PRESENTATION ON INVESTIGATION OF PIPELINE FAILURE

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ABSTRACT: *Investigation of the causes of failure of a large diameter, high density polyethylene (HDPE) pressure pipeline. The conduit is a 25km long, 650 to 800mm diameter HDPE buried irrigation pipeline, installed parallel to the Gasgoyne River in WA. The pipeline failed during testing in December 2016. Investigations included inspection of the failed pipe length and determination of the cause of rupture of the 32mm thick pipe wall. Failure included ballooning (yielding of the pipe wall) with resulting rupture. The factors that were investigated included stress capability of HDPE material, earth loading, temperature, excessive internal static pressure, air entrapment, hydraulic surge and duration of test pressures. Following the investigation, the remediation included replacement of the failed pipe length and improved testing procedures, including having the pipe refilled, and pressure tested at 450 KPa.*

KEY WORDS: High density polyethylene pipeline, air valves, test pressure, safety factor, filling process.

1. INTRODUCTION

In 2016, a 25 km long, large diameter buried high density polyethylene (HDPE) pipeline was installed parallel to the Gascoyne River near Carnarvon WA. During final filling operations on Dec 19, 2016 (prior to a scheduled pressure test) a section of 800 mm diameter pipe failed (burst). The following discussion outlines the investigation into the cause of the failure. The pipeline is a transmission main for collecting and conveying groundwater from a bore field to irrigation properties adjacent to the Gascoyne River.

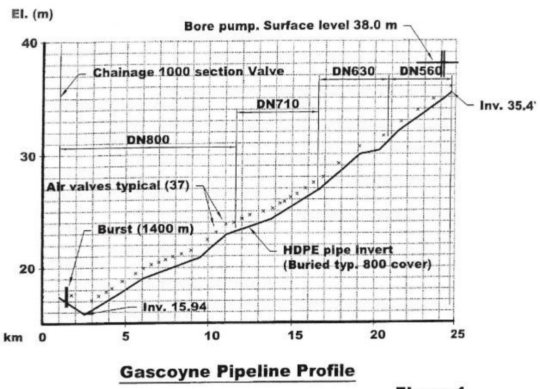

Figure 1.

Figure 1"** indicates the profile of the pipeline. The pipeline is a pressure conduit designed for direct delivery of variable flow rates. The estimated maximum operating pressure at the lower (west) end was forecast to be 40 m. **The test pressure was specified to be 60 m (600 kPa).

The pipeline was installed in generally well drained sand (with about 15 % fines). Bedding and backfill was specified to be compacted excavated material. A minimum cover for the 800 nominal diameter piping was specified to be 850 mm.

2. FAILURE

The pipeline failed during the final filling operations on 19 Dec, 2016. A length of 800 nominal diameter PN6.3 pipe (inside diameter approx. 736 mm) yielded along the crown of the pipe and subsequently fractured. The failure was near the lowest point of the pipeline (invert approx. 16 .5 m AHD).

***Photograph 1:** is a photo of the failed pipe in the trench before dewatering and removal.*

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Photograph 2: *is a photo of the failed length of pipe after it was transported to Perth for detailed inspection and testing.*

3. SOILS INVESTIGATION

Initially it was presumed that a cause of failure could have been due to backfilling and compaction procedures. A detailed investigation of soil types and compaction techniques was conducted. It was concluded that "**the rupture of the pipe was not related to the level of compaction in the trench."** Consequently a separate investigation was conducted after the failed pipe length had been transported to Perth.

4. YIELD CHARACTERISTICS OF HDPE

Inspection of the failed pipe indicated that the pipe wall had yielded from an average thickness of 31.8 mm to 5.2 mm before final rupture. The yield was equivalent to about 612 %. Published test data for HDPE indicates that elongation prior to rupture is typically 636 %. At the time of the failure it was estimated that ground temperature adjacent to the pipe would have been in the range of 30 to 35^{o} C which could have lowered the pressure rating of the pipe by about 10 % (from 630 kPa to approx. 580 kPa).

Based on inspection and measurement of the yielded pipe wall, it was obvious that the pipe had failed due to excessive internal pressure.

5. FILLING PROCESS

The pipeline had been gradually filled and checked for leaks during the 10 day period prior to final filling. The Contractor stated that: "a number of leaks were identified and rectified". The pipeline was filled from a bore pump near the upper (east) end of the pipeline. See Figure 1. (The pipeline has a volume of 9,600,000 litres and at an average pumping rate of 25 L/s, it required more than 106 hours of pumping to fill the line). The temporary connection between the bore pump and the pipeline included a conventional pressure gauge, a visual flow meter and a throttling valve. There was no automatic recording equipment and **there was no method of limiting pressure applied to the pipeline.**

Curve A on Figure 2 indicates the head capacity curve of the bore pump. The curve is based on the bore pump manufacturer's performance curve and it was adjusted to account for bore drawdown and actual static lift [3].

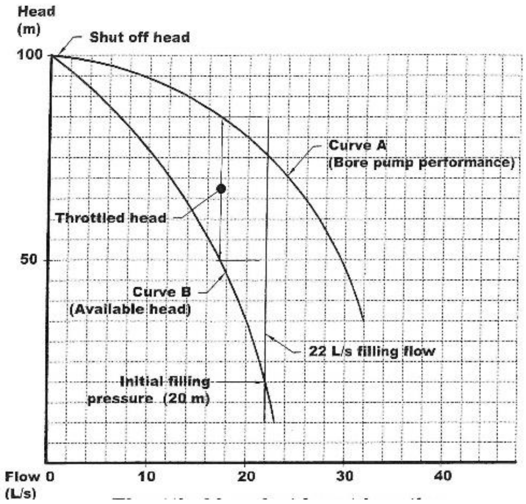

Figure 2: *Throttled head at burst location*

Curve B on Figure 2 indicates the available head that could be transferred to the pipeline after passing thru the throttling valve. On the day of the final filling, the throttling valve was adjusted so as to initially limit the inflow to 22 L/s. All section valves along the length of the pipeline were open and the **applicable pressure from Curve B would have gradually been applied (based on the elevation) as the pipeline became pressurised**.

As the pipeline became completely full and the back pressure on the pump increased, pumped flows decreased and the effect of throttling was also decreased. Additional head (due to less effective throttling) would have been applied to the pipeline**. There was no record of actual pipeline pressure at the time of failure.**

6. AIR VALVES

A total of 37 air valves were installed along the 25 km length of the pipeline. The valves were effective in discharging trapped air during the 10 day filling process. During the final filling process (19 Dec, 2016) it was observed that there were no discharges from air valves. The locations of the air valves became an issue relative to the cause of the burst. A review of the as constructed records (ASCON drawings) confirmed, however, that there was no location where a measurable volume of air could be trapped.

7. TEST PRESSURE

The initial specifications stipulated that an appropriate test pressure for the specified HDPE pipe (rated PN6.3 or 630 kPa) should be 60 m. HDPE pipe manufacturers indicate that **their nominal rating includes a 2 to 1 safety factor based on an ambient temperature of 20ºC.**

The stress patterns in HDPE pipelines (that are joined by thermal fusion) are in some respects related to continuously welded steel pipelines. Temperature induced longitudinal stresses can be substantially influenced by variations in closing temperatures plus deviations in alignment and the radius of curves. Earth loading and Poisson's Ratio complicate the overall pattern .The need for a 2 to 1 safety factor appears to be judicious. There is, however, a need to ensure that miscellaneous (non pressure induced) stresses are recognised for large diameter non flexible pipe applications.

8. PRESSURE RELIEF VALVES

The completed pipeline included a pressure relief valve (PRV) on a branch at chainage 1424 m, near the lower (west) end of the conduit. It was necessary to isolate the PRV prior to pressure test that was to be scheduled after final filling. It was subsequently suggested, after the failure, that the pressure relief device should be adjusted to operate at 450 kPa, under normal operations. See Section 9 (b).

In addition to the PRV, the pipeline included nine scour valves at low points. The scour valves were utilised for discharging dirty water during initial filling operations but were closed on 19 Dec, 2016.

9. CONCLUSIONS

There was no written record of the pressure at either end of the pipeline at the time of the burst. Based on information available to us we concluded**:**

(a) All evidence suggests that the pipe was subject to a pressure higher than 500 kPa. The failure occurred near the lowest point in the pipeline under very low flow (essentially static) conditions. The pipeline was buried and it was not possible to determine if there was any damage elsewhere. We doubted it. Filling and pressurisation had located the most vulnerable situation.

(b) It was suggested that the damaged section of pipe be replaced and that the pipeline be refilled and pressure tested at 450 kPa (at the lowest point of the conduit).

(c) It was also concluded that all air had been effectively displaced from the conduit and that air did not contribute to the failure.

Overall it was observed that HDPE material has similar yield characteristics to steel and actual fracture is preceded by gradual elongation.

(d) It was concluded that failure was not instantaneous but occurred over a time span of about 5 seconds, as the volume of the pipe increased due to increasing pressure.

(e) A very important issue with large diameter HDPE pipe lines is that the assumption of flexibility does not apply. Piping with SDR ratings greater than about SDR 15 are rigid and miscellaneous stresses can be locked into installed pipelines.

For relatively thin wall pipes, curved alignments, bedding variations and other factors lock in non pressure induced stresses. South Australia Water Corporation, for instance, requires that PN 12.5 SDR 13.6) is the minimum pressure rating for Water supply applications. For large diameter HDPE pipe, the applicable in situ test pressure may need to include a safety factor of, say, about 2.

ACKNOWLEDGEMENT

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