Case Study: Real-time leak prevention for Slurry, Oil and Gas pipe networks

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Abstract

As technology advances, mines are looking for more ways to harness emerging methods of increasing productivity, worker safety as well as reducing operating costs. Real-time monitoring of pipeline networks are one of the many best practices which are becoming increasingly popular as a means to preventing environmental and costly disasters for all pipeline network owners these ends. In order to lower monitoring costs and become proactive, it is crucial that the correct monitoring system as well as the appropriate system components are selected. While commissioning pipeline networks which integrate with the tools usually associated with monitoring pipelines and slurry networks, Fuller Industrial developed a proprietary solution which lowers implementation and ownership cost of steel pipe network infrastructure by adding leak detection technology to each spool and pipe they build. Through years of manufacturing rubber lined pipes and applying speciality coatings, Fuller Industrial was able to develop a simple detection concept through innovative calendaring of rubber and coating application. This paper will discuss some of the various challenges encountered and draws conclusions about the critical requirements that potential pipeline owners should be considering for their steel pipe networks.

Biographies

Pat Dubreuil MBA, CEMI R&D Director, Industry Topic Expert

With an MBA from Athabasca University and an Honours degree in Psychology and Business from the University of Ottawa, Pat Dubreuil represents, CEMI's Ultra Deep Mining Network, taking on mining and related industry challenges. Pat has held positions as Vice President of Business Development for BESTECH, the role of General Manager for Fuller Industrial and Director for Les 'Entreprises Boréal', where each role included responsibility for strategic business development, market segmentation and the coordination of sales teams and products. His skill set include the development and coordination of solution based programs/projects in the complexities of dealing with partnerships in industry, and the public sector. Mr. Dubreuil has been with the Centre for Excellence in Mining Innovations since 2014.

Seppo Haapamaki, P. Eng. CEMI R&D Director, Industry Topic Expert

Mr. Haapamaki has over thirty years of experience in the hard-rock underground mining industry in both engineering and operations. He graduated from Laurentian University in 1980 with a B. Eng. and has been employed in mining related positions in the Sudbury and Timmins area and as well in Northern Manitoba. During his work with Glencore Kidd Creek Mines, he received his Six Sigma Black Belt Leader certificate with the Juran Institute. Mr. Haapamaki has been with the Centre for Excellence in Mining Innovations since 2012.

Introduction:

The Problem — the use of steel pipes in resource extraction sector, including mining and oil and gas is very common. Their robustness, capacity and general longevity of service make them an ideal medium to carry several types of media. Fuller Industrial, a fabricator of rubber lined steel pipe and speciality coatings for the resource extraction sector, which include mining and oil and gas, understands the issues and risks associated with the installation and operation of steel pipe networks. The industry has implemented and continues to implement important pipe infrastructure across the globe. There are several critical networks that provide essential services to industry and citizens worldwide. The continuous operations of these steel pipe networks are essential for the economic wellbeing of our economy and for each network owner. There maintenance, protection and monitoring are essential in order to preserve their integrity

Having said this, it becomes imperative that these essential steel pipe networks be fitted with real time monitoring system that are capable of detecting media breach before they actually make it out into the environment and become an environmental concern or impose additional operational challenges to the industrial site they service. The business of replacing critical spools and sections of a steel pipe network on a pro-active basis are implicitly needed for any sizeable network. The costs associated with emergency spool or pipe replacement represent a large operational risk to industry which in turn is overshadowed by the larger steel spool and pipe failures which often have graver environmental consequences for the owner of the network.

Rubber linings, ceramics, plastic liners, hard facing all offer longer additional longevity to spool and steel pipe networks. Eventually all linings and or coatings wear and require replacement. The cost associated with plant downtime, in addition to potentially greater repercussions build a cost effective business case to find a solution that will both help with preventative maintenance and provide quicker response time to accidental damage to the steel pipe network.

In the oil and gas industry the best leak detection system available today is the public. According to the Dec 10, 2012 Leak Detection Study by the US

Department of Transportation. From Jan 2010 – July 2012 there were 766 Hazardous liquid pipeline leaks. With an average release volume of 10,771 gallons. The number one method of reporting a leak in a pipeline has been through the intervention of the general public. It has been estimated that 23% of leaks are notified by the public. (p3-29) Public confidence in overland pipelines are at an all-time low. Accidents like the 2014 March 12th, East Harlem apartment explosion in New York City, New York.

Several examples exist and showcase the need for pro-active rather than reactive systems.

> 'NTSB investigators noted that their testing determined there was natural gas in the soil nearby, indicating that a gas leak had went on for a while before the explosion'.[416] or
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> 'the 2014 20 inch Mid-Valley Pipeline Company who's pipeline failed in Hamilton County, Ohio on March 18, spilling at least 364 barrels of crude oil into the adjacent Oak Glen Nature Preserve. Animals in the area were affected'.[417][418].
>
> 'In Canada, On January 25, 2014, a fire broke out around 1:15 a.m. local time on the Canadian Mainline natural gas pipeline system near the community about 25 kilometres south of Winnipeg near St. Pierre-Jolys, Manitoba. Five homes were evacuated as a precaution after a natural gas pipeline explosion.'

There are several thousand examples of similar incidents of this nature for gas and oil piping networks. There are even more of these types of incidents inside industry such as mining which go unreported due to their containment and site specific impact.

Much has been done in the area of producing efficient, long lasting piping but the strategy for pipe or system failure has traditionally been a wait and see approach. You wait for the product to fail and then replace those sections through regular plant maintenance shutdowns or energy reactive repairs. When taking these approaches into consideration one realizes that there is room for improvement, one that builds a business case based on the cost of monitoring equipment and material, that is offset by monitoring and preventative maintenance in order to eliminate and reduce large interruptions in the process plants operations.

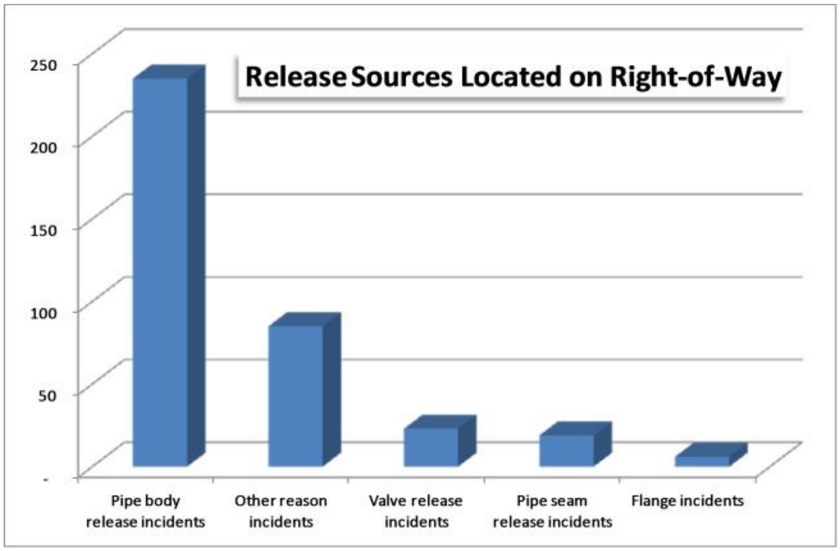
The predictability of the life of the pipe however can vary considerably, depending on the rate of flow, pressures exerted, the abrasiveness and corrosiveness of the material transported, and other external factors such as mechanical damage, installation shortcomings, etc... Any one of these can reduce the expected life of the pipe and prematurely induce failure. Normally, with a rupture or leak from a pipe, there are few fatalities directly resulting due to best practices being in place. However, the ensuing issue could cause high amount of environmental damage and escalate rehabilitation cost to levels that are insurmountable to the operation.

Introduction of new more resilient materials and coatings for piping have been very successful in increasing pipe durability. Nonetheless the issue of when and where a pipe will fail has not been addressed. Current event based methodology which evaluates small changes in energy and momentum are currently being used in industry. These approaches are suitable for use in gas, liquid and multiphase product lines. The typical RTU (remote terminal unit) installation plugged into a good SCADA Control system can be made to monitor pressure drops or changes in the rate of flow. All of these systems have front end communication systems which collect and transmit data from the RTU's and transfers them to ModBus or converts them to engineering units that can be fed into analytical algorithms which trigger alarms or processes based on human machine interface rules and exceptions. In the end, all of these represent reactive methods of determining the defect. Prevention or pro-active systems still eludes industry.

Mining process system leaks are general not formally tracked by that industry. Industry best practices such as rotation of pipes, replacement of bends after a certain number of hours, volume throughput, time in service are implemented in order to increase pipe life and longevity of the piping networks. Each of these represent some form of preventative maintenance or best practice and are meant to save costs or reduce potential liability over a period of time.

In a recent study performed by the U.S. Department of Transportation Pipeline and Hazardous Materials Safety Administration, report #DTPF56-11-D-000001, they present a number of recorded leaks in pipelines in North America. The summary of these incidents are displayed in a table of recorded leaks and their method of detection.

The following graph was compiled by an independent consultant group from incident reports from the oil and gas sector from the period of January 1, 2010 to July 7, 2012.



It becomes evident that there were a substantial number of incidents which are associated with the actual pipe structure failures over the other components of the delivery system such as valves, seams or flanges. It therefore becomes quite evident that monitoring the actual structural integrity of the steel inner tubing and its outer structure are critically important to preventing seapage or material breach.

The following statistical representation and graphic indicate the detection method used to identify the actual medium breaches.

National All Pipeline Systems: All Reported Incident Details: 2014 YTD

Reported Cause of Incident [A]	Number	%	Fatalities	Injuries	Property Damage as Reported	% of Property Damage
CORROSION						
EXTERNAL CORROSION	8	5.5%	0	0	$1,083,680	6.4%
INTERNAL CORROSION	9	6.2%	0	0	$1,136,339	6.7%
Sub Total	17	11.7%	0	0	$2,220,019	13.1%
EXCAVATION DAMAGE						
OPERATOR/CONTRACTOR EXCAVATION DAMAGE	1	0.6%	0	0	$30,000	0.1%
THIRD PARTY EXCAVATION DAMAGE	3	2.0%	0	0	$1,025,134	6.0%
PREVIOUS DAMAGE DUE TO	3	2.0%	0	0	$1,090,745	6.4%

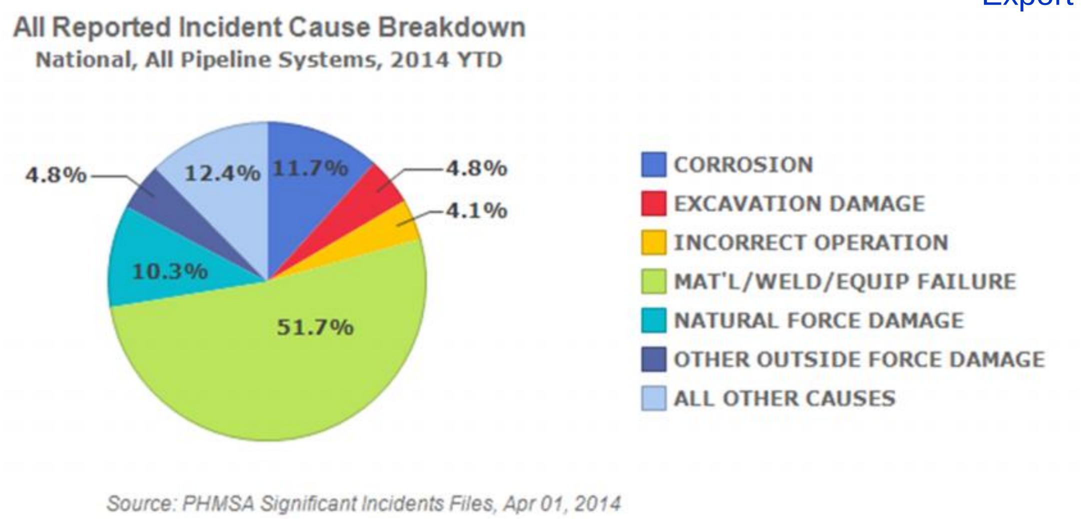
National All Pipeline Systems: All Reported Incident Details: 2014 YTD

Reported Cause of Incident [A]	Number	%	Fatalities	Injuries	Property Damage as Reported	% of Property Damage
EXCAVATION						
Sub Total	7	4.8%	0	0	$2,145,879	12.7%
INCORRECT OPERATION						
OVERFILL/OVERFLOW OF TANK/VESSEL/SUMP	1	0.6%	0	0	$1,720	0.0%
INCORRECT VALVE POSITION	2	1.3%	0	0	$34,815	0.2%
INCORRECT INSTALLATION	1	0.6%	0	0	$13,228	0.0%
OTHER INCORRECT OPERATION	2	1.3%	0	0	$29,769	0.1%
Sub Total	6	4.1%	0	0	$79,532	0.4%
MAT'L/WELD/EQUIP FAILURE						
CONSTRUCTION, INSTALLATION OR FABRICATION-RELATED	4	2.7%	0	0	$266,445	1.5%
MANUFACTURING-RELATED	3	2.0%	0	0	$281,934	1.6%
BUTT WELD	1	0.6%	0	0	$27,930	0.1%
MALFUNCTION OF CONTROL/RELIEF EQUIPMENT	12	8.2%	0	0	$1,565,161	9.2%
PUMP/COMPRESSOR-RELATED EQUIPMENT	19	13.1%	0	0	$393,050	2.3%
THREADED CONNECTION/COUPLING FAILURE	5	3.4%	0	0	$186,096	1.1%
NON-THREADED CONNECTION FAILURE	9	6.2%	0	0	$60,195	0.3%
DEFECTIVE OR LOOSE TUBING/FITTING	4	2.7%	0	0	$19,237	0.1%
FAILURE OF EQUIPMENT BODY	8	5.5%	0	0	$1,556,149	9.2%
OTHER EQUIPMENT FAILURE	10	6.9%	0	0	$421,166	2.5%
Sub Total	75	51.7%	0	0	$4,777,363	28.3%
NATURAL FORCE DAMAGE						
EARTH MOVEMENT	2	1.3%	0	0	$135,456	0.8%
TEMPERATURE	11	7.5%	0	1	$1,035,776	6.1%
OTHER NATURAL FORCE DAMAGE	2	1.3%	0	0	$322,048	1.9%
Sub Total	15	10.3%	0	1	$1,493,280	8.8%
OTHER OUTSIDE FORCE DAMAGE						

National All Pipeline Systems: All Reported Incident Details: 2014 YTD

Reported Cause of Incident [A]	Number	%	Fatalities	Injuries	Property Damage as Reported	% of Property Damage
VEHICLE NOT ENGAGED IN EXCAVATION	2	1.3%	0	1	$93,198	0.5%
ELECTRICAL ARCING FROM OTHER EQUIPMENT/FACILITY	1	0.6%	0	0	$52,284	0.3%
INTENTIONAL DAMAGE	1	0.6%	0	0	$82,603	0.4%
OTHER OUTSIDE FORCE DAMAGE	3	2.0%	0	1	$1,696,560	10.0%
Sub Total	7	4.8%	0	2	$1,924,645	11.4%
ALL OTHER CAUSES						
MISCELLANEOUS CAUSE	6	4.1%	0	0	$377,077	2.2%
UNKNOWN CAUSE	12	8.2%	1	6	$3,855,918	22.8%
Sub Total	18	12.4%	1	6	$4,232,995	25.0%
Totals	145	100.0%	1	9	$16,873,713	100.0%

Export Table



The most recent statistics continue to support the evidence that the largest part of pipe breaches are associated with material/weld/equipment failure which mean that prevention strategies such as early detection systems are required to identify these potential underlying issues before they convert to leaks or breaches. Furthermore, it could also be hypothesized that all of these failures could benefit from a system that alerts the operators following any and all breaches regardless of the underlying cause. Prevention is the first measure or responsibility and response is the second most important factor to consider when faced with a material breach of a piped network or infrastructure.

All piping networks contain or represent implicit risks, for some, a breach of the medium represents environmental consequences, for others, the loss of valuable resources and for all of them the inherent risk of downtime or full closure depending on the severity of the breach. In all cases, the financial burdens associated with network failures due to leaks, breakage or complete destruction can and will hurt a company's bottom line. Predicting when a failure may occur could substantially mitigate vulnerability and liability as a whole.

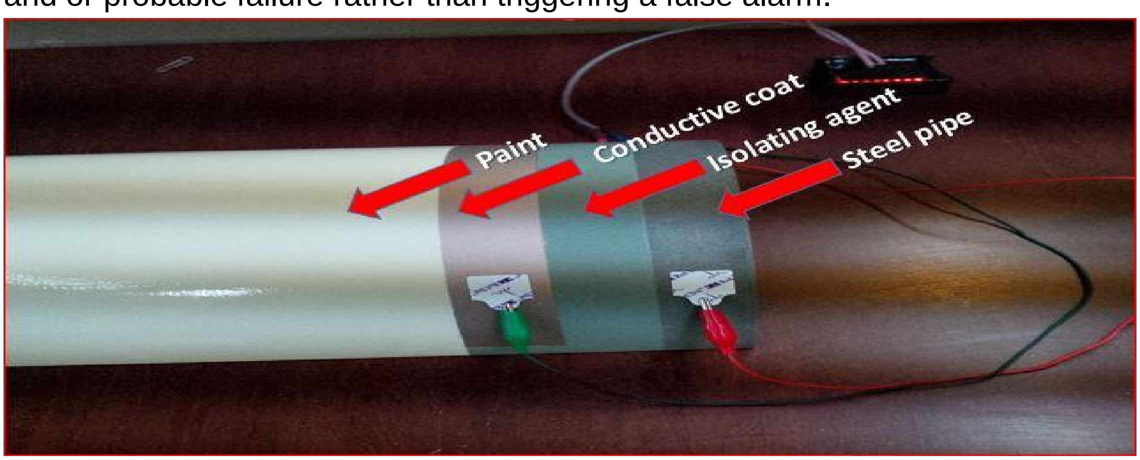
For industry verticals such as Mining: planned shutdowns, scheduled maintenance and preventative maintenance supported by a real time monitoring system represent substantial savings for any mining operation that implements and adopts such a maintenance program and best practice. The outcome following such an implementation is measured in millions of dollars in savings. The impact on the oil and gas industry is threefold: preventing environmental spills, improving operational up time translates also into millions of output dollars for the sector.

There are several systems and processes that are used to monitor pipe networks. There are passive systems that rely on people reporting issues and other more advanced systems which rely on SCADA or HMI and Computer Monitoring Process (CPM) technology. The challenge with any and all these systems is they report after the fact and do not provide preventative notification alerts indicating that there is an inherent issue with the piping network. Rubber lining coatings, hard-facing, and plastic inserts can delay corrosion and abrasion inside the pipe but once breached offer very little indication that they are no longer performing their key purpose. Only significant changes in a networks operations and flow are detected via the SCADA or CMP systems. Early detection following innerwear or outer shell protective coat breaches or deterioration have until now been unpredictable and undetectable.

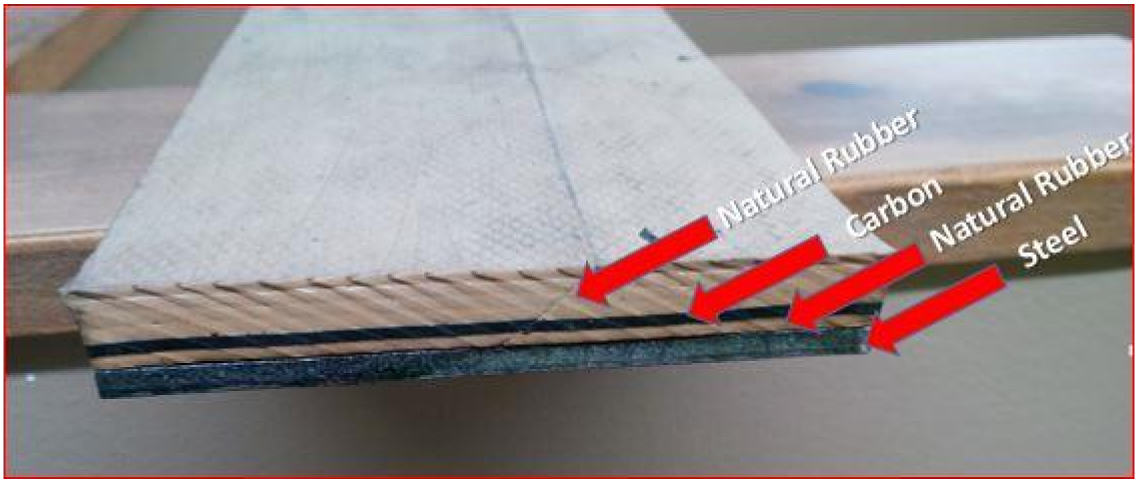
Fuller Industrial's proactive leak detection system provides a continuous monitoring system of the lining or coating without the use of statistical based flow or pressure readings. The systems design and simple current detection design make it an affordable simple solution. In addition to being simple, the system is capable of using different communication protocols and RTU's in order to inform a user or group of people that there has been a system breach.

The technology is similar in nature to that of a Geoelectric leak system (The Water Puddle test) where geomembranes which are electrically isolated by interlining the inner membrane of a calendered rubber with a coating of clay to help with conductivity. In calendered rubber a coating of carbon is used as the conductive material. Traditionally geoelectric leak detection systems charge the surface water with low voltage and then measure the spike in energy which flows through the membrane in locations where it is perforated. The electricity follows with the water through the perforation and seeks the outer grounded source i.e. the outside of the rubber coating which is grounded. The method known as ASTMD 7002 Water Puddle or the better known the ASTM D7007 Dipole method can be compared with the Fuller Industrial leak prevention system. The Dipole probe will capture the voltage spike followed by a distinct drop in voltage before resuming to a baseline ‘background noise categorized as the benchmark. Using a grid pattern, location is determined. The Fuller Industrial leak detection system used the ‘Spark testing’ method used for NDT of rubber lined pipe and pressure vessels. The idea is that once current travels from one side of the membrane to the other, a circuit is closed and an alarm is triggered. The principle and methodology is applicable to the outer paint coating of pipe.

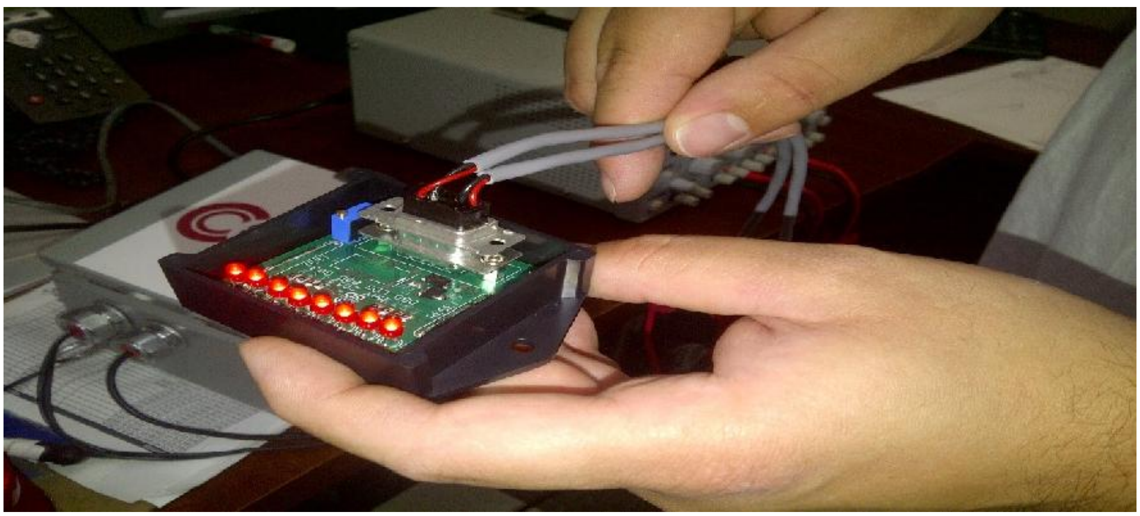
Once a breach is detected, the system is capable of sending an e-mail, a text or a sms message to the responsible authorities and notify them of the status and integrity of the pipe network. Detection or triggers occur once the outer coating or protective inner-liner of the pipe network fails and the actual media or in-situ fluids close the connection circuit consequently triggering the monitoring system verification process. Depending on the operator’s implemented confirmation and re-verification protocols, the systems redundancy verification process can be cycled over a definable number of times in order to confirm system failure and or probable failure rather than triggering a false alarm.

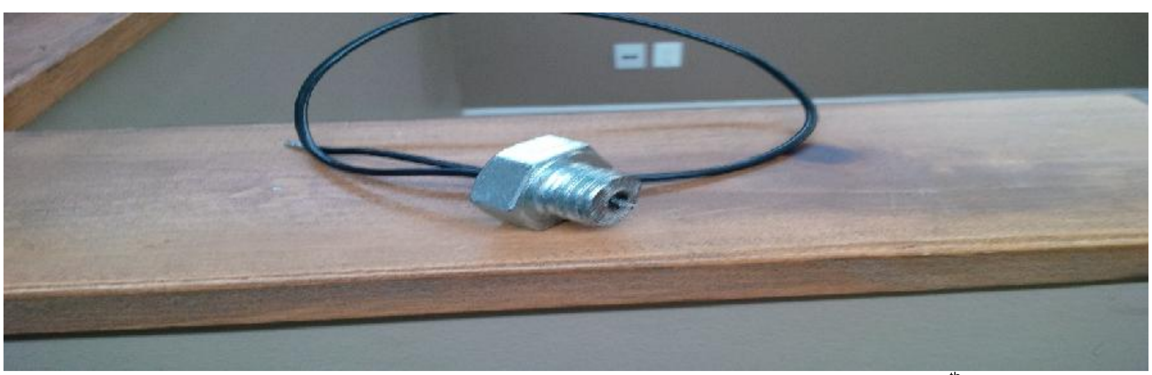


The above diagram shows the different layers of isolated material segregating the current from the charged pipe and outer layer. Current is only initiated once the isolating agent is breached.



The above diagram shows the different layers of isolated material segregating the current from the charged steel place and the 1/4in rubber layer which is calendered with 1/8th layer of Carbon and further insulated by 1/8th natural rubber.


Detection and monitoring device is affixed to pipe. Current is applied and triggers event once the ground or material inside rubber completes the current loop indicating breach.


'Spark-plug' like device is used to detect breach of 1/4in natural rubber following activation of the 1/8th Carbon layer. The device is screwed into the pipe wall and puncture the 1/8th rubber all the way to the 1/8th layer of Carbon electrifying the entire carbon layer. The circuit is completed once the media exposes the Carbon layer and the 1/4in Rubber has been breached.

Prevention entails that there is imminent or eventual danger. In all cases, safety protocols and processes will always be needed in order to determine and or confirm probabilities for eventual breaches. Physical review of the identified probable breach location needs to be confirmed and acknowledged. Once confirmed, repair and maintenance procedures can be implemented.

In many cases, preventative maintenance following and incident, can be resolved by changing the protective lining or coating inside the pipe, preventing further erosion or abrasion of the infrastructure or pipe network. The net result is that mine sites and processing plants will be able to schedule maintenance and down time in an orderly fashion. Replacement spools can be ordered in advance under regular rates.

It is possible to implement the Fuller Industrial leak prevention system in an oil and gas application by using the exterior coating as the detection sensor. By using the outer coating of a pipe network, in a similar fashion where current is it is possible to not only detect what is happening from inside the pipe network but also what is happening on the outside environment. Corrosion, abrasion, wear and or general failure of the coating could all be used as the triggers for the systems detection system.

Fuller Industrial has installed the technology at three (3) different client sites. All installations have been installed on critical sections of the pipe network. The clients have identified through historical performance that certain sections of the pipe process networks have a tendency to fail before other sections due to design or pressures exerted at these particular locations.

> Detour Gold installed a 30” diameter 90 degree long radius (90” centre line radius) elbow attached to the Cyclone underflow. Liner wear was detected within a two week period. The operators concluded that the use of ¼ inch natural rubber was the wrong inner lining coating application for the pressure and velocity of the cyclone system were too abrasive for a rubber coating.
>
> Vale Clarabelle mill installed 14” X 10” eccentric reducer fitted to a Warman intake pump. Detection of cut rubber lining was instant as there was an error during installation which damaged the rubber during installation. The breach was subsequently detected upon initializing the monitoring system.

Fuller Industrial test facility performed testing on a 20 foot spool. The detection/monitoring sensor were placed at the furthest points from where the experimental methodology would be executed. Strategic cuts were attempted in order to replicate environmental conditions. Initial test results demonstrated that distance from the breaches did not impact sensor sensitivity or response. The system detected time and time again that the inner liner had been breached. Similar testing was performed on the outer lining and similar results were obtained.

The monitoring of these key assets via the Fuller Industrial leak prevention system enables the operators to plan shutdowns for these critical spares. The system provides piece of mind and helps them concentrate on other sections of their operations.

General Conclusion

In summary, it is possible to identify and predict mechanical failures by using a system and methodology which monitors the inner lining or outer coatings of a steel pipe network. By energizing different layers of either the inner lining or of the outer coatings it is possible to create a reactive energy loop which can be used to signal a potential underlying issue. Detecting issues before the media actually breaches the steel infrastructure is key to prevention and is paramount to operating better networks.

Current systems monitor pressure and flow using CPM and SCADA networks that are tied into RTUs. The technology is very reliable and dependable as it is being used in most large steel pipe networks. The underlying weakness and challenge for any of these large networks is clearly stated in the National Pipeline incident report identifies that 52% of all spills are due to material, weld, and or equipment failure. This clearly indicates that the implementation of a monitoring system for the inner and outer cores of the pipeline network would be very beneficial to the industry. Reactive and post failure systems should be supported by preventative detection solutions in order to decrease the potential risk and liability associated with steel pipeline networks.

Further study and testing is required for the Fuller Industrial leak prevention system since it has yet to be tested over time. Initial testing and research demonstrate that the system is capable of detecting the smallest of breaches, to the point where improper installation detection upon onset is identified makes this technology promising and interesting for steel pipeline owners. An owner wants to make sure that his network has been properly commissioned and is set to work without issue from day one.

Different types of steel pipe networks and industrial settings installations are required in order to provide supporting data and demonstrate significant improvement and response times within established networks where wear and erosion are common issues for pipeline operators. The technology needs to be adapted to all types of steel networks in order for this research to conclusively demonstrate a step change in steel pipe network leak prevention and mitigation.