Plastics Industry Pipe Association of Australia Limited ACN 086 511 686

# Long Term Performance of PVC Pressure Pipes

## INTRODUCTION

The Millewa Waterworks District Scheme, in North Western Victoria, was a major project undertaken to replace an open channel domestic and stock water distribution system with pipelines.

The system to be replaced comprised a pumped supply from the River Murray into an open channel to Lake Cullulleraine.

From Lake Cullulleraine the water was delivered by an open channel system, with further relift stations, to earthen storages on 126 farm holdings.

Approximately 5% of the water entering the channel system at the River Murray pumping station became available for use on the farms, the remainder being lost through seepage and evaporation.

Following a State Government Inquiry in 1965, the program to replace the open channels with a closed pipe system was approved, and construction commenced in 1970. As a consequence, water was reticulated through 644 km of pipelines serving the 126 holdings and two urban locations spread over a total area of 227,000 hectares. In addition, as part of the project, approximately 500 km of on-farm pipes were laid from the meters to sealed holding storages. Funding of the project was by a combination of State Government loans and Federal Government grant. See Appendices A and B for a plan of the area showing pipe details and layout.

After almost 30 years of successful operation, samples of PVC pipe were exhumed for testing, to determine whether there had been any deterioration in the quality of the pipes during their service life.

This scheme was selected for the exhumation project because it represented a large reticulation system with very good operating performance over many years. Furthermore it was known that comprehensive installation and operational records had been retained.

## DESIGN AND CONSTRUCTION

The State Rivers & Water Supply Commission (SR&WSC ) carried out all design work and project management for the construction of the scheme.

The climate in the Northern Mallee district of North Western Victoria is such that consideration had to be given to possible elevated ground temperatures for determination of the appropriate pipe pressure classes. The CSIRO, Merbein Office, reported peak ground temperatures, at a depth of 20" (500mm) below the surface, ranging from 55°F (13°C) in August to 80°F (27°C) in February. It was considered that, at 30" (760mm) minimum depth, no special provision needed to be made for elevated-temperature operating conditions. That is, ground temperature would not be a limiting factor in the use of PVC. However, the sporadic rainfall conditions and the nature of the native soil necessitated consideration of the effects of potential ground movement. Accordingly, only plastics pipes, with their inherent flexibility, were considered in sizes below 8" diameter.

With the exception of some pipelines installed by SR&WSC day labour forces, pipelines were constructed on a "supply and install" basis by contractors selected by the SR&WSC.

Pipe used in the project were of either PVC or asbestos cement (AC). Concrete pipes were considered unsuitable due to pressure restrictions, whilst polyethylene pipes were not an economical proposition. The use of AC pipes was restricted to diameters 200mm (8") and above due to concerns about the beam strength being sufficient to cope with possible ground movement. There were no limitations placed on the use of PVC, which was subsequently installed in sizes from 20mm to 200mm, (3/4" to 8"). Pipe pressure classes ranged from Class 4.5 to Class 18 ('A' to 'F' under the now defunct classification system). Pressure classes were selected solely on the basis of the internal working pressure of the relevant location in the system.

There was no adjustment to the pressure class of pipes for the many rail and road crossings. The latter included both sealed and unsealed roads. Pipe lengths were generally 20ft (6m). However, for one contract, incorporating all sizes up to 8", solvent cement jointed 34 ft (10m) lengths were used.

The fittings and appurtenances included air valves, isolating valves, fire plugs (used for scour outlets), and metered services. Fittings types used in the system were moulded PVC pressure fittings, coated aluminium, wrapped cast iron gibaults, flanges and tees together with cast iron and brass valves.

**UPVC PIPES SPECIFICATION & MANUFACTURE**

PVC pipes and fittings were manufactured to Australian Standards ASK138:1967 Rigid PVC Pipes for Pressure and Non-pressure Applications, ASK138:1969 Rigid PVC Pipes for Pressure and Non-pressure Applications, and AS1477:1973 Unplasticized PVC Pipes and Fittings for Pressure Applications, as appropriate. However, the specification used for most of the PVC pipes was ASK138:1969. During manufacture pipes were routinely tested for resistance to flattening, impact resistance at 0°C and 20°C, resistance to acetone and sulphuric acid, reversion, softening point and resistance to internal hydrostatic pressure.

The PVC pipes were manufactured by Vinidex Tubemakers, Hardie Extrusions, and Humes Plastics at sites specifically approved by SR&WSC. The PVC resins used in these pipes were produced by I.C.I. Australia for Vinidex, BF Goodrich (Aust) for Hardie Extrusions, and Sekisui (Japan) for Humes Plastics. As the pipes were lead stabilised, the SR&WSC took samples of water from the system for lead testing shortly after commissioning the first major line in 1971. The concentration of extracted lead in the samples was below the limits of detection.

Joint types used for PVC pipes were elastomeric seal (rubber ring, RRJ) and solvent weld (SWJ) with both types of joints being used in sizes up to 200mm. However, the use of SWJ was minimal by comparison with RRJ. The rubber ring joint designs were as used to this day by Vinidex Tubemakers and Iplex Pipelines. Rubber rings, as now, were manufactured from natural rubber compounds.

**INSTALLATION**

**General**

Installation, including handling and storage, pipelaying and jointing, and pressure testing, was in accorda

nce with SR&WSC specifications. These specifications were subsequently incorporated into Australian Standards AS CA 67:1972, and AS 2032:1977. Pipes were installed with a minimum of 750mm cover, increasing to 900mm at road and rail crossings.

**Trench Conditions**

Pipes were surrounded by granular material obtained from the excavation or, in the case of rock excavation, from nearby.

A layer of granular material was placed beneath the pipe to a minimum depth of 75 mm throughout the project, including areas of rock excavation.

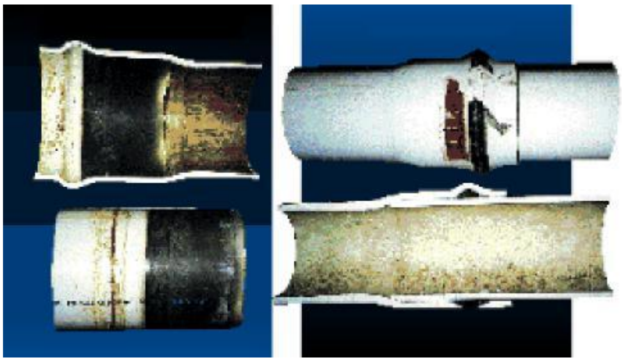
Typical trench conditions are illustrated in the photo at left.

**Jointing**

Whether RRJ or SWJ were used was determined by the ‘in-ground’ cost. Both solvent cement and elastomeric seal systems were approved by the principal. Rubber ring joints were made to the SR&WSC specification which required the spigots to be inserted into the sockets to a witness mark that allowed for subsequent thermal movement. In practice, the spigots were generally inserted past the witness mark.

Elastomeric seal joints as exhumed and subsequently sectioned are depicted below.

Vinidex Polidex Rubber Ring Joint     Hardie Rubber Ring Joint



Dark staining is evident on the matching socket and spigot surfaces where the water would be essentially dormant. This staining is likely to be due to sulphides reacting with the lead stabiliser in the pipe. The staining is only a surface effect.

Solvent weld sockets were manufactured to have an interference fit with the spigot. It was reported that some solvent weld joints leaked when the lines were first pressure tested. This was attributed to poor workmanship during installation rather than the quality of the pipes supplied.

Solvent cement jointing for pipes up to 8" dia. was conducted to the SR&WSC specification using appropriate cements for the products and environment, plus disposable brushes and containers. These pipes were usually jointed above the trench and lowered into the trench the following day.

**Pressure Testing**

Pipelines were tested to 1.3 times nominal working pressure of the pipe, the time of test being varied from two hours to 24 hours, depending on the length of pipeline under test.

**PERFORMANCE**

The first pipeline was put into service in 1970, with subsequent sections being commissioned as they were completed. The project was completed in 1975. Sunraysia Water Corporation, the current operator of the system, has reported the following:

Asbestos Cement. - AC pipe joints have been reported as leaking and subject to tree root intrusion. Pipe barrel failures due to ground movement have occurred.

PVC - No reported leaks in either elastomeric seal joints or solvent weld joints, with the exception of one 40mm solvent weld joint failure.

The cause of this single failure is not known. No pipe barrel failures have been reported, other than those resulting from third party damage.

Valves and Fittings - Corrosion has occurred with some valves. Air valve blockages due to ants have been reported.

Water Quality - As mentioned above, the possibility of lead extraction adversely effecting the water quality was investigated and discounted early in the project.

Some pipelines are currently "contaminated" by a grey "sludge", as can be seen in the photograph shown at right.

This material is thought to be at least partly composed of dead organisms and has had no apparent effect on the performance of the PVC pipes.

**EXHUMATION AND TESTING**

The prime objective of the pipe exhumation project was to determine, by physical testing, whether there had been any deterioration in either the PVC pipes or joints. This assessment to be made in conjunction with reports of operational performance. The field performance of the PVC pipes has been excellent, as described above.

The following pipes were exhumed in 1996, after approximately 25 years of service:

| Manufacturer | Diameter and Pressure Class | Specification | Joint Type |
|---|---|---|---|
| Vinidex | 2" Class PD | ASK 138:1969 | RRJ |
| Vinidex | 4" Class PC | ASK 138:1969 | RRJ |
| Hardie Extrusions | 4" Class PD | ASK 138:1969 | RRJ |
| Hardie Extrusions | 6" Class PC | ASK 138:1969 | RRJ |
| Humes Plastics | 6" Class PD | ASK 138:1969 | SCJ |
| Humes Plastics | 8" Class PB | ASK 138:1967 | SCJ |
| Humes Plastics | 4" Class PD | ASK 138:1969 | SCJ |

Unless otherwise specified the tests were performed at 20 ± 2°C.

1. Resistance to flattening was carried out by deflecting short sections to 40% of the original diameter and inspecting for any damage or fracture.
   Test Method: AS 1462.2
   Test laboratories - Vinidex Tubemakers Pty. Ltd., Sunshine, Vic.
   Iplex Pipelines, Technical Centre, Gladesville, NSW

2. Resistance to impact.
   Test Method: AS 1462.3
   Test laboratories - Vinidex Tubemakers Pty. Ltd., Sunshine, Vic.
   Iplex Pipelines, Technical Centre, Gladesville, NSW

3. The gelation level was measured using a Perkin Elmer differential scanning calorimeter using the method described by Potente and Schultheis [1] and Gilbert and Vyvoda [2].
   Test laboratories - ICI Australia Operations Pty. Ltd., Ascot Vale, Vic.
   Iplex Pipelines, Technical Centre, Gladesville, NSW

4. The dispersion of the resin in the pipes was assessed on microtomed samples approximately 0.02 mm thick under low power magnification. Test laboratory - Iplex Pipelines, Technical Centre, Gladesville, NSW

5. Tensile properties of the PVC were determined on four pipe samples, using the average of five determinations for each.
   Test Method: ASTM D638M-1991, using an Instron 4302 Tester.
   Test laboratory - ICI Australia Operations Pty. Ltd., Ascot Vale, Vic.

6. The fracture toughness of the pipes was determined using the C-ring method. Test Method: Draft Australian Standard No. 2570. Test laboratory - CSIRO, DBCE, Highett, Vic.

**RESULTS**

1. Resistance to Flattening

| | |
|---|---|
| Vinidex 4" PC - | 8 pass, 1 fail |
| Hardie Extrusions 4" PD - | 2 pass, 1 fail |
| Repeat Test - | 3 pass, 0 fail |
| Humes Plastics 4" PD - | 3 pass, 0 fail |
| Hardie Extrusions 6" PC - | 2 pass, 0 fail |
| Humes Plastics 6" PD - | 2 pass, 1 fail |
| Repeat Test - | 3 pass, 0 fail |
| Humes Plastics 8"PB - | 2 pass, 0 fail |

2. Resistance to Impact

| | |
|---|---|
| Vinidex 4" PC - | 22 strikes, 10 fail |
| Hardie Extrusions 4" PD - | 24 strikes, 0 fail |
| Humes Plastics 4" PD - | 6 strikes, 0 fail |
| Hardie Extrusions 6" PC - | 24 strikes, 7 fail |
| Humes Plastics 6" PD - | 26 strikes, 4 fail |
| Repeat Test - | 2 pass, 1 fail 4 |
| Humes Plastics 8"PB - | strikes, 1 fail 2 |
| Vinidex 2" PD - | strikes, 2 fail |

3.Gelation

| | Percent Gelation | Heat of Fusion J/g | Melt Temp. °C |
|---|---|---|---|
| Humes Plastics 6" PD | 44 | 1.9 | 185 |
| Humes Plastics 8" PB | 48 | 1.9 | 183 |
| Hardie Extrusions 4" PD | 44 | 2.3 | 175 |
| Humes Plastics 4" PD | 54 | 2.2 | 183 |
| Hardie Extrusions 6' PC | 64 | 2.7 | 183 |
| Vinidex Tubemakers 4" PC | 60 | 3.3 | 181 |

4. Dispersion

Dispersion, as judged from the microtomed sections, was variable and generally not as good as current production.

See samples at right

Dispersion in Humes 8" Pipe (x10)

Dispersion in Vinidex 4" Pipe (x10)

5. Tensile Properties

| Sample | Tensile Strength at Yield (MPa) | Tensile Strength at Break (MPa) | Elongated at Break (%) |
|---|---|---|---|
| Humes Plastics 4" PD | 51.4 | 35.1 | 31.4 |
| Vinidex 2" PD | 49.7 | 36.4 | 30.8 |
| Hardie Extrusions 6" PC | 50.0 | 31.4 | 36.8 |
| Humes Plastics 8" PB | 50.8 | 31.5 | 34.7 |

6. Fracture Toughness

| Sample | Linear Regression Equation | True Fracture Toughness at 15 min (MPa√m) | Minimum AS 1477:1999 Requirement |
|---|---|---|---|
| Humes Plastics 4" PD | Kic = -0.1903Ln(x) + 3.9265 | 5.12 | 3.25 |
| Vinidex 2" PD | Kic = -0.3255Ln(x) + 4.6683 | 4.19 | N/A |
| Hardie Extrusions 6" PC | Kic = -0.2241Ln(x) + 4.5507 | 4.86 | 3.30 |
| Humes Plastics 8" PB | Kic = -0.2132Ln(x) + 4.8064 | 5.10 | 3.50 |

## CONCLUSIONS

The PVC pipes and joints in the Millewa water scheme in North Western Victoria are performing well, having been in service for almost 30 years. The pipes were installed in a variety of terrains including sandy soil and solid limestone. The performance has been satisfactory in all situations. In addition, the pipes in the system traverse both roads and rail lines. In neither instance was the pressure class of the pipe upgraded to accommodate the dynamic loads imposed by passing road traffic or trains. Nevertheless, no failures have been reported as a consequence of dynamic loading.

For the four pipes tested, the tensile strength at yield and elongation-at-break were essentially the same. Moreover, the results are the same as expected for contemporary pipes tested at the time of manufacture. Thus it can be concluded there has been no degradation in the strength or elongation characteristics of the PVC during the service life of the pipes. The exhumed pipes have not suffered any loss of strength as a consequence of operating under pressure for almost 30 years.

The fracture toughness of all the samples tested was higher than the values reported by J. M. Marshall et al [3] and G. P. Marshall et al [4] for pipe made in the UK at about the same time.

In addition, the fracture toughness exceeded the enhanced levels specified in the recently revised Australian New Zealand Standard AS/NZS 1477-1999. These results imply there has been no deterioration in the fracture toughness during a service life approaching 30 years.

Some variability occurred in the impact test results but this did not appear to be related to a particular manufacturer, pipe size or pressure class. The variability is possibly due to surface damage caused during the exhumation, transport or original installation.

Weathering of the pipe during the original storage and transport period might also have contributed to the variability of the impact resistance. The field performance of the pipeline has not been adversely affected by such surface damage.

Flattening test results on the exhumed pipes were also variable and again it is possible surface damage could be a contributing factor.

The degree of gelation and the quality of the dispersion would be expected to be higher with contemporary PVC pipe production. Nevertheless, the performance of the pipes has not been adversely affected by these factors.

**References:**

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