchless industry. The success of PE pipe is undeniable. Recently, another product has attempted entry into the trenchless pipeline industry. This product is a fusion joinable, proprietary polyvinylchloride (PVC) pipe. This product has been presented to be the best of both PVC and PE. However, the intrinsic material characteristics of the fusion joinable PVC product present a potential hazard of catastrophic failure called Rapid Crack Propagation (RCP).

Rapid Crack Propagation

Resistance to Rapid Crack Propagation (RCP) is a critical property for fusion joined thermoplastic pipes. RCP is sometimes referred to as a “fast brittle fracture” and, by the construction industry, as a “linear split”. Once initiated, a crack under sufficient pressure can travel the entire length of a pipeline in seconds. Today’s polyethylene pipe materials have a very high resistance to RCP. This has been recognized for decades by the designers of PE piping materials as PE pipe is used for natural gas distribution. Over the years, researchers have developed highly improved PE pipe resins with resistance to RCP. PVC pipes do not have the toughness and resistance to RCP that PE pipes have. Historically, PVC pipe is non-continuous pipe connected by gasket joints. If an RCP crack develops, it is usually arrested when it reaches the end of the bell or spigot. This offers some protection against catastrophic RCP events in PVC pipe. The pipe will be unusable but damage is usually limited to a single piece of pipe.

In fusion joined pipes, when RCP or linear splits occur, the fusion joint does not generally provide a barrier to the crack propagation. Once the crack initiates, generally it travels between 1550 to 1950 ft/sec in the material along the length of the entire pipeline [1]. The crack is driven by the pressurized medium in the pipe. The crack will continue to run the entire length shattering the pipeline, or until the pressure driving the crack has dissipated. RCP events (linear splits) have been reported to occur during hot tapping of PVC pipes and as a result of in-service damage to PVC pipes [2]. For gasketed pipe, it may not be an easy prospect for repair but at least it can be replaced and the line put back in service rather quickly. Because fusion jointed pipe is continuous, there are no bells or spigots to act as safe termination points. If a fused pipeline were to have the same crack occur during tapping or due to in-service damage such as rock impingement, 3rd party impact, or fatigue, the entire pipeline may have to be abandoned.

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Preventing RCP

If a force is applied to the pipe but does not cause a crack, then RCP will not occur. This resistance to RCP can be characterized by toughness, impact resistance, notch sensitivity, and fatigue resistance. Toughness is a general term that refers to the pipe's ability to absorb impact and strain without fracturing. Toughness is a primary reason that fused PE pipe has proven to be the pipe of choice for gas distribution. PE pipe has high ductility, high toughness and very high impact strength compared to PVC. Impact resistance for thermoplastic pipes can be measured by ASTM D256, "Standard Test Methods for Determining the Izod Pendulum Impact Resistance of Plastics". The impact strength of PVC pipe resin per D256 Method A is reported in AWWA M23 as 0.65 ft-lbs/in., whereas the impact strength of HDPE pipe resin per D256 Method A is 4 to 5 ft-lbs/in. As PE has more than 6 times the impact strength of PVC, a crack from impact is much less likely to occur in PE pipe.

Cracking initiated by cyclical fatigue of pressurized water pipes may also result in RCP. Distribution pipes typically experience millions of surges during their operational lifetime. PE pipe has up to eight times higher resistance to repetitive surges than PVC pipe. See Marshall et al. [4].

The pressure above which RCP will occur in the presence of a brittle crack is called the "critical pressure." If pipe is operating above the critical pressure and a brittle crack is introduced in the pipe, the crack can propagate indefinitely. If the pipe is below its critical pressure and a brittle crack occurs it will arrest with no sustained RCP. Greenshields and Leever [1] report that "The 100 percent water pressurized critical pressure falls well below the rated pressure in PVC-U" meaning that the normal operating pressure for PVC pipe is above the critical pressure and a brittle crack could cause RCP. They further report that the critical pressure for a 100 percent water pressurized PE line is well above the pressure rating for PE pipes, meaning that the crack will not propagate. RCP events have occurred in the field with fused PVC pipe. For instance, Edwards and Duvall [3] reported on an 1100 ft long crack that occurred in a 30" DR25 fused PVC pipe in Collier County, Florida.



Collier County, FL, fused PVC failure during pressure test.

Crack propagation in RCP is arrested if the decompression wave in the water travels faster than the crack velocity. In other words, if the water pressure driving the crack drops off faster than the crack can propagate, arrest will occur and thus no sustained RCP can occur. The decompression wave speed increases with increasing wall thickness. Calculations of the wall thickness required to increase the decompression wave speed to a velocity above which RCP cannot occur in water show that PVC requires a DR 13 or thicker wall pipe whereas PE pipe requires a DR29 or thicker wall pipe. [1]. For PVC pipe, DR 13 is a much heavier wall thickness than is being promoted for directional drilling and trenchless applications whereas for PE pipe DR29 is a much thinner wall than being used for directional drilling and trenchless applications.

In "The Effect of Air Pockets on Rapid Crack Propagation in PVC and Polyethylene Water Pipe" Greenshields and Leever [5] state that "Although PVC-U pipe has improved considerably over the last 20 years, its resistance to RCP still appears to be a cause of concern" while "PE-80 [pipe] appears to be more than adequate to resist RCP."

Summary

RCP is not the result of poor or inferior pipe quality; it is a combination of intrinsic material characteristics, the type of impact or damage, the pipe size and DR and the presence of pressure in the pipe.

Toughness, including resistance to RCP, is probably the most important characteristic of a fusion joined piping system. If a material is lacking in toughness then it is susceptible to catastrophic failure. While testing and field experience has shown that RCP is extremely unlikely to ever occur in a PE water or sewer line, it is a very real possibility with fusion joined PVC pipe.

References

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