Pipeline Right of Way Encroachment

Exploring Emerging Technologies that Address the Problem

Nearly 90% of excavation damage release incidents occur along the right of way.

BY STEVE CHASTAIN, SR/WA

FRAMING THE PROBLEM

Every pipeline right of way professional is familiar with the encroachment clause in a right of way agreement.

"XYZ Pipeline Company shall have the right hereafter to cut and keep clear all trees, brush and other obstructions that may injure, endanger or interfere with the construction and use of said pipeline…"

In concept, a defined right of way would be clearly marked and maintained at its full defined width. Operations and right of way professionals would work jointly to ensure that the right of way remains clear and unobstructed, and that the public is informed and aware of the safety concerns and permissible uses of the right of way. Excavators and private landowners would always dial 811 to locate the underground lines prior to digging. Unfortunately, in practice this is not always what takes place.

In recent years, major pipeline incidents resulting in loss of life, serious injury and/or major property damage have caused the industry and regulatory agencies to ramp-up efforts to identify encroachment issues and develop measures to prevent them. The passage of the 2006 Pipeline Inspection, Protection, Enforcement and Safety Act (P.I.P.E.S.), H.R. 5782 and the Pipeline and Hazardous Materials Safety Administration's (PHMSA) Pipeline and Informed Planning Alliance (PIPA) are two prominent examples of the increased awareness and evolving industry dynamic.

SHARPENING THE FOCUS

According to recent statistics provided by PHMSA, excavation activities constitute one of the primary threats to public safety and pipeline integrity. Between 2002 and 2006, 80% of fatalities associated with significant incidents involving onshore gas transmission pipelines, and 63% of fatalities (a single incident) associated with significant incidents in hazardous liquids pipelines, were attributed to excavation damage. In the twenty years between 1988 and 2008, 34% of all serious incidents (fatality or in-patient hospitalization) associated with gas transmission or hazardous liquids pipelines were attributed to excavation damage.

The American Petroleum Institute (API) recently reported that between 1999 and 2006, "…excavation damage release incidents produce more fatalities than other incidents and larger barrel losses. Almost 90 percent occur along the right of way."[1] In the same period, they reported that excavation damage resulted in:

- 77% of fatalities
- 49% of injuries
- 49% of incidents involving evacuations
- 41% of barrels released in right of way incidents
- 27% of incidents involving a release of 50 barrels or more[2]

Clearly, the identification of right of way intrusions in real time, coupled with immediate actions to protect the public—and prevent damage to the pipeline—must be an industry priority.

ADDRESSING THE PROBLEM

In response to the tragedies caused by unsafe excavation, the pipeline industry and its associated professional organizations are rallying to the call, working with non-profit research and development organizations such as Pipeline Research Council International, Gas Technologies Institute and NYSEARCH.

Alongside these organizations, private industry is also providing a host of products. The industry's options for right of way encroachment monitoring and third party damage prevention are rapidly increasing. The technologies highlighted here are only representative samples of what's available.

TARGETING THE ESSENTIALS

To maximize the effectiveness of a right of way monitoring system, there are several essential components:

1) **Reliability** – the system must provide consistent and reliable data. False alarms decrease confidence and foster complacent monitoring.

2) **Near real-time notification** – operations personnel must be able to respond to an intrusion as it happens.

3) **Precise locating** – the system must pinpoint the location of the intrusion.

4) **Data cataloging** – ideally, systems will provide an accurate inventory of new and legacy encroachments, as well as identifying areas where the frequency of encroachments is high.

5) **Financially feasible** – the system must be affordable.

Remotely piloted aerial patrol drones can provide recorded video monitoring and is equipped with anomaly detection software to provide real time detection of high risk targets within the corridor. Photos courtesy of Vector P USA.

EXPLORING THE TECHNOLOGY

Remotely Piloted Aerial Patrol Drones

The latest wave of technology in the flight reconnaissance arena involves the use of remote piloted drones. These aircraft can be equipped with some of the same digital and geo-referenced video options as the piloted aircraft. The primary advantage to these systems is cost.

Intellitech Microsystems's Vector P vehicle is a commercially available model that can be remotely launched from a 100-200 meter grass, dirt or asphalt runway and can fly for several hours without refueling. It can be controlled remotely or once aloft, the aircraft can fly autonomously using predetermined way points along your right of way and its onboard GPS controlled autopilot system. Emergency recovery points are also programmed into the aircraft in the event of an equipment problem. The aircraft can provide recorded video monitoring in the form of downloadable AVI files and is equipped with anomaly detection software to provide real time detection of high risk targets within the corridor. In the event such a target is identified by the system, a highly compressed photo, which shows both the entire video frame and the target, is sent to the remote operator for comparison with baseline photos to determine whether the target is hazardous or benign. The operator can direct the aircraft to return to the location for additional analysis, if needed. It patrols at a typical altitude of about 200 meters with flight speed of 60 knots (about 69 mph). It has a payload of 5 kg fully fueled and is capable of day or night surveillance. Since it uses commercial off-the-shelf technology, it is also economically maintained.

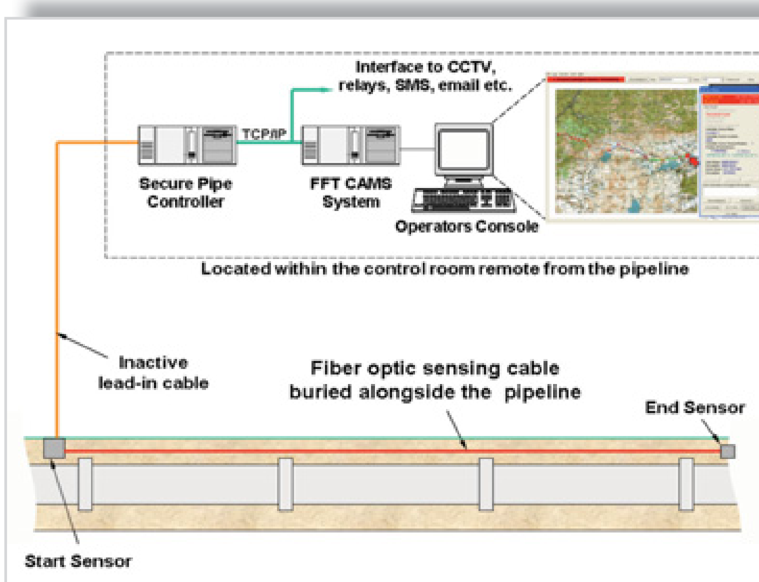
The drone's 2.6 meter wingspan makes it easily transportable from one location to the next.

One requirement of this type of system includes the ability to handle multiple landings and recovery points. Its 2.6 meter wingspan makes it easily transportable from one location to the next.

FIBER OPTIC PIPELINE ENCROACHMENT DETECTION

Fiber optic technology may be another solution offering real-time monitoring and low operating costs. The Gas Technology Institute has investigated a system involving a fiber cable buried above a pipeline. Light signals are periodically sent through the specialized fiber (which is sensitive to changes in stress and vibration), and reflected light is recorded back at the source. When heavy equipment is within the right of way, it compresses the soil and creates vibrations which change the dynamic of the light and reflect those changes back to the source. Using a custom designed optical time domain reflectometer, which is able to measure the reflected light and accurately interpret the signal, the system objective was to identify a target and determine its status as hazardous or benign. If the signal is determined to be hazardous, an alarm is triggered. Since the velocity of the light is known, the equipment will be able to pinpoint the precise location and notify the operator for a response. Field testing proved the basic concept of the system however the report stated that "...the sensitivity of the technique needs substantial improvement to be practical." [3]

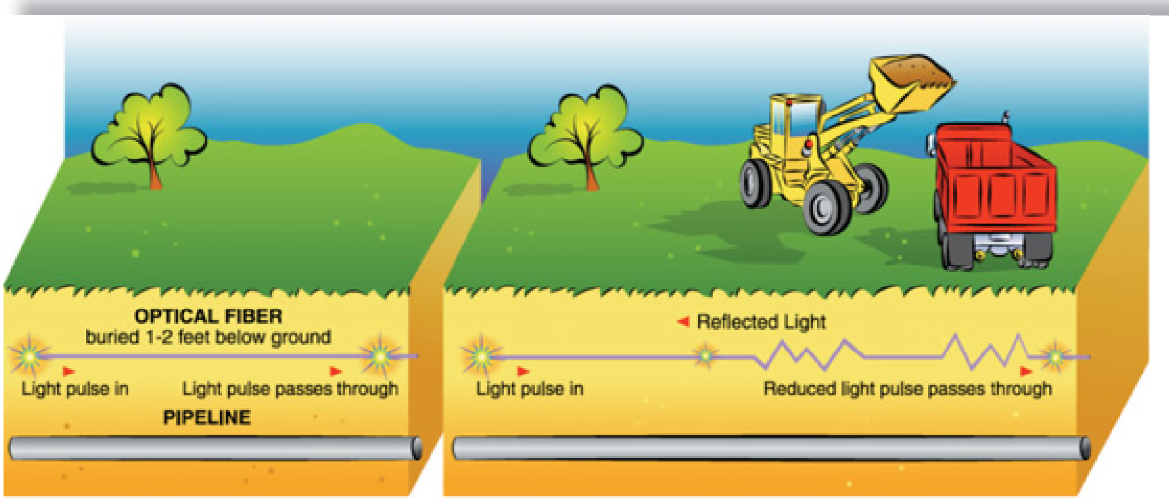
Future Fibre Technologies (FFT) has developed a fiber system with similar objectives called Secure Pipe™. Their system also uses a buried fiber cable along the pipeline but incorporates a different measuring apparatus. It uses three sensing fiber strands within a single cable. They send a continuous signal, instead of pulsed light, through two of the fibers forming an interferometer, which measures any change in motion, sound or vibration within the measurement area. If there is a change in motion, sound or vibration, the third fiber delivers information to specialized software, which determines where the event occurred and whether the event is an intrusion or the result of a change in ambient conditions. The company advertises that the system is capable of locating intrusions within 150 meters of the pipeline, depending on the cable type and location. The system ensures 95% detection of intrusion events.



Three sensing fibers within a single cable can signal a change in motion, sound or vibration. Photo courtesy of Future Fibre Technologies.

The company's brochure boasts "...no equipment, no electronics, no enclosures, no grounding and no power supplies anywhere along the pipe for up to 25 miles."[4] They report a calculated mean time between failures of 130,000 hrs (nearly 15 years). This system can also provide perimeter protection for facilities along the pipeline. FFT's systems are currently being used in the U.S. and Europe by transmission gas and petroleum pipeline companies. They are also being used by the U.S. Border Patrol, the U.S. Army and Navy, Homeland Security and several foreign ministries of defense.

Neither of these systems requires the fiber to be broken or impacted by the intrusion target. Both systems would require installation of the cable in proximity to the pipe.

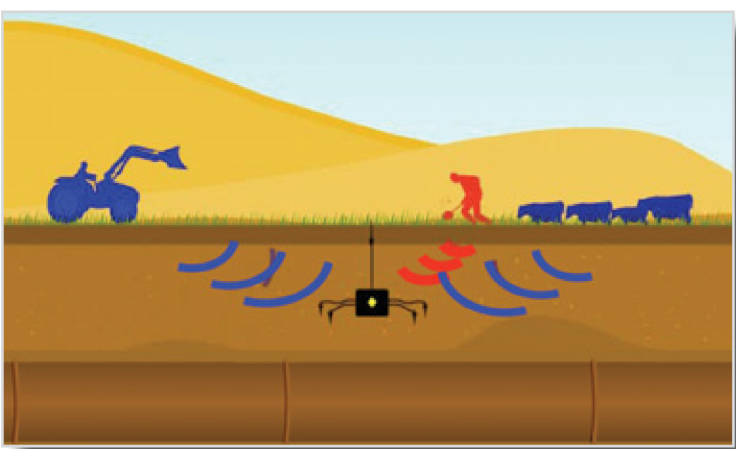


A fiber cable buried above the pipeline may be another solution offering real-time monitoring and low operating costs. Photo courtesy of the Gas Technology Institute.

SEISMIC SENSORS

PHMSA, NYSEARCH and Physical Sciences, Inc. (PSI), have field tested and proven a system of infrasonic seismic sensors that are capable of locating and identifying intrusion threats based on their acoustic signature (www.psicorp.com). The system, which is still under development, is called PIGPEN for Proactive Infrasonic Gas Pipeline Evaluation Network. Smart sensors are placed astraddle the pipe (above ground) at 100-500 meter intervals dependent upon soil type. Up to 16 of these sensors can be integrated to communicate with the system's remote monitoring equipment Bullhorn®, American Innovations (www.amerinnovations.com) for alarm notification. The system boasts a detection range of greater than 300 feet. It can locate the threat to within 30 feet. It has a 99% probability of detection rate and a probability of false alarms at one per month. The system has a target cost per mile installed of $10,000 and a target operation cost of $100 per mile. It does not have to be installed on top of the pipeline, nor does it need to be installed along the entire length of the line.

A commercially available system using underground sensors is offered by Magal Security Systems, Ltd. called PipeGuard™. This system is currently being investigated by NYSEARCH. The sensors are buried at depths of approximately three feet and may be placed over, or at, offsets to the pipe. Sensors are placed 200-300 meters apart. They are powered by a lithium battery with an approximate lifespan of five years. The company reports that the system can identify excavation equipment by its acoustic signature with an intrusion recognition rate of better than 98%. NYSEARCH reports an estimated cost of approximately $11 per foot pipe run.



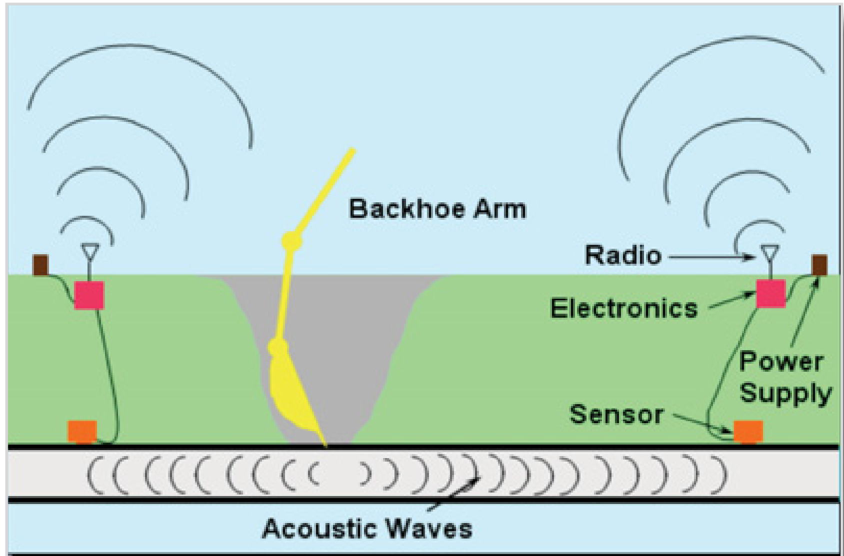
Infrasonic seismic sensors are capable of locating and identifying intrusion threats based on their acoustic signature. Photo courtesy of Magal Security Systems, Ltd.

ACOUSTIC IMPACT DETECTION SYSTEMS

The Gas Technology Institute (GTI) is currently conducting research on acoustic impact detection for providing real time monitoring against third party damage. The system is comprised of multiple acoustic sensors, power supplies and remote transmitting devices which are placed along the pipeline at fixed intervals. When a piece of equipment, such as the shovel of a backhoe, strikes the pipeline, the sound generated travels through the gas stream and the pipe to the nearest acoustic sensor in both directions. The sensor's electronics filters and analyzes the sound to determine if an alarm is warranted. If the sound meets the alarm criteria, a radio alert is transmitted to operations personnel or the monitoring service. The acoustic sensors transmitting the alert will identify the location of the strike to facilitate rapid intervention.

A commercially available system uses underground sensors and a lithium battery with a potential lifespan of five years. Photo courtesy of Magal Security Systems, Ltd.

Research is underway on an acoustic impact detection system for providing real time monitoring against third party damage. Photo courtesy of the Gas Technology Institute.



The GTI lists the following system essentials:

- Widest possible spacing between sensors
- High sensitivity
- Very effective noise-rejection capabilities
- Ability to distinguish third party damage from background noise
- Installation and communications cost must be low[5]

General Electric Oil and Gas (GE) developed and is marketing an acoustic impact detection system called ThreatScan™ . Their system uses hydrophone technology and can be used on pipes from 6-48 inches in diameter, buried or above ground. It has applications for natural gas, crude oil and refined products. The power supply is solar with a battery backup for "no sun" conditions. Each sensor communicates directly with the satellite system and relays data to GE's monitoring facility where it is analyzed. Their facility provides 24/7 monitoring and reporting, and GE promotes a 30-minute report time on detected incidents. The product also has monitoring software which is integrated with Google Map® and allows for import into your GIS system. Along with real time detection, GE's system provides monthly logs which can aid in the development of trending data to identify high encroachment areas where increased public awareness might be required. The company lists as "non-guaranteed" the ability to provide early warning of excavation activities. ThreatScan™ is currently being used by pipeline companies in the U.S. and Europe.

The PRCI conducted testing on ThreatScanTM in coordination with Duke Energy, Eon Ruhrgas and Northern Natural Gas. The executive summary reported that, "The performance of ThreatScan™ always met or exceeded advertised capability in localization error and notification time. In detection range (hydrophone sensitivity), it consistently exceeded expectations."[6] The testing further demonstrated that this system could be installed without "adversely affecting line operation or requiring a hot top."[7]

This acoustic impact detection system using hydrophone technology offers applications for natural gas, crude oil and refined products. Photo courtesy of GE Oil & Gas ThreatScan™

SATELLITE DETECTION OF ENCROACHMENT EVENTS

The concept of identifying an encroachment event from space using satellite imagery is also being explored. With this technology, a satellite monitoring system photographs a given corridor as it passes over. Subsequent passes generate new images of the same corridor. These images are constantly compared using computerized change detection analysis software. If an encroachment event is identified within a right of way corridor, the imagery is further analyzed using a database of heavy equipment signatures. In theory, the system can identify a piece of heavy equipment on the right of way, pinpoint its location using GPS technology and contact the operations center for on-the-ground investigation.

Identifying an encroachment event using satellite imagery is currently being explored

HIGH ALTITUDE SECURE BALLOON-BORNE NETWORK

This system is currently being used to monitor wireless cathodic protection systems, however, it has been proposed for use in monitoring third party damage. A company called Space Data Corporation (www.spacedata.net) proposed the use of a secure, high altitude (60,000–80,000 feet - near space orbit), balloon-borne relay network to monitor a ground-based laser detection system within a natural gas pipeline right of way. In the proposal, a field proven laser-based monitoring system would be used on the ground. Two laser beams would traverse the right of way at an elevation of 3-5 feet above the pipeline. The laser would detect third party damage, as well as gas leaks. If equipment broke the beam or the laser detected the presence of natural gas, an alarm would be triggered and a signal would be sent to the balloon-borne network. The network would communicate the signal to the appropriate gas control center for immediate response. Each balloon borne-transceiver unit has a 400-mile overlapping footprint to ensure optimum coverage.

A high altitude balloon-borne relay network can monitor a ground-based laser detection system within a natural gas pipeline right of way. Photo courtesy of Space Data Corp.

CONCLUSION

The technologies covered here are only a representative sample of some of the innovative ideas being explored to promote public safety and protect pipeline infrastructure from third party damage. The industry will likely use a combination of technologies due to the diversity of right of ways, the volume of right of way and the cost of retrofitting the enormous pipeline infrastructure.

Currently, there are approximately 290,000 miles of natural gas transmission pipelines and 170,000 miles of petroleum pipelines. Some systems will better suit rural monitoring, while others will be better adapted for urban areas. The changing technology does not reduce the need to maintain a cleared and unobstructed right of way. To the contrary, new technologies, especially imagery driven technologies, will depend more heavily upon a clearly identifiable right of way, free of obstructions. If the technology can be made cost effective, near real-time encroachment prevention may become a reality for right of way in the near future. ✪

References:

[1] PPTS Advisory 2008-4, American Petroleum Institute, September 2008, p. 1.

[2] PPTS Advisory 2008-4, American Petroleum Institute, September 2008, p. 3.

[3] "Detection of Unauthorized Construction Equipment in Pipeline Right-of-Ways", GRI-05/0044, Abstract, Report Period 10/01 – 07/05, http://www.gastechnology.org/webroot/app/xn/xd.aspx?it=enweb&xd=10AbstractPage/050044.xml, 2/27/09.

[4] "A True Breakthrough in Pipeline Safety and Security", Future Fiber Technologies, www.fft-usa.com, 2/27/09.

[5] "Third Party Damage Real Time Monitoring", FOCUS, Gas Technology Institute http://www.gastechnology.org/webroot/app/xn/xd.aspx?it=enweb&xd=4reportspubs\4_8focus\thirdpartydamagerealtimemonitoring.xml

[6] PII North America ThreatScanTM Impact Detection System, PRCI Demonstration Report, Feb. 28, 2007, p. 5

[7] Ibid