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# Root Cause of Failure of Large Diameter Buried PVC Pipe

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## Introduction

Poly(vinylchloride) (PVC) piping is the highest volume of all plastic piping products. Rigid PVC pipes are highly ductile when properly manufactured. Their long term service life of PVC pipe has been determined to be >50 years.[1] However, there are occasional brittle failure of PVC pipes and fittings.[2] PVC pipes occasionally fail due to a number of reasons including defective manufacture, defective installation, and defective operation. The main manufacturing defects that cause PVC pipes to fail include incomplete resin fusion,[3-6] incomplete fusion of extrusion knitlines (also called “weldlines” or “spider-lines”)[7] and inhomogeneity of the filler content.[8] The main installation errors are over-belling and improper soil conditions. The main operational defects include over-pressurization due to water-hammer and liquid column separation due to improper venting.[9] PVC pipes are generally ductile when exposed to long term stress but their inherent toughness is rate dependent.[2] They can undergo catastrophic failure if exposed to high speed stress events. Therefore our forensic failure analysis investigations include tests to investigate which of these factors caused the failure.

## Background

PVC pipes are manufactured by an extrusion process where PVC powder is melted and forced through a circular die under high pressure. The center of the die-face is a solid metal plug held in place by thin metal webs or vanes (Figure 1). The vanes slice the melted plastic as it flows through the circular slits in the die. The plastic then fuses back together to form a solid pipe wall. Occasionally the knitting process does not take place completely producing what are called “weak extrusion knit-lines”. Therefore, it is common for pipes to fail with a straight longitudinal split running down the full length of the pipe because it follows the path of least resistance which is an imperfect knit-line. When a straight line longitudinal split does occur, the pipe wall on each side of the split may overlap allowing the pipe to curl up with the two sides of the pipe overlapping as shown in Figure 2. The curl results from differential cooling of the inside of the pipe compared with the outside surface of the pipe; i.e., the inside surface of the pipe is cooled more rapidly than the outside surface. This differential places the pipe under residual stress making it like a coiled spring. Pipes that are under high residual stress are much more prone to creep rupture failure than pipes that are under low residual stress. When the pipe cracks, the residual stress in the wall of the pipe is relieved. The degree of residual stress in a pipe can be estimated by cutting a ring from the end of the pipe and then cutting through the ring in one location. If the pipe is under residual stress, the cut ring will contract and the two ends of the ring will overlap. The extent of overlap provides an estimate of the degree of stress.