Advancement of condition assessment techniques for large diameter pipelines

Condition assessment of ageing pipelines is a continual challenge in South Africa and around the world. Owners of large diameter water and wastewater pipelines face particular difficulties due to several factors, including severe skills shortages, and financial, environmental, demand and access restrictions. While desktop studies can identify pipelines with a high likelihood and consequence of failure, actual condition assessment data has traditionally been difficult to collect, especially in pressurised pipeline systems. This information is particularly important when estimating the remaining useful life of a pipeline, or when considering repair or replacement programmes. A toolbox approach is required for the variety of pipeline materials and conditions encountered. Regardless of the technique used, collecting the information is critical to making informed decisions regarding any pipeline. Rather than embarking on conservative and expensive replacement projects, inspection programmes enable significant cost savings through targeted repairs and rehabilitation.

INTRODUCTION AND BACKGROUND

Recently, the SAICE Infrastructure Report Card for South Africa 2011 (SAICE 2011) highlighted the dire condition of bulk water and sanitation infrastructure in South Africa, and identified key challenges facing the industry. The Department of Water Affairs (DWA) estimated that an annual re-investment of at least R1.4 billion is required to maintain current infrastructure in South Africa. Internationally, the situation with regard to bulk water and sanitation infrastructure is very similar. In 2005 the American Society of Civil Engineers’ Report Card for America’s Infrastructure gave water and sanitation systems a D-rating (ASCE 2005). The need to develop a system of sustainable infrastructure and spend billions of dollars on infrastructure over the next 20 years has also been identified and documented (USEPA 2005 & AWWA 2001).

In the face of this ever growing challenge, it is critical that water utilities spend their funds wisely on maintaining their bulk conveyance systems by identifying specific sections of pipeline in need of rehabilitation or replacement instead of replacing entire pipelines based on decision-making criteria such as recent failures, age, material, and risk and consequence of non-supply. To effectively manage buried infrastructure, accurate and effective techniques and technologies must be applied to assess the condition of the assets and gather information to make the best engineering decisions possible.

This article will focus on the toolbox of technologies currently available (or in advanced stages of development) to accurately assess the condition of pressurised bulk conveyance pipelines. It will further highlight the ability of most of these technologies to inspect pipelines while in service, thereby avoiding the risk and cost of exposing or de-commissioning the pipelines.
EFFECTIVE MANAGEMENT OF BURIED INFRASTRUCTURE

Buried infrastructure has a limited life span. It has been documented that the service life of a pipe is often shorter than the design life that was originally anticipated. In addition, not all pipes installed in the same year will fail in the same year (Livingston 2008). The service life of a pipeline is affected by corrosion (both internally and externally), manufacturing processes and material, poor installation practices, third party damage, as well as intentional or unintentional operational impacts during the lifetime of the system (i.e. uncontrolled drainage and recharge, transient pressure surges, etc). Large diameter pipelines will fail when the pipe cannot withstand the applied internal and external forces anymore. However, the failure mechanism of large diameter pipelines is multi-faceted and complex to accurately predict. While catastrophic failures of large diameter pipelines are quite rare, the cost and risk of reactively repairing a large diameter pipeline failure could be significantly higher than pro-actively assessing and refurbishing or replacing affected pipe sections. This is an important consideration in deciding whether to pro-actively inspect, rehabilitate or replace a pipeline (Gaewski 2007).

In order to prevent such catastrophic failures and ensure the long-term viability and affordability of water transport, advanced risk management strategies should be considered (Baird 2011). There are now various levels of decision-making processes that are being used by utilities to minimise their operational risk, while also optimising the investment of their expenditure on repairs to preserve or even enhance the asset value of their pipeline infrastructure. The development of a pipe risk management strategy is a critical step in effectively managing major assets. The basic steps include:

- Implementing comprehensive inspection programmes to accurately assess the condition of pipelines using appropriate technologies.
- Conducting an engineering evaluation to identify and prioritise pipe sections in need of repair or replacement.
- Implementing monitoring programmes to track the active deterioration of assets.
- Developing risk management plans for the entire network to pro-actively allocate funds to where they are most needed.

Knowing the condition of existing pipeline assets forms the basis of a sound risk management strategy. Tools and technologies available to assess the condition of pipelines are constantly evolving. Selecting the most appropriate technology is determined by the level of accuracy and pipeline coverage required. This, in turn, is guided by the risk profile of the asset and the risk tolerance of the service authority, as well as availability of funding. A toolbox of advanced inspection technologies which can be applied, is described below.

CONDITION ASSESSMENT TECHNIQUES FOR LARGE DIAMETER PIPELINES

A holistic and multi-disciplinary toolbox approach is required to ensure that relevant and appropriate information is gathered to enable an accurate assessment of a pipeline’s condition. Different pipe materials and the type, level and accuracy of information required, will determine the type of survey methods and techniques used.

Tethered leak detection and CCTV inspection

Tethered inline leak location is a non-destructive and non-intrusive condition assessment technology that pinpoints the location, and estimates the magnitude of leaks and air pockets in bulk water pipelines of all material types with a diameter of at least 300 mm. With over 1 600 km of inspections, this technology has proved sensitive to leaks as small as 0.02 litres per minute. Leaks are located in real time and their surface locations marked to an accuracy of less than 1 m. As illustrated in Figure 1, the system is inserted into a live pipeline through any tap of 50 mm or more in diameter. Carried by the flow of water, the tethered sensor head can then travel through the pipe for distances up to 2 000 m.
per survey. The position of the leak is located and marked on the surface in real time, facilitating subsequent repairs.

The latest development of the Sahara® system incorporates the ability to perform simultaneous acoustic leak detection and live Closed Circuit Television (CCTV) inspection on potable water mains. It is now possible to pinpoint the location of leaks while at the same time inspecting the internal condition of the pipeline using a combined acoustic hydrophone with integrated CCTV camera. The system uses the same Sahara insertion platform and is capable of being inserted into live pipelines (Figure 2).

Untethered free-swimming leak detection

Recognising the value of acoustic leak detection technology, yet realising some of the limitations associated with having a tethered system, an untethered, free-swimming acoustic monitoring device called SmartBall® was developed.

The free-swimming device consists of a foam ball containing an aluminium sphere with sensitive acoustic instruments (Figure 3). It is inserted into and extracted from a pipeline under live operating conditions through pig-launching facilities in oil and gas pipelines or through 100 mm diameter flanged openings fitted with a valve (Figure 4) in water and wastewater applications.

The SmartBall technology was originally developed and successfully implemented for the water industry, and has now been refined for use in oil and gas pipelines larger than 100 mm in diameter. SmartBall has been proved capable of detecting leaks in liquid lines of less than 0.4 litres per minute, and development work is continuing to reduce the detection threshold still further.

Electromagnetic inspection and long-term monitoring of pre-stressed concrete pipelines

Electromagnetic or Remote Field Eddy Current/Transformer Coupling (RFEC/TC) inspection enables the detection of the actual numbers and locations of broken wires in an individual section of pre-stressed concrete pipe (PCP) at the time of inspection. Since becoming commercially available in 1997, RFTC/EC has become the industry standard in assessing the condition of PCP. This baseline is the most comprehensive piece of information available to an operator in trying to assess the condition of a pipeline.

The number of broken wires alone is, however, not the only indicator of the probability of failure. A failure model for PCP has been developed (Mergelas 2001). The model is based on the combined strength of the concrete and steel liner, takes into consideration partial loss of pre-stress in the windings, and may be used to predict the failure pressure of a pipe section with a given number of wire breaks. Depending on the operating pressure (including surge pressure) that the pipe may be subjected to, individual pipe sections can be prioritised for repair or replacement.
Inspections were initially performed under drained or partially drained (de-pressurised) conditions requiring the pipelines to be decommissioned. The inability of utilities to decommission their pipelines due to demand, risk or practical considerations, however, led to the development of a free-swimming inspection platform called PipeDiver.23

PipeDiver

The PipeDiver system has been specifically designed for use in PCP pipelines that are live or cannot be taken out of service due to a lack of redundancy or operational constraints. PipeDiver is an innovative free-swimming tool that consists of a battery module, Remote Field Transformer Coupling (RFTC) module and a tracking module. The system is neutrally buoyant and has flexible fins that are used to centre the tool within the pipe and provide propulsion. Its flexible design ensures that PipeDiver can navigate butterfly valves and bends in the pipeline, while travelling long distances (Figure 5). Data is recorded and interpreted by an experienced analyst to pinpoint and quantify locations of distress. Compared to alternative methods of condition assessment, the PipeDiver solution offers significant cost savings, as the pipeline remains in service, eliminating the need for dewatering and service shutdown.

The outcome of an inspection will provide a ‘snapshot’ of the condition of the pipeline. With the baseline condition known, the next step is to continuously monitor the pipeline to track whether it is actively deteriorating.

Acoustic fibre-optic monitoring

Acoustic monitoring has been used since 1997 and is a proven technology for monitoring the condition of PCP. The major advantage of acoustic monitoring over other methods is the availability of real-time information on the deterioration rate of the pipe. Acoustic Fibre-Optic (AFO) systems enable cost-effective monitoring of long lengths of pipeline. The AFO
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The successful candidate will have had experience with the design and construction of urban and rural roads and / or railway infrastructure development.

The successful candidate will interface with clients, submit relevant reports; keep updated with latest engineering software and maintain all quality and ISO standards. The role may involve some regional travel.

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Only short listed candidates will be contacted.

The HR Manager, Mokolwane House, Plot 67978, Fairgrounds Office Park, Private Bag 00235, Gaborone, Botswana Email: consult@bergstan.co.bw

Acoustic pipe wall assessment

Acoustic pipe wall assessment relies on the known relationship between the speed of sound in a pipe, and the thickness or stiffness of the pipe wall. This technique has been employed for several years using pairs of external sensors to calculate average wall thickness between hydrants or service connections on distribution network piping. Recent advancements now allow this technique to employ in-pipe acoustic sensors, such as Sahara or Smartball, to provide average wall thickness measurements over much shorter pipe distances, thereby enabling reporting to a higher level of accuracy on large diameter pipelines.

Inline electromagnetic testing

Inline electromagnetic testing of metallic mains has been commercially available for several decades, based on the Remote Field Eddy Current (RFEC) testing technique, also known as Remote Field Testing (RFT). The efficacy of this technique is well established. However, the high cost and stringent pipe access requirements have resulted in limited use. This is particularly true for large diameter pipelines where the requirement for a near full-diameter entry point is often not feasible.

With the development of the PipeDiver in-service inspection platform for PCP pipeline inspection, RFEC inspections can now also be performed on metallic mains while they remain in service. Initial laboratory testing of the PipeDiver RFEC concept has indicated good sensitivity to moderate levels of corrosion.

Magnetic flux leakage

Magnetic flux leakage (MFL) is the most accurate method of metallic pipeline inspection using advanced non-destructive
testing methods. In-line MFL is used to scan the full circumference and length of a pipeline at an extra-high resolution. MFL scans the pipe through linings to measure remaining wall thickness and provides depth and location of metal wall loss (Pure Technologies 2011).

High-powered magnets are used to temporarily magnetise ferrous pipelines. Sensors are positioned to record any deviation in the field. If the magnetic field is uniform, there are no flaws in the wall of the pipe. If internal or external flaws are present, such as pitting or corrosion, the magnetic field is distorted, and this distortion or ‘leakage’ can be measured by the sensors.

New developments in this technique mean that contact with the pipe wall is not a requirement to accurately detect flaws, allowing for cement mortar or epoxy-lined ferrous pipes to now be assessed with great accuracy.

Both shop tests and field trials (Figure 6) have been completed successfully with MFL inspection tools (Hannaford 2010). The inspections yielded very accurate results and confirmed that MFL is setting the new benchmark in the field of ferrous metal pipe wall assessment. MFL inspection tools have subsequently been developed for the commercial water pipeline market (Figure 7).

CONCLUSION
Condition assessment of ageing pipelines is a continual challenge in South Africa and around the world. The weighted average age of South African water infrastructure is 39 years. Existing infrastructure is therefore reaching the end of its original design life, while new infrastructure is continually being added to keep up with growth in demand and expansion. This is increasing the maintenance burden on Service Authorities. At the same time serious constraints regarding skills, funding for maintenance and procurement processes are hampering the effective management of infrastructure.

There is an urgent need for a more holistic approach to infrastructure management, considering life-cycle costing (including capital and operating/maintenance costs), instead of only capital expenditure as the most important performance indicator. In this regard, reliable, consistent and accurate data is crucial for maintenance planning, prioritisation and budgeting.

In the face of this ever growing challenge, it is critical that water utilities spend their funds wisely on maintaining their bulk conveyance systems by identifying specific sections of pipeline in need of rehabilitation or replacement, instead of replacing entire pipelines based on decision-making criteria like recent failures, age, material, and risk and consequence of non-supply. To effectively manage buried infrastructure, accurate and effective techniques and technologies must be applied to assess the condition of the assets and gather information to make the best engineering decisions possible.

A toolbox of advanced inspection technologies as described in this article has been developed to accurately assess pipeline infrastructure. Pipelines previously considered as candidates for replacement due to age and other risk factors can now be inspected with confidence. Assessment and repair initiatives can typically be performed at a fraction of the cost of a replacement programme.

NOTE
The list of references is available from the editor.