The North American Society (NASTT) and the
International Society for Trenchless Technology (ISTT)
International No-Dig Show 2009

Toronto, Ontario Canada
March 29 – April 3, 2009

Paper # C-5-04

AQUALINER – A NEW PROCESS FOR THE LINING OF WATER AND SEWER PIPES

Gerry Boyce[1], Dr. Kevin Lindsey[1], Julian Britton[2], and Simon Baylis[3]

[1] Aqualiner Ltd, Unit 10, Charnwood Business Park, Loughborough, UK
[2] Wessex Engineering and Construction Services Ltd., Wessex Water, Kingston Seymour Somerset, UK
[3] OnSite Ltd., Unit 14, W&G Estate, Wantage, Oxfordshire, UK

ABSTRACT: Aqualiner Limited is commercialising a patented process for a novel trenchless pipelining technology for the water and sewerage markets. The process was developed by a consortium consisting of:

Severn Trent Water Ltd.
Anglian Water Ltd.
Yorkshire Water Ltd.
NCC Construction Danmark A/S
EPL Composite Solutions Ltd.

Aqualiner has refined the technique further with the help of Wessex Water and its contractor partner OnSite. During this period of commercialisation the process has extended beyond laboratory based trials into field trials on existing pipeline infrastructure with Wessex and other regional Water Companies within the UK.

The self contained Aqualiner equipment lines the water or sewer pipe with a thin, but extremely strong thermoplastic polymer composite. This process has world-wide applicability with licensees in Asia, Africa and Europe, with advanced discussions in Australasia and the US. Product evaluations are underway with a number of approval agencies.

The process itself is similar to many existing technologies, but the absence of liquid resins and their mixing gives many advantages. The key benefits over existing methods are:

- Simple - no complicated storing and mixing of chemicals.
- Long shelf life – with no liquid resins there are no shelf life concerns.
- Potable (no harmful chemicals to leach out of the liner).
- High strength (a structural liner that can withstand water pressures to 16 bar).
- Thinner liner –a smooth inner surface which can aid water flow.
- Sustainability – liners can be recycled upon exceeding lifespan.
- Low socio-economic costs – low energy consumption and short lining times.

1. INTRODUCTION

Aqualiner Ltd. was set up at the beginning of 2007 to deliver a unique pipe lining technology for the water and sewerage industries. Although new, the company can fall back on the collective experience and strength of a number of the United Kingdom (UK) water companies along with UK and worldwide contractors. The Aqualiner process was born out of initial discussions with the UK water companies who steered the initial specification and the development of the process. The original consortium was:

Severn Trent Water Ltd.
Anglian Water Ltd.
Yorkshire Water Ltd.
NCC Construction Danmark A/S
EPL Composite Solutions Ltd.

Severn Trent Water, Anglian Water and Yorkshire Water are three of the major water and sewerage companies in the UK. Both Anglian Water and Yorkshire water are of similar size each providing water and sewerage facilities to approximately 2.6 million properties. Geographically Anglian and Yorkshire cover the eastern and north eastern regions of England. Severn Trent Water covers the central region of England and has approximately 3.7 million properties to service. These three water companies cover approximately 50% of the English consumers, and they provide the market pull and product specifications that Aqualiner needs to meet. NCC Danmark A/S is part of a major Swedish Construction and rehabilitation company NCC-Group which has a group turnover of approximately US$7 Billion. NCC Danmark carries out pipe rehabilitation and replacement across Scandanavia. NCC Danmark provided Aqualiner with pipe rehabilitation contractor requirements. EPL Composite Solutions are the technology providers. Using their product development knowledge and their experience of the materials used in the Aqualiner process they provide the final technology solution to Aqualiner. Aqualiner is fortunate in having this very strong consortium of end users, contractors and technology providers to steer the product development

In addition to working with the original consortium companies, recently Aqualiner has also carried out trial installations with Wessex Water and OnSite. Wessex Water is one of the major water and sewerage companies covering the South West of England. OnSite are a UK based pipe rehabilitation contractor and are a part of South Staffordshire Plc.

Many of the techniques used in the Aqualiner process will be familiar to pipe lining practitioners. The next section identifies how Aqualiner compares to existing technologies.

2. COMPARISON OF CURED IN PLACE PIPE LINING AND AQUALINER

Cured-in-place pipe (CIPP) lining has been the mainstay of pipe lining techniques for the last 30 years. The technologies have proved to be successful across a large range of applications. The underlying CIPP techniques are essentially the same technology. Typical, CIPP lining requires the use of a dry fibreglass fabric or felt tube that is impregnated with a liquid resin. This resin impregnation process usually takes additional time, but there are also limitations for the shelf life of the resin impregnated materials – often just a few hours.

The Aqualiner process does not use a liquid resin which means that there is effectively infinite shelf life for the material. Thermoplastic fibres are an integral part of the Aqualiner material. The material that arrives on site for installation contains both glass fibres (for stiffness and strength) and thermoplastic polymer fibres (which, after processing, becomes the matrix that surrounds the reinforcing fibres).

3. THERMOPLASTIC MATERIALS

Typical CIPP systems use a thermoset resin such as polyester, vinylester or epoxy. Thermoset materials are characterised as materials that permanently change their state. Liquid resins undergo a polymerisation reaction that changes the resin into a solid material (commonly called the cure). Once the resin is cured, heating will not melt the material again.

With thermoplastics, unlike thermosets, heating will cause the material to melt and cooling the material causes it to solidify. This is a reversible process and can be repeated.

The material used in the Aqualiner process is a mixture of polypropylene (PP) fibres and glass fibres that are intimately mixed or co-mingled (see Figure 1). When heated, the PP fibres melt and flow around the glass fibres to form the finished composite. These bundles of fibres can then be woven into a fabric. To form the liner, this fabric is folded and stitched to form a tube (known as a sock). The thermoplastic composite sock is made up of up to 3 layers of fabric formed inside each other. Outside of these composite socks is a protective plastic tube (usually polyethylene, 140µm thick). This tube protects the material from dirt ingress during storage and installation.

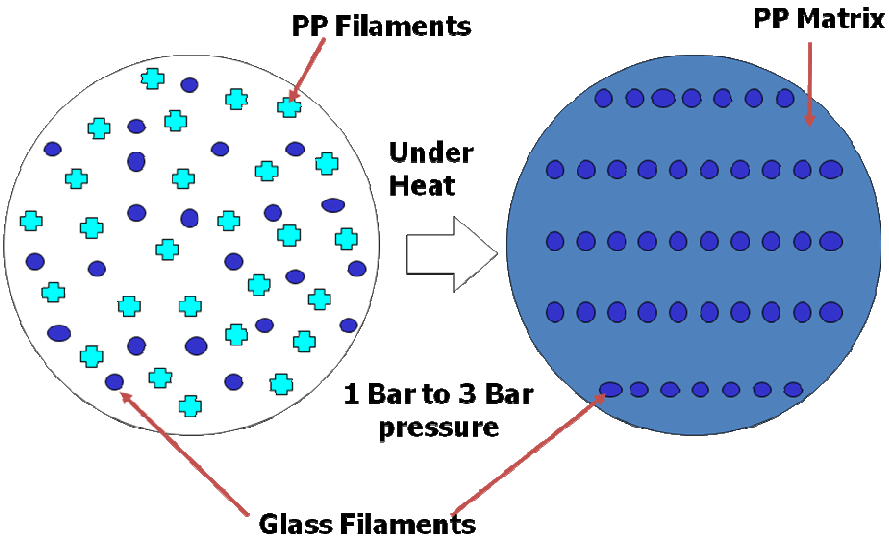

Figure 1. Construction of a bundle of fibres

4. THE AQUALINER PROCESS AND EQUIPMENT

Aqualiner has developed customised equipment that ensures the manufacture of high quality pipe linings. A schematic of the process is shown in Figure 2. The essential elements of the process are:

1. Heating pig – heats the composite material using hot air.
2. Temperature controller – controls the heating pig air exit temperature
3. Compressor – for heating air and pressurising inversion drum
4. Generator – provides electrical power for the heaters
5. Thermoplastic composite sock
6. Inversion drum to pay out inversion bag
7. Inversion bag – used to push heating pig along the pipe and consolidate the material
8. Umbilical connects the air, power and temperature sensors to the heating pig

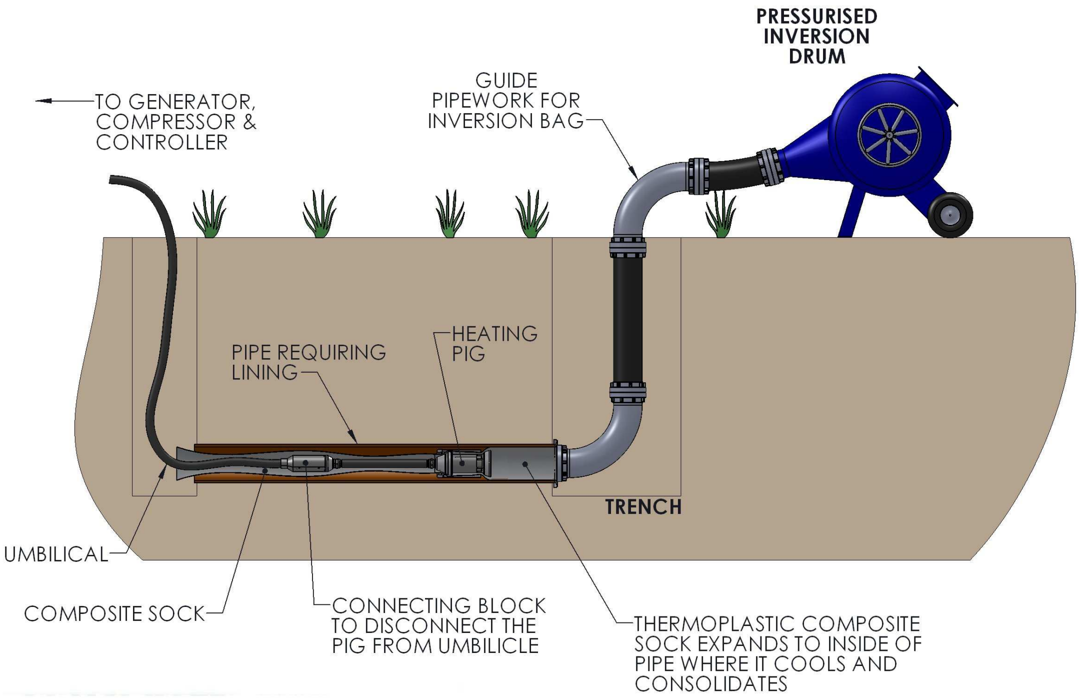

Figure 2. – Schematic of the Aqualiner process

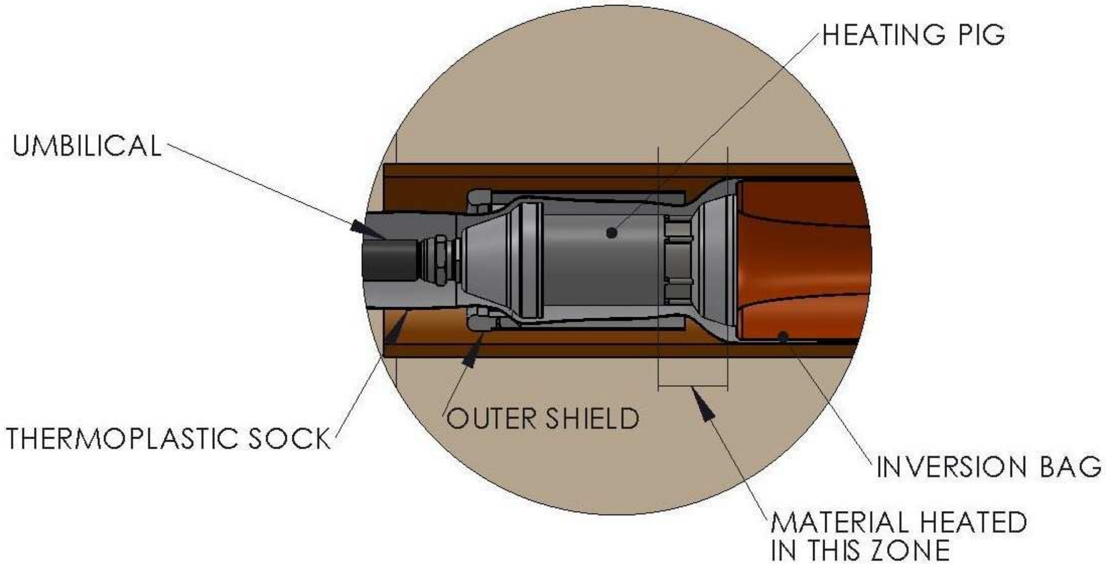

Figure 3. – Detail of Heating Pig Inside the Composite Sock

The process steps can be summarised – refer to Figure 2

- Pipes are prepared for lining with a closed circuit television (CCTV) inspection, followed by cleaning and, for example, root removal when required.
- The thermoplastic composite material sock is winched into the pipe to be lined.
- The umbilical that contains the air and the power for the heating pig is then pulled through the composite sock in the pipe.
- The heating pig can then be attached to the umbilical. The thermoplastic fabric sock, see Figure 3, is then fed between the heating pig and the outer shield.
- An inversion bag (similar to a CIPP calibration bag) is entered into the pipe (See Figure 3) under pressure to seal the pipe.
- Compressed air (7 bar, up to 200cfm) is fed down the umbilical to the heating pig where electrical heaters heat the air to 200℃, The heate d air exits the heating pig in the heating zone indicated in Figure 3. The heating pig is designed to force hot air through the composite sock. The majority of the air then exits the pipe between the sock and the host pipe with the remainder going down the inside of the sock. This exhaust air also pre-heats the material in the pipe to around 50℃
- The inversion drum (pressurised up to 3 bar) deploys the inversion bag at a controlled rate. As the inversion bag is allowed to extend under pressure it pushes the pig along the pipe. When the pig moves down the pipe (from right to left in Figure 2) the heating zone moves down the liner (Figure 3). As the molten material exits the pig (on the right hand side in Figure 3), the inversion bag squashes the material together to form the finished liner. The residual heat in the material is then transferred to the host pipe.
- When the pig has traversed the pipe, the pressure in the inversion bag is maintained for 10 minutes whilst the last section of the pipe to be lined has cooled. (Note: the previous sections of the pipe have already cooled). The pipe is ready to be surveyed and put back into service.

The Aqualiner process is generally unaffected by the lining environment. The pipe temperature or material do not affect the heating of the material, since this is carried out between the heating pig and the outer shield. Successful application trials have also been carried out when there is water flowing in the pipe being lined through lateral pipe connections. The thermoplastic composite also flows into any connections in the pipe causing an indentation in the pipe wall. This allows easy identification for later opening of the laterals using standard robotic cutting techniques.

The control system (see Figure 4) is relatively compact and can be installed in a trailer or small truck. The control system comprises two parts;

the box on the left in Figure 4 is the air conditioning and control system. Air from the compressor passes through standard coalescing filters to remove the majority of the oil and water vapour. Also the pressure of the air is controlled here using a manual control valve and the air flow rate is measure using an electronic flow transducer.

The box on the right in Figure 4 contains the heater power control. The heating pig contains four heaters split across three electrical phases. Three of the heaters have simple on/off control. Controlling the power to the remaining heater allows the fine temperature control of the air to be achieved, typically ±2°C from the set point. Air o utlet and inlet temperatures are recorded on the control and data acquisition software for later analysis if required. The installed heating power varies between 10kW and 18kW depending upon the size of the heating pig employed. The system complies with applicable EU safety and use regulations.

Figure 4 – Control System Assembled in the Workshop

Although a relatively common item in the lining industry, the inversion drum has been modified by Aqualiner to work at higher pressures (up to 3 bar). Also, these inversion drums have an updated control interface to ensure that the inversion drum bag inverts through the pipe at the correct rate.

5. TRIALS AND TESTING

Extensive workshop and laboratory trials have been carried out on the materials and processes. Workshop trials have been performed in 200mm, 225mm and 250mm diameter pipes and on a range of pipe materials. The workshop testing has been used to define the operating parameters of the process. These process conditions are then input into the logic in the control system. A number of trials have been carried out on existing infrastructure in the UK. These trials have been tested on 225mm diameter unreinforced concrete pipes and 225mm diameter vitrified clay pipes. Throughout these trials in the Wessex Water region and other UK regions, Aqualiner has used contractor partner OnSite. OnSite have worked with Wessex Water and a number of other UK water companies on pipe relining for a number of years and they have considerable experience of developing pipelining technology. This makes them preferred partners for this initial type of trials. OnSite were able to carry out the installations successfully with minimal training from Aqualiner. Lessons learned from these early trials with Wessex Water and OnSite have steered the process development to provide a user friendly and robust lining process that can withstand the rigours of field use.

Areas of particular interest have been the ease of set up. In the absence of impregnation of the fibre materials with resin, initial set up is very easy. Most system set up can be completed without the heating pig being inside the manhole or trench. Initial underground trials of up to 35m in length have been successfully achieved. There is, in principal, no limit on the length of the lining that can be accomplished, since the material is heated while moving along the length of the pipe. Also, initial developments have concentrated on the pipe sizes 200mm to 250mm diameter This range will be extended to include sizes 150mm to 300mm diameter, and developments are underway to extend to larger diameters to allow the lining of water transmission mains. One of the major benefits of the use of thermoplastics is that they can be reheated and reformed. This forms the basis of a range of interesting joining systems using welding. This also means that internal joints can be easily formed by thermally joining (welding) different pipes together, either during the lining process itself, or, if required, by additional joints by using electrofusion. Mechanical properties of trial samples have been measured.

The Aqualiner process has been designed to meet the requirements of BS EN 13566-4:2002(1), and full testing to meet this standard is underway. The Flexural Modulus of Elasticity of up to 13,000Nm^{-2} (to ISO 178(2)) is typical, depending upon the materials used. Aqualiner currently has two main material types, one for gravity pipelines and another for water and pressure pipelines.

Approval for potable water is also underway. In the UK, Aqualiner needs to meet the requirements laid out in The Drinking water Inspectorate (DWI) Regulation 31(3). Regulation 31 defines the materials that are allowed for potable water contact and it also defines the approved installation method. . For the United States (US) Aqualiner is undergoing testing to ensure compliance with NSF/ANSI 61-2008(4).

6. ENVIRONMENTAL IMPACT

One area that is gaining attention from the water companies is to recognise the environmental impact of different lining systems. The UK government requires water companies to consider the socio – economic cost when assessing each job site. The Aqualiner lining process has a low overall energy burden lending to a very low environmental impact. Also, the short set up and break down times reduces the effects on these socio-economic costs.

7. SUMMARY.

Aqualiner is a new lining system applicable to both water and sewer applications. The main difference between the current CIPP technologies is the Aqualiner system uses thermoplastic composites rather than thermosetting resins. Below are the leading benefits:

- Simple - no complicated storing and mixing of chemicals.
- Long shelf life – with no liquid resins there are no shelf life concerns.
- Potable (no harmful chemicals to leach out of the liner).
- High strength (a structural liner that can withstand water pressures to 16 bar).
- Thinner liner –a smooth inner surface which can aid water flow.
- Sustainability – liners can be recycled upon exceeding lifespan.
- Low socio-economic costs – low energy consumption and short lining times.

REFERENCES

1. BS EN 13566-4:2002 Plastics piping systems for underground non-pressure drainage and sewerage networks – Part 4: Lining with cured in place pipes. British Standards Institution December 2002.

2. ISO 178 Plastics – Determination of flexural properties International Standards organisation 2001

3. Regulation 31 of the Water Supply (Water Quality) Regulations 2001 in Wales, Regulation 27 of the Water Supply (Water Quality)(Scotland) Regulations 2001, and Regulation 30 of the Water Supply (Water Quality) Regulations (Northern Ireland) 2007

4. NSF/ANSI 61-2008 Drinking Water System Components - Health Effects 27th Edition NSF International 19-Dec-2008