WHITE PAPER

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SmartBall Technology

A free-swimming multi-sensor tool for inspections of a multitude of pipeline types

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The industrial power generation and coal ash industries are enhancing pipeline safety by exploring technologies more commonly used in the water, oil and gas industries. High-Density Poly Ethelyn (HDPE) pipelines have helped to minimize pollution, being less prone to corrosion than metallic lines. However, very few options exist to assess HDPE pipeline integrity, especially leak identification.

Further compounding this challenge is the use of dual containment HDPE pipelines. Dual containment piping decreases the chance of pollution by offering an extra layer of protection against leaking. However, this double piping composition makes it difficult to assess, particularly when the inner pipe has been compromised. Relieving pressure on the outer pipe may indicate there is a leak but not the exact location. Xylem's SmartBall technology can be used to locate the point of a leak inside the inner line providing the outer line can be depressurized. Since 2005 this unique technology has been used across the municipal water industry to find leaks in pipelines and is now also addressing similar issues across the power generation, wastewater, oil and gas, and mining industries.

What is SmartBall and how does it work?

SmartBall is a free-swimming inspection platform that can be used to support good pipeline management by:

- Identifying and locating hidden leaks and gas pockets with high accuracy; with a lower leak threshold of 0.03 gallons per minute (gpm).
- Mapping the pipeline to confirm alignment
- Measuring the pressure along the pipeline to identify partial blockages and confirm pipeline elevations
- Identifying and locating potential undocumented features and pipe type changes
- Contributing current inspection data to engineering analysis used for capital planning

SmartBall is designed to be smaller in size than the pipeline it inspects. It is negatively buoyant, sitting along the bottom of the pipe and rolling with the product flow to detect leaks and gas pockets.

During a typical inspection SmartBall is inserted into a live pipeline collecting data as it flows through the line. It is highly accurate, 'listening' to every point along the line. The tool is then captured downstream and the data that has been collected is downloaded and inspected.

SmartBall evolution & track record:

SmartBall was first designed in 2005 for water utilities. In 2008 Xylem decided to explore other industries that could benefit from the innovative tool. Scaled up versions of the original 4-inch tool – 6, 8, 10 and 12 inch in size - where designed for oil pipelines. These larger versions of the original SmartBall feature enhanced battery life. While the original version can inspect for up to 24 hours the larger versions can inspect for as long as six days. A 22 hertz transmitter was also added to the larger versions so that the tool could be tracked with traditional Above Ground Markers (AGMs).

In 2016 Xylem launched another revamp featuring a new shell design. This three-piece banded design replaced the original clam shell shape making it more robust with no open ports. This version is explosion proof and features further enhanced battery; up to 15 days.

Since 2005, SmartBall has performed more than 1,000 inspections across 44,000 miles of pipelines, successfully identifying more than 3,800 leaks.

SmartBall features:

- Accelerometer: ascertains the movement of the SmartBall
- Magnetometer: identifies larger pieces of metal such as joints, bends and valves
- IMU sensor: helps to pinpoint the location of the SmartBall during analysis. This is also useful when mapping pipelines
- Pressure and temperature sensors can identify if there are issues with blockages or with insulation, for example
- 22 hertz transmitter allows the SmartBall to be externally tracked while within a pipeline
- Acoustic sensor which records the entire time SmartBall is in a pipeline

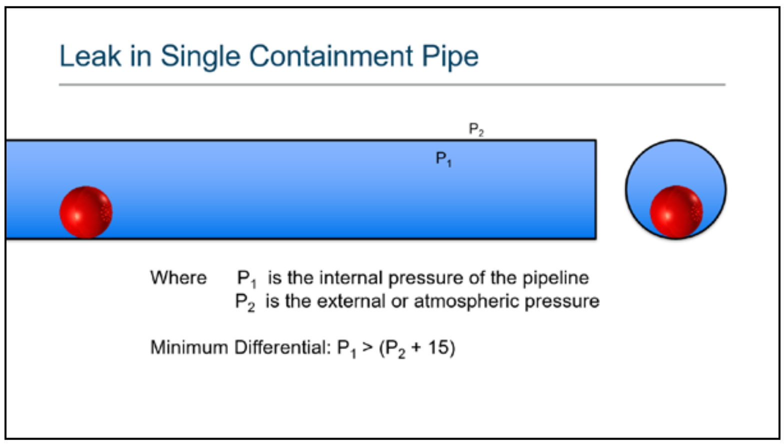
Leaks

Leaks result in loss of product and can have a significant effect regardless of product. This can be detrimental to the environment, to infrastructure and even human health and life. Therefore, identifying, locating and fixing leaks as soon as possible is critical to effective pipeline management.

How does SmartBall detect leaks using acoustics?

Leak in a single containment pipe

To detect a leak in a pipeline there must be a minimum differential in pressure of at least 15 pressure per square inch (PSI). The internal pressure of the pipeline (P1 in the image to the right) must be at least a 15 PSI greater than the external or atmospheric pressure (P2 in the image to the right). Municipal water pipelines are usually 50 PSI while in oil & gas pipelines its much higher.



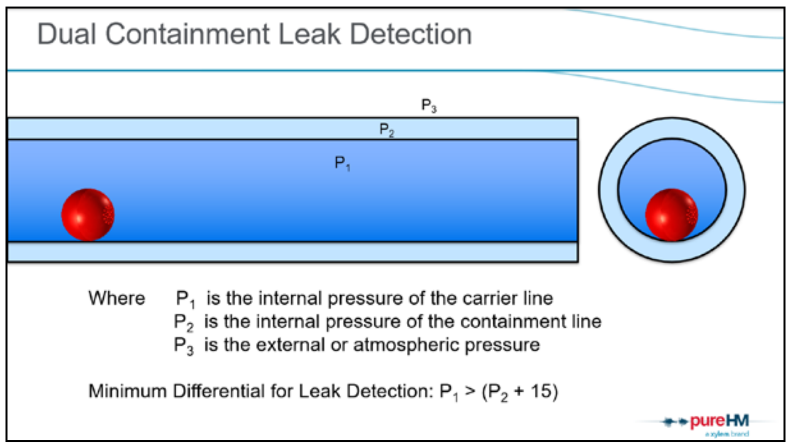
Taking a closer look at the pipe wall itself, imagine that a pinhole leak is present. P1 (internal pressure) still needs to be greater than P2 (external pressure) by a differential of 15 PSI. Let's imagine a scenario where P2 (external pressure) is 15 PSI and P1 (internal pressure) is 50 PSI. In this scenario, where there is a leak, water will move through the pipeline from a high pressure zone to one of low pressure or the path of least resistance, such as a hole or crack where there is a leak.

From an acoustic perspective the SmartBall detects the sound generated by the water moving through the small orifice as it moves towards the leak along with the water, or pipeline fluid. If we were to increase that pressure to 100 PSI, the velocity of the product would be increased through that orifice resulting in a louder hissing sound. Higher pressure generally means a louder and larger leak.

Dual Containment pipe:

Dual containment pipe is also known as secondary containment pipe, double containment or pipe in pipe. Essentially it consists of two pipes in one; a carrier pipe inside a larger secondary pipe with a gap in between so that if a leak occurs inside the carrier pipe the second pipe keeps it enclosed. There are pros and cons to dual containment pipe. The positive is having containment 'insurance' but there are negative aspects; it costs at least double that of doing leak detection in a single wall pipe. Some leak detection can be built into a pipeline but typically more identification is needed to locate the leak. While a fluid or pressure alarm will identify that there is a leak it won't know where it is located. Tools like correlators can be quite challenged with dual containment pipelines as they can't get to the pipe wall.

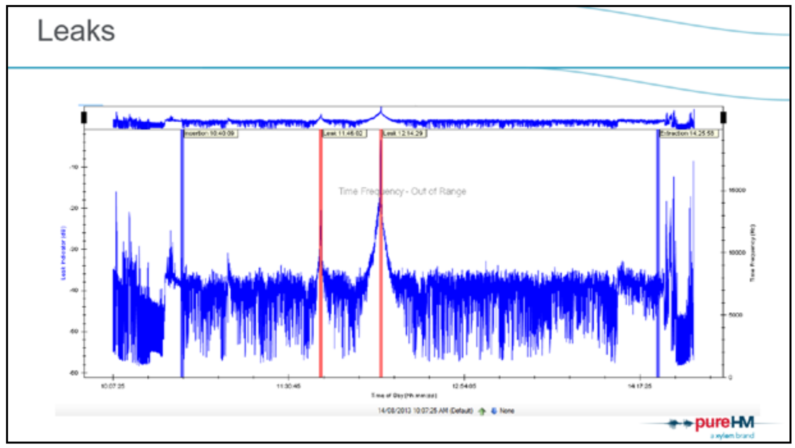
Dual Containment Leak Detection:



Looking at a similar example but in a dual containment pipe; P1 is the internal pressure of the carrier pipe, P2 is the internal pressure of the containment line or secondary pipe, P3 is the external or atmospheric pressure. To successfully detect a leak the pressure differential between P1 and P2 must be 15 PSI or greater. If there is a leak there would be an equalization of the pressures of P1 and P2. To perform acoustic leak, the product would need to be removed from that annularly space. By draining the annularly space between the inner and outer pipeline (which most of these dual pipelines have built-in), 15 PSI or greater can be achieved and a SmartBall inspection can take place.

Leak Analysis:

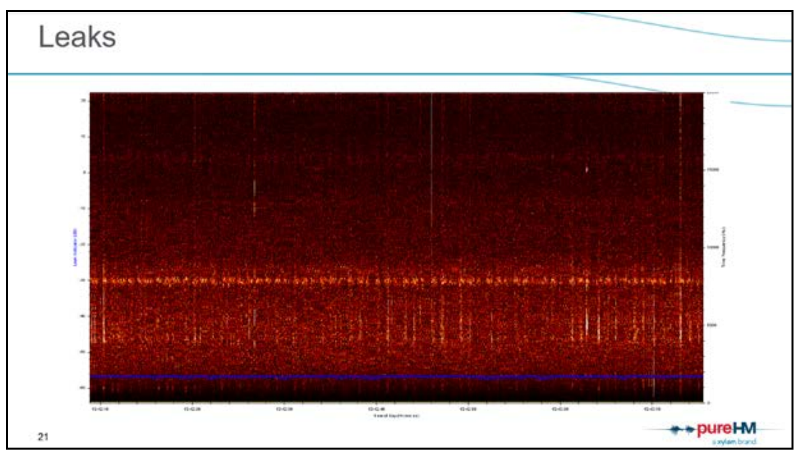
Once the inspection has been performed, the acoustic data that SmartBall has collected is converted into a 'Time Frequency Spectrum'. This allows the acoustics to be visualized (see image on the right) which aids in quicker analysis of the data. We also listen to the acoustics, but the process is a lot quicker if we visualize it first.

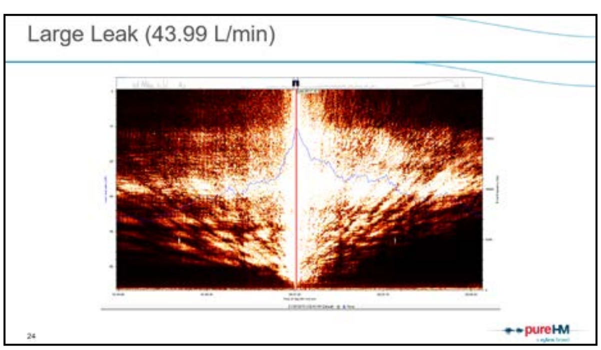


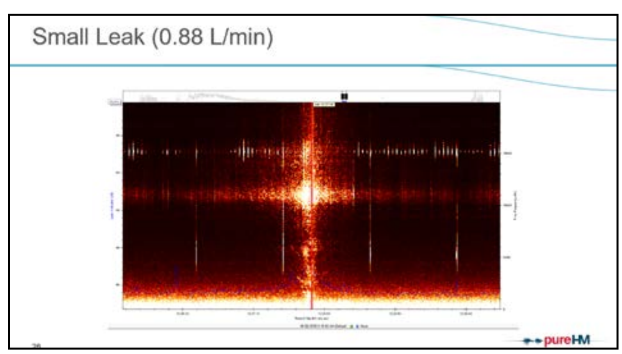
The blue line, or leak indicator, will provide a quick snapshot of acoustic activity. This image shows three hours of data collection with the peaks indicating leaks. If we zoom in we can see more detail in the time frequency graph.

The image on the right shows essentially a quiet location in the pipeline, a little background noise but a fairly quiet section in general. In the graph, black indicates silence increasing to red, orange, yellow and white with white being full saturation of that specific frequency.

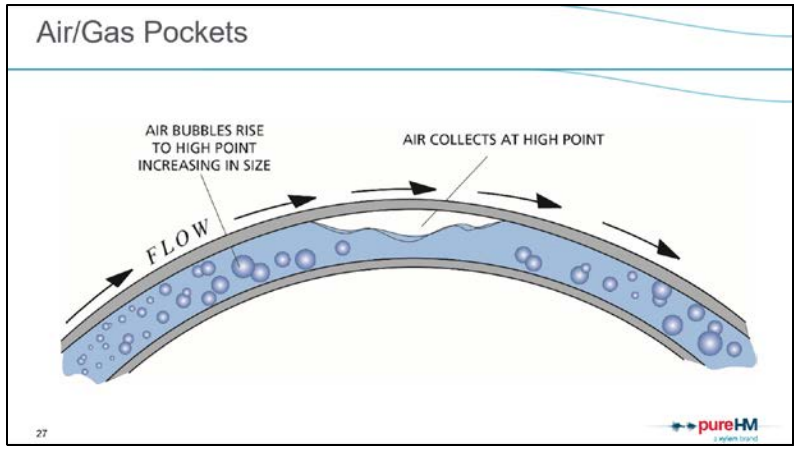
Where it is loudest or where the most acoustic energy is located, is where a leak has been detected.







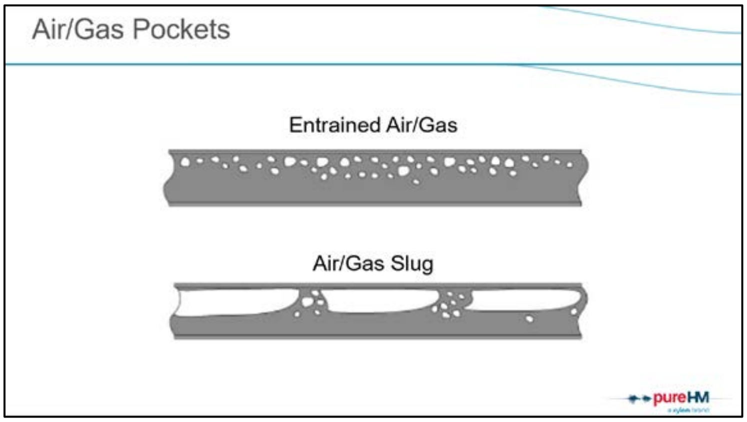
Air/Gas Pockets: what these are, how SmartBall detects them and why it's important to pay attention to them:

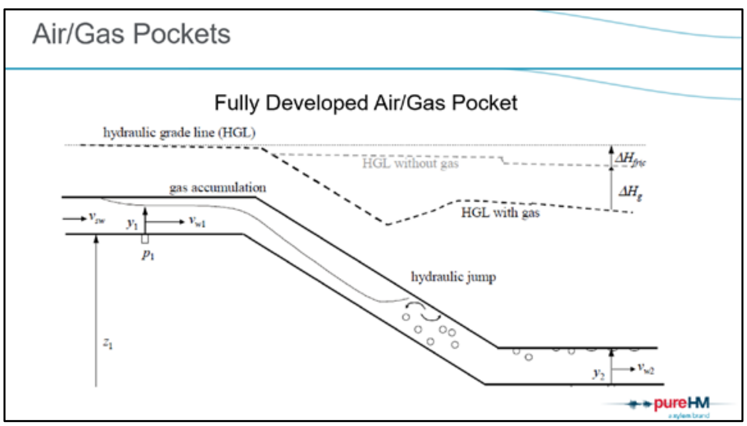


Air or gas pockets can collect at high points in a pipeline. Ideally these high points will have air or gas releases but if a pipeline release or valve is not working then air/gas pockets can collect. While many people are aware that leaks can be a serious issue, it's not commonly understood that air/gas pockets can also be challenging, causing significant damage to pipelines.

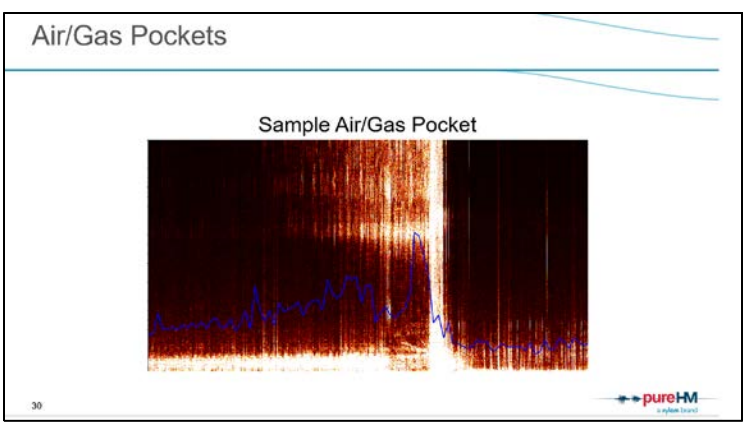
We classify them as:

1. **Entrained air/gas**: small, dynamic bubbles that will move down the pipeline. Typically, these are not much of a concern until they start to collect at isolated high points.
2. **Air/Gas slug**: larger bubbles that are also considered dynamic and will move with the flow of the pipeline. Again, these are not much of an issue until they develop into a gas pocket.
3. **Fully developed air/gas pocket:** Isolated pockets of collected air/gas that collect at high points in the line and are typically static in nature. These gas pockets can be detrimental to the pipeline for several reasons:
    a. Restriction/reduction in capacity of the line which affects the efficiency of the pipeline, meaning pumps must work harder than they would if there wasn't an obstruction in the line.
    b. In a metallic line a wet/dry cycle will begin to develop on the top side of the pipeline which causes corrosion of the pipeline.
    c. On the backside of where the air/gas pocket is located a 'hydraulic jump' can form. This is when the product or fluid moves quickly through the area where there is reduced diameter due to the gas pocket and once it leaves that it flashes back creating turbulence, particularly on the bottom side of the gas accumulation. If the product contains suspended solids, cavitation can begin on the bottom side of the pipeline where it scours or scrapes away at the bottom of the pipeline. Therefore, corrosion on the topside and scouring on the bottom side can cause failures on both areas of pipeline. Most people think leaks are the main issue, but air/gas pockets can also be challenging.



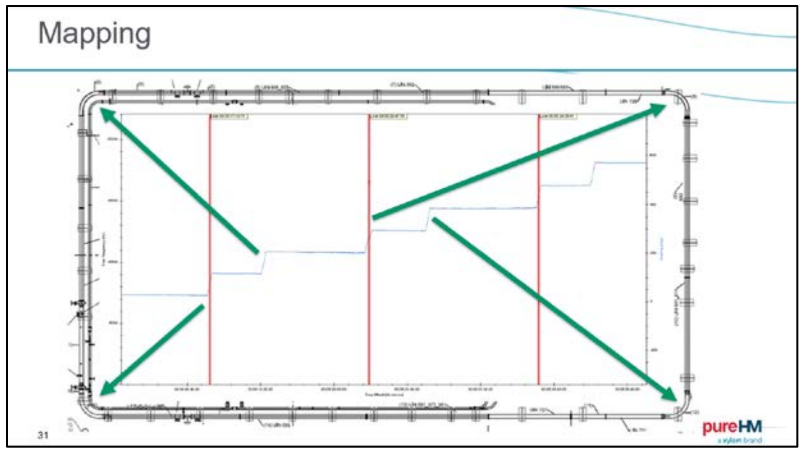


Visually air/gas pockets show up differently on the acoustic diagram:



Pipeline Mapping:

SmartBall can also be used to map pipelines since the introduction of the gyro/IMU.



The image on the right shows a test Xylem is doing with the pipeline research council International (PRCI) in Houston, Texas. This is their test loop, we ran SmartBall through the outer section where it loops continuously while also actively performing leak testing.

What we get is this blue data set that 'steps up' from left to right at regular intervals which corresponds to the four corners of the loop. The angle of the bends can be calculated based on the IMU output - in this case the bends are 90 degrees. We can also calculate the radius of the bend by looking at the time it takes to move through the bend. This is a simple example of what is possible with mapping. This is in the X Y space. When it comes to Z space and elevation, we rely on pressure readings.

Confirmation of containment:

Leak detection is not always about finding an active leak. There is value in performing a SmartBall inspection to confirm containment - to show internal/external stakeholders (clients or regulatory bodies) that a pipeline is contained and there are not any leaks. This may be necessary following a previous leak/spill to confirm that issues have been resolved, it could be a routine survey, or a pipeline in a High Consequence Area (HCA) where confirming containment of that line is important.

When it comes to pipeline integrity and inspections, there are tools that are good at identifying cracks, corrosion or wall thinning but they are not great at identifying when those defects are actually through the wall and the pipeline is leaking. SmartBall can be used to confirm if there is an actual leak in areas where a crack/corrosion or wall thinning has been identified.

SmartBall can also be used alongside other forms of continuous leak monitoring. Other leak detection systems can be good at identifying large bursts but are not as accurate at identifying smaller leaks. If you are getting alarms that are questionable from a mass balance / input / output calculation SmartBall can help to confirm whether that is due to a leak.

Water Main Condition Assessment Case study

Inspection on a municipal water line

SmartBall was deployed in a 48-inch PCCP water transmission main constructed in the 1970s. Five surface mounted acoustic sensors tracked the SmartBall over the 1.5 miles inspection. The SmartBall was inserted through a four-inch drain valve and extracted in a reservoir using an underwater ROV. Xylem detected one leak in a wooded area. The pipe was exposed and the leak was discovered within three feet of the reported location. Interestingly, crews tried to confirm the leak with a ground microphone but it was not detectable using this method.

Wastewater Force Main Case Study

A client experienced a failure on a relatively new (constructed in 2000) 20 and 24-inch Ductile Iron (DIP) force main. Xylem performed a SmartBall leak and gas pocket detection inspection identifying four suspected gas pockets. The inspection data was showing wall thinning on the top side – corrosion from a wet/dry cycle.

Visual inspection and ultrasonic thickness (UT) measurements were performed on exposed pipe sections where gas pockets were identified. Verification on exposed pipe determined it was failing due to internal corrosion which is a common mode of failure on DIP force mains.

Remaining Useful Life (RUL) calculations determined that failures may occur within the next two years where gas pockets were located and 15 to 30 years where there are no gas pockets. Xylem recommended that the client replace each pipe where a gas pocket was located within one year and rehabilitate the entire force main within 15 years.

Platform benefits:

- Multi-sensor tool that provides a variety of pipeline data.
- Able to identify small leaks undetectable using conventional systems.
- Can complete short or long surveys in a single deployment.
- Easy to deploy and track throughout survey.
- Able to assess difficult-to-pig and unpiggable lines.
- Lightweight platform for easy shipping and tool preparation.

Operating environment:

- **Pipe materials:** PCCP, RCP, AC, PVC, HDPE, Steel, Ductile Iron, Cast Iron, GRP, & other
- **Max pressure:** 2000 PSI
- **Min pressure:** 15 PSI
- **Pipeline diameters:** 4-inches and greater
- **Max flow velocity:** 6 feet/second (*Maximum flow for mapping 3 feet/second)
- **Min flow velocity:** 0.5 feet/second, minimum of 1.5 feet/second required to travel up vertical (*Ensure consistent flow rates for mapping)
- **Max deployment time:** 24 hours to 15 Days
- **Max fluid temperature:** 158° F (300F available upon request)

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