Smart Pipes:
Hi Tech Conduits Can Warn About Flaws

By Mark Solof

Pipes made of plastic with an embedded layer of metal allow utility officials to electronically monitor the pipe's condition.

Utility crews put down the orange cones, close off the street, bring in the backhoes and begin digging to get at a ruptured water main. It's a familiar scene in communities around the nation, one that occurs as a section of pipe finally succumbs to the combined assaults of age, corrosion, vibration and water pressure.

Before the pipe is fixed, surrounding homeowners and businesses—if they are lucky—will find themselves without water for a time, or—if they are not—find their basements and valuables stored there inundated. Drivers are detoured to often congested alternate routes. Towns, especially cities with aging water systems, must budget millions yearly to address ruptures and perform preventative maintenance.

NJIT Research

Within the next decade, if research and development goes as planned, communities could have new technologies and materials to bring to bear on these challenges. Researchers at the New Jersey Institute of Technology (NJIT) in Newark are investigating composite "smart pipes," made of plastic with an embedded layer of metal that will allow utility officials to electronically monitor the pipe's condition.

Signals transmitted or reflected through the metal layer can be analyzed by computer to gain information about flaws, such as cracks and corrosion. Such flaws cause perturbations in the expected waveform "signature" of the signal. A mathematical model that NJIT researchers are developing can then be used to estimate the location of the flaw, its nature and extent.

This information will give utilities the ability to target preventive maintenance to the "weakest links" in their systems and avoid most of the unforeseen ruptures that are now so costly and disruptive.

Listening for Leaks

Thomas Juliano, NJIT Associate Professor of Engineering Technology, notes that many utilities now use audio systems to detect leaks. Audio transducers—essentially specialized microphones—can be attached to pipe outlets or organized into arrays that are snaked into pipes to detect the distinct hissing sound of water leaks. Computer algorithms are used to filter out background noise and triangulate to find the location of leaks.

But, says Juliano, this only works

Associated Press

Emergency construction crews examine a ruptured water main in Queens, New York City, January 3, 1996.

with pipes carrying water under pressure and it "only tells you if you already have a leak; it doesn't tell you if a pipe is deteriorating." Physical inspections—including sending robotic "pigs" through lines—tend to be expensive and disruptive.

Jay Meegoda, NJIT Professor of Civil Engineering, notes that the composite smart pipes being developed at NJIT combine and adapt technologies in use elsewhere. Short lengths of similarly constructed pipe—along with more rudimentary detection systems —have been used in several paper processing plants to warn of weaknesses in pipes carrying acids and other highly corrosive fluids. Algorithms to analyze electric signals similar to those under development at NJIT are commonly used by electrical engineers to identify the location and extent of flaws in power transmission lines.


Associated Press

A water main break in Gillette, Wyoming in August 2006. About 3 million gallons of water erupted causing at least $100,000 in repairs and requiring traffic diversions.

Other Approaches

Researchers elsewhere are looking into other approaches to creating smart pipes. Many natural gas utilities now use "active cathodic protection" systems that involve applying an electric current to a pipe's metal to inhibit corrosion. Changes in the electric "draw" of these systems can indicate flaws. Researchers are seeking ways to better analyze these variations.

Other researchers, particularly in Great Britain, are looking into pipe coatings containing miniaturized piezoelectric sensors which convert physical pressure into electric current. Changes in the signature of this current occur when the coating is subject to corrosion—though the faint currents involved present a challenge for detection.

All smart pipe technologies confront a cost hurdle before they can become commercially viable for water systems. For pipelines carrying industrial solvents, natural gas or oil where ruptures have severe safety, environmental or economic consequences, even expensive smart pipes and detection systems could be cost effective. Smart pipes, for instance, potentially could have averted the rupture in the Alaska oil pipeline in August 2006 that contributed to a spike in world oil prices.

But water systems are another matter. "Water is not a dangerous substance, unless there is a catastrophic leak," says Juliano. "With a transcontinental gas pipeline there is much more at stake in terms of health, safety and money." Indeed, Juliano notes, many municipal water systems tolerate a certain percentage of leakage.

The NJIT researchers see the composite pipes they are investigating as holding the best promise of meeting the cost requirements of being applied to sprawling water systems. This is especially the case for arid locations where leakage must be minimized or for sections of pipe where reliability is important, such as water mains and those feeding fire hydrants or hospitals.

Simple Idea

Meegoda said the composite smart pipes are basically "a very simple idea." Once workable systems are devised and tested, they can be put into production without the need for sophisticated new materials or electronics. He said that DSL technology, now widely used for internet access, was based on a similarly simple concept that was commercialized to bring new capabilities to existing infrastructure.

Professors Meegoda and Juliano, working with NJIT graduate students, expect to have composite smart pipes ready for commercialization in five to ten years. ❑