Vyrnwy Aqueduct Refurbishment

relining of 50km of 39" cast iron main by die drawing

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The Vyrnwy Large Diameter Trunk Mains (LDTM) consists of 3 (No.) parallel, 80km long gravity pipelines, laid a 3m centres. Lines 1 and 2 are unlined cast iron and Line 3 is bitumen lined steel, with diameters ranging from 39" to 42". These mains transfer up to 210Ml/d of potable water from Oswestry WTW to Prescot Service Reservoirs near Liverpool, supplying 900,00 United Utilities (UU) customers in Cheshire and Merseyside. First constructed in 1890, deposits of iron and manganese have accumulated inside the pipes due to historic deficiencies in water treatment. Re-suspension of these solids could lead to water quality incidents and discoloration of customers' supplies. UU have a legal undertaking with the Drinking Water Inspectorate (DWI) to clean and refurbish the entire length of the aqueduct, 240km, at an estimated cost of £177m. This paper discusses the AMP5 element of the project consisting of 52km of thin walled polyethylene lining of the mains between Oswestry WTW and Malpas Balancing Tank.

The die draw towing head being pulled into the winch excavation - Courtesy of United Utilities

Needs and initial investigations

An investigation programme was initiated to confirm the need for cleaning and/or rehabilitation of the Vyrnwy LDTM as Oswestry WTW had a historic issue with iron compliance. The investigation techniques employed were specifically tailored to provide information relating to the asset condition and water quality, and included:

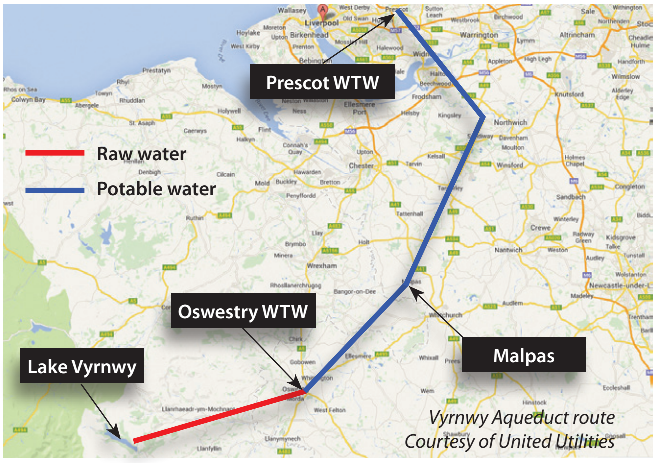
- Endoscope investigations.
- Water quality samples.
- Destructive and non-destructive testing.
- Soil conductivity surveys.

This concluded that there was a remaining asset life up to 61 years based on the 50% wall thickness failure mode for Lines 1 & 2, and 80 years for Line 3.

Hydraulic and PODDS modelling

To permit lining, various sections of the Vyrnwy LDTM would have to be temporarily taken out of service and flows transferred between mains using existing valves and cross connections. To ensure customer's supplies and their water quality water did not deteriorate extensive hydraulic modelling was undertaken to simulate the numerous flow scenarios. Additional turbidity monitoring was also installed and trials of the flow changes were undertaken to assist in model verification.

A further simplistic water quality model had also been developed using the University of Sheffield software PODDS software tool (Prediction of Discolouration in Distribution Systems). This model was calibrated against the trial and historical turbidity data and was used to predict turbidity values and risk of discoloration during the various pipelines outages.



Vyrnwy Aqueduct route
Courtesy of United Utilities


Refurbishment Techniques utilised on the Vyrnwy LDTM
Courtesy of United Utilities

Extensive preliminary design work was undertaken into the various refurbishment techniques. This initial work confirmed that just cleaning the unlined cast iron mains was not feasible as the newly cleaned surface could 'bleed' iron into the water leading to potentially high iron levels and possible water quality failures.

A detailed review of techniques and cost benefit analysis indicated the most cost effective solution was thin walled lining on Vyrnwy Lines 1 and 2 and use a combination of slip lining and pressure jetting on Line 3.

Trial area

UU had not previously used the thin walled folded liner technique at this diameter and a trial of the technique was undertaken to determine its suitability. A length of 1.35km of 980mm OD SDR 51 PE100 was installed into the existing 990mm (39") ID host main. A 5mm annulus was allowed to ensure complete unfolding of the liner.

The trial was divided into 2 (No.) pull lengths of 657m and 714m, with a total of 8 (No.) air valves (AV) and sluice valves (SV) being replaced. The liner was deformed by a specialist folding machine, the restraining bands were applied manually and the deformed liner was winched into position.

Winch forces up to 18 tonnes were experienced during the installation of the liner. The liner was reverted manually, at excavations, to allow the installation of specialist end restraint couplings. The remaining liner was reverted by internal water pressure, at approximately 2 bar.

Post lining, the main was inspected by both CCTV and 'Lightline'. This confirmed full reversion and any permanent deformation or 'flat spots' which were present from the folding process.

The die drawing process involves reducing the liner diameter by means of a reduction die to allow the liner to be pulled into the

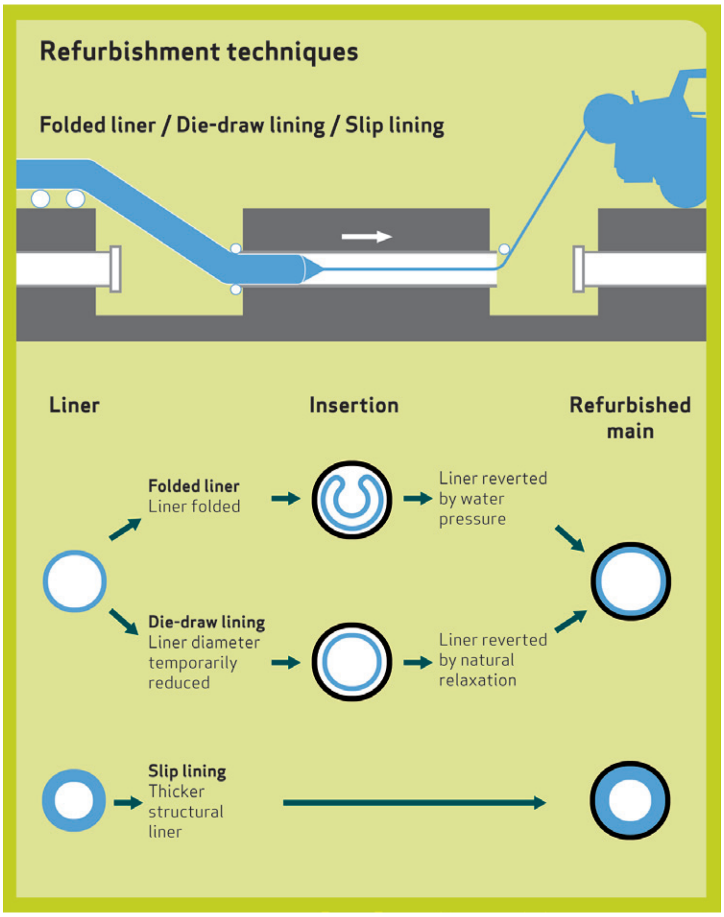


Figure 2: Refurbishment techniques utilised on the Vyrnwy LDTM
Courtesy of United Utilities

host main. As the liner is winched through the die and the diameter reduced the pipe length increases (the Poisson effect). The liner is winched through under constant tension to maintain the reduced diameter. On completion the tension is released; the Poisson effect reverses, the length reduces and the diameter increase to form an intimate fit with the host main.

North West Water (UU's predecessor organisation) jointly developed the die drawing technique with British Gas in the 1990s and UU had not used this technique, at this diameter, since then. Consequently, a second trial was undertaken at the same location, (on the parallel main), using the die drawing technique. This allowed UU to make a direct comparison of both techniques.

In this second trial a 1,030mm OD PE100 SDR 51 pipe was installed in 2 (No.) pulls, of the same lengths as the first trial, into the existing 990mm (39") ID host main.

The trials confirmed that both techniques were suitable for the Vyrnwy project and enabled the original design assumptions, such as scraping/pull lengths, winch forces, quantity of corrosion products to be removed etc. to be confirmed. They also provided robust comparative results between the two techniques which included costs, construction issues and potential risks.

Oswestry to Malpas

The Oswestry to Malpas section of the Vyrnwy was designed in two phases by UU Engineering and constructed by their Network Construction Partner, Balfour Beatty.

Both techniques which had been trialled were included in the specification. In both phases the die drawing technique had the lowest capital costs. Specialist sub-contracts were let for the lining installation. Various elements of the design and construction have contributed the success of the project as follows.

Liner design

Assuming an average internal diameter of 990mm for the host main, the liner was designed to create an intimate fit into the host pipe within 24hrs of installation. Utilising specialist software a 1,030mm OD SDR 51 PE100 pipe and a reduction die of 11% were chosen.

The software predicted a running diameter of 965mm within the host main, taking into account the die swell. This is an immediate increase in diameter of the liner pipe as it exits the die. Following discussions with industry experts and experience gained from the trials a maximum pull length of 800m was assumed.

Launch and reception excavations were located, where possible at existing air valve and sluice valve locations. This minimised the number of excavation locations and consequently reduced costs and disruption to landowners.

Launch excavations, typically 17 x 3 x 3m, required working areas of 180m long to allow for the formation of pipe strings. Individual pipes (13.5m long) were delivered to site and welded into approximately 80m strings ready for installation.

Scraping and proving

The internal corrosion products which had formed over time in the host main were removed from the host liner by means of a mechanical scraper. The main was then plunged to remove the dislodged debris. This process removed approximately 0.75m^3 of debris per 100m of main.

After scraping the host main was 'proven' using a flexible 'pig' manufactured from the same material as the liner. This was sized approximately 10mm larger than the calculated liner running diameter. Proving the main highlighted any potential restrictions, deviations in diameter/level, bends which could have increased the winch loads or fouled the liner.

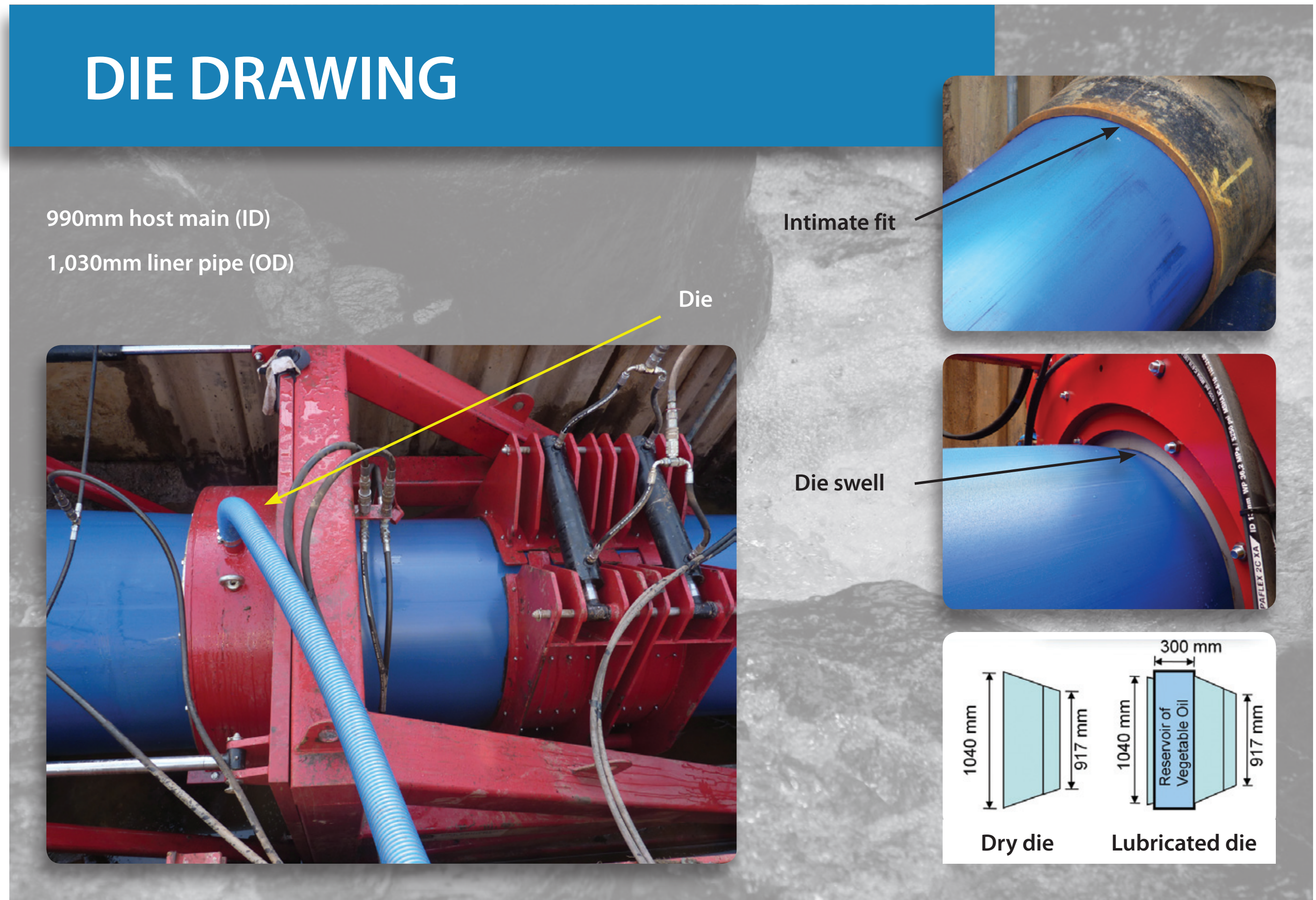
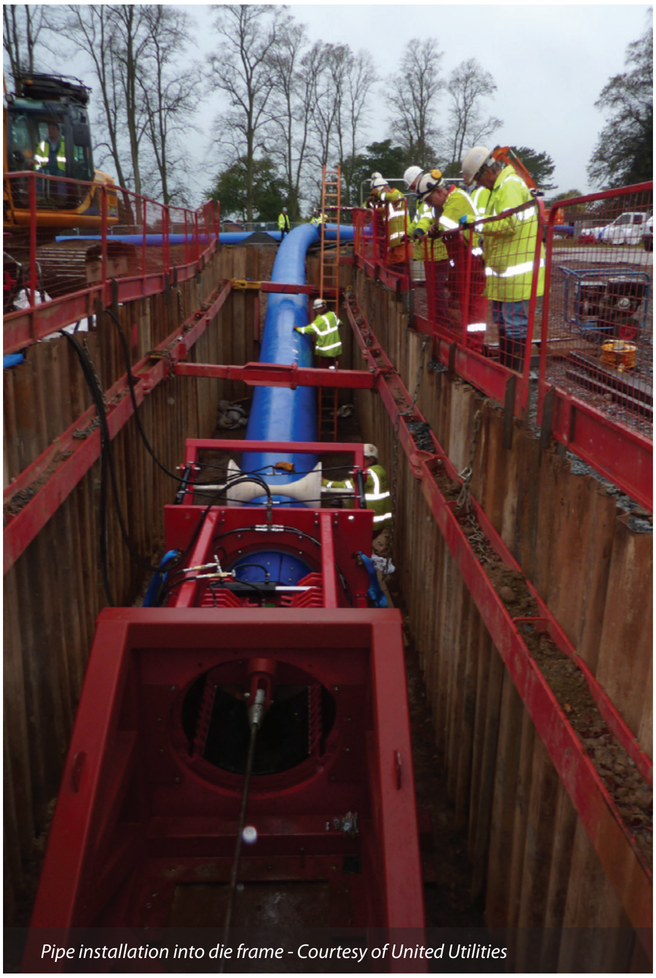


Figure 3: Die Drawing - Courtesy of United Utilities

Pipe installation into die frame - Courtesy of United Utilities



Pipe installation into die frame - Courtesy of United Utilities

Liner installation

A bespoke compact track mounted 100 tonne capstan winch and drop arm was designed and manufactured specifically for the project. The design allowed flexibility at each location as winching operations could be undertaken from various positions around the excavation. The winch also produced digital outputs of tonnages, speed, time and chainage for each pull. This information will be utilized to improve the specialist software used for die drawing.

The liner was inserted at a rate of 3-4m per minute with winch forces varying from 60 to 100 tonnes, depending on topography, pull length and ambient temperature. As each string was installed the pull was 'locked off', at both the die and the winch, to maintain longitudinal forces and prevent early reversion. This allowed the following string to be butt fusion welded on and form a continuous pipe string. The original horizontal and vertical cast iron bends were limited to a maximum of 10 degrees over a 1.8m length. The liner was successfully drawn through these bends with a subsequent increase in winch load. This increase was dependent on the position of the bend within the pull.

On completion of liner installation initial reversion was commenced. Using the pusher attachment on the die frame, liner was forced into the host main, which allowed initial reversion and more liner to be pulled along host main into the winch excavation.

As the liner becomes intimate with the host main reversion does not cease but slows down. Reversion may continue for many months and to prevent the liner creeping into the host specialist end restraint fittings were installed.

A new fitting was jointly developed by UU Engineering and Nova Siria for the project. This has proved very successful in use with a simple installation method and reduced fitting times. The piece up between the pull lengths generally occurred at the existing AV and SV locations. These were replaced with fusion bonded epoxy coated mild steel pipework and fittings. Man entry points, at AV's, were also included to facilitate future man entry inspections of the main.

Temporary works design

The temporary works were designed to pass the winch forces below both the host and adjacent pipes and into the surrounding ground. Considering the age of the mains, their strategic importance, material, and their proximity to each other, the capability of the existing cast iron host mains to resist any winch forces was ignored.

The forces were transferred from the winch into the 'drop arm' and subsequently into the reinforced concrete base slab and temporary works. This design was standardised for all excavations to ensure efficient and economic construction.

Tapered 'lead-in trenches' were added to the launch excavations and the angle of entry into the die was limited to 10 degrees to minimize the stress imposed on the liner.

Progress to date

The Vyrnwy LDTM passes through both urban and rural locations and the project team has had to manage numerous issues such as badgers, great crested newts (GCN), excavations adjacent to a primary school, road and footpath closures, sites of special scientific interest and many more. Work is currently on-going and 52km of lining is programmed to be complete by March 2015. Approximately 32km of liner has been installed. By the end of the contract 18km of haul road, 24km of GCN fencing, 38km of stock fencing and 3,700 individual pipes will have been utilized on the project.

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