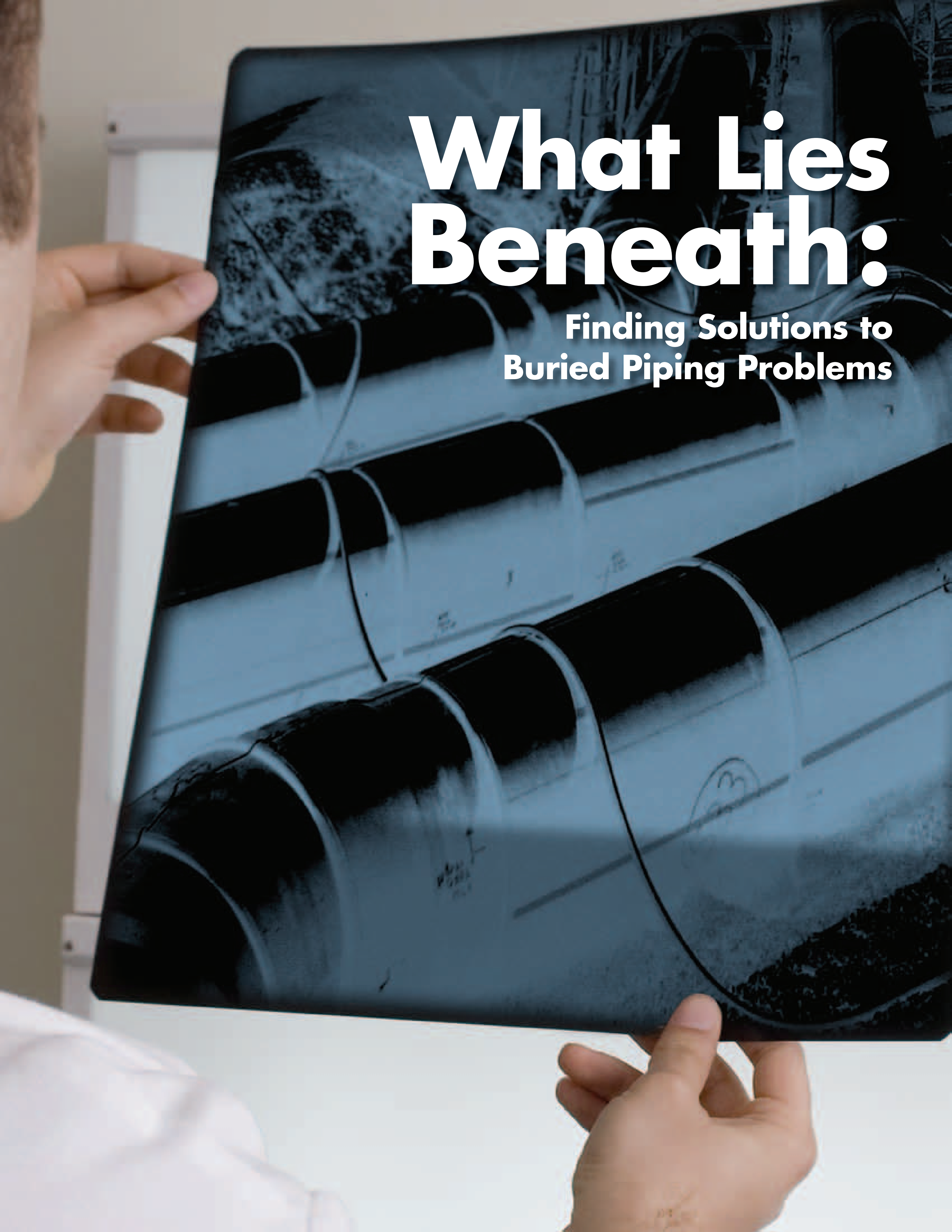

What Lies Beneath:

Finding Solutions to Buried Piping Problems

When it comes to safety at nuclear plants, out of sight can't be out of mind. Pipes that were buried decades ago can degrade over time, leading to possible leakage and highlighting the need for vigilant monitoring.

While rare in the nuclear power industry, failures do occur. Recent instances include an estimated 100,000-gallon emergency cooling water leak at a northeastern U.S. nuclear plant and several instances of the discovery of ground water tritium, some resulting from buried piping leaks. None of these leaks posed a public threat or a safety risk, but perceptions matter, especially when firms are working to extend the operation of existing units or obtain permits to build new facilities.

"Buried systems are usually passive, out of sight, and have generally provided reliable service," said Maria Korsnick, Senior Vice President, Nuclear Operations, for Constellation Energy Group of Baltimore, Maryland, which operates three nuclear generating stations with nearly 4,000 MW capacity. "They usually only draw attention when a failure occurs."

Buried piping integrity is a significant issue in maintaining safe, reliable, and economical plant operation, and in addressing other industry drivers, such as meeting NRC requirements related to license extension and meeting internal industry performance expectations as evaluated by the Institute of Nuclear Power Operations.

To fully understand these issues and implement long-lasting solutions, more utilities are developing formal programs for buried pipe aging management and posting staff as buried pipe program managers. EPRI is supporting these efforts through research and development and training.

THE STORY IN BRIEF

Interest in nuclear plant life extension has directed attention to the miles of decades-old service piping buried beneath existing generating stations. As plant operators set up formal programs to ensure the continued integrity of such underground piping systems, EPRI is offering support with research, technology, and training.

Attacks From Within and Without

A maze of buried pipes lies beneath most nuclear power plants. Depending on how close the plant is to the cooling water source, nuclear generating stations can have anywhere from a couple miles to more than ten miles of buried piping. These range from small instrument air lines to 16-foot-diameter recirculating water lines, with process fluids ranging from air to cooling water to fuel oil.

A plant can have as many as 30 separate buried piping systems traversing the property (see "Types of Buried Piping," page 23). While these pipes have generally held up well over the 30–40 years that many plants have operated, going beyond that requires the implementation of adequate aging management programs. "As nuclear plants age, leaks in some buried pipe systems have occurred, as might be expected given their age and service environment," said Korsnick.

"Our biggest single challenge is the inability to readily access the piping to determine its condition," said Shane Findlan, manager of EPRI's Balance-of-Plant Corrosion program. "A second significant challenge is that, rather than just worrying about the internal environment and how it affects the pipe, we have to be concerned about the external environment—the pH levels of the soils and different moisture levels."

Most buried piping is fabricated from coated carbon steel or stainless steel, which are both susceptible to a number of degradation mechanisms. Internally, the coating can break down and expose the steel to corrosion and erosion from the fluid and any associated contaminants. Tuberculation, the build-up of hard mounds of rust inside the pipes, increases friction and decreases water flow. Over time, the walls thin, eventually leading to a breach of the wall. Salt water, in particular, is a problem.

"We have one plant that uses salt water, and wherever internal coating flaws are present, we see greatly accelerated corrosion compared to what you would see in freshwater plants," said Greg Lupia, Corporate Buried Pipe Program Owner for Exelon Corporation (Chicago, Ill.). "But even among our freshwater plants, differing water chemistries result in varying corrosion rates."

While pipes are also coated on the outside to protect them from corrosion, problems still occur. Rocky L. Jones, a technical specialist at Entergy Corporation's Arkansas Nuclear One plant in Russellville, Ark., said that most buried pipe trenches were backfilled with sand, which has a low corrosivity factor. In some cases, however, rocks or other materials have gotten into the ditches, which can damage the coating. Jones also noted that the salt used at some plants to de-ice the roads in the winter winds up in the groundwater and corrodes the pipes.

To supplement coatings and reduce corrosion, therefore, nuclear plants use cathodic protection systems. These systems typically consist of a DC power source connected to anodes buried under the ground. Other wires connect to the pipes, which act as cathodes. Any breaches in the coating provide a path for the electricity to pass from the anodes through the ground and into the pipe, and then back through a cable to the power source. The flow of electricity into the pipe limits the corrosion.

None of these protective measures, however, are foolproof, and over time they tend to degrade.

"Regardless of the specific failure mechanism, the industry is concerned with preventing leakage from any buried system," said Korsnick. "In addition to immediate operational consequences, the industry is concerned with protecting the environment and the community that surrounds the plant."

Risk Ranking Assessment Software

Each nuclear plant may have several thousand segments of buried pipe at risk of failure. Since they can't all be inspected at once, this spring EPRI released BPWORKS—software that can help plant owners prioritize inspections of buried pipe systems. The software determines both the likelihood of a leak or break and the consequences of that leak or break. This information is plugged into a risk matrix to help prioritize the inspections.

"BPWORKS takes operational data and compares it to plant experience from NDE results, assessment results, and failure observations and allows operators to do some predictive modeling," said Findlan. "When you are talking about miles of buried piping in a single plant, software can help focus attention at the right location and help guide your assessment efforts."

BPWORKS (1019178) is available from the order center at 800.313.3774 or 650.855.2121 or by sending an email to orders@epri.com.

Leak Prevention

Preventing leaks in underground piping is a three-step process: evaluation, inspection, and repair or replacement.

Evaluation. The first step is to conduct a risk ranking assessment. Digging up and inspecting all those miles of piping for a direct inspection is simply not practical. It also isn't desirable, because digging could exacerbate any existing problems: a thin wall is more likely to burst if no longer surrounded by the backfill. Further, buildings and security fences may have been built on top of pipes over the decades.

"Exelon has developed a ranking system to help categorize all the piping so we can focus our resources for inspection," said Lupia. "We can't get all the piping inspections done in one year; our goal is to get all the high-risk piping inspected in some manner in three to four years."

Risk ranking involves first assessing the consequence of a leak for each pipe, based on factors such as whether the leak would compromise nuclear safety systems, reduce power production, or have measurable environmental impacts. For example, a tritium or fuel oil leak poses a greater environmental threat than a makeup water leak. The consequence is then multiplied by the susceptibility of that pipe to corrosion, which is affected by the type of pipe, local soil conditions, location, etc. Software such as EPRI's BPWORKS (see sidebar) can track the characteristics of each piping system and the relevant environmental characteristics to help set priorities.

Inspection. Several technologies are available to help determine the condition of pipes without having to dig them up. Ground-penetrating radar can be used to map their locations. Direct current voltage gradient (DCVG), which measures the voltage in the ground produced by the cathodic protection system, can locate faults in the coating. Guided-wave technology—using a collar that clamps onto a pipe and sends an ultrasonic signal down its length—allows inspection of 30 to 50 feet in either direction from a single location. EPRI is working to improve guided-wave techniques so that longer lengths of pipe can be inspected. Finally, there is internal inspection by robotic instruments that crawl through the pipes when they are out of service. EPRI has developed a crawler vehicle that uses transducers to interrogate a given pipe's condition.

None of these individual methods offer a complete solution, and they are often used together to provide a more complete understanding of current condition. DCVG, for example, can identify the general area where a coating breach and possible leak is present. Guided-wave technology can further narrow the search area, which would then be directly inspected using a crawler or by digging up the pipe.

Jones said that his firm is using DCVG, guided-wave technology, and crawlers to inspect the pipes at Arkansas Nuclear One. "DCVG is a fairly inexpensive way to investigate whether you have outside diameter corrosion due to lamination in your coating," he said. "In other cases, such as one pipe system at ANO where we can get inside for 2,000 feet, a crawl-through is more effective."

Repair or replacement. The third step in addressing pipe leakage involves repair or replacement of damaged piping, preferably using improved methods and materials that will prevent future corrosion. To ensure long-lasting repairs, EPRI is working to qualify non-metallic repairs such as sprayed resins and wraps for partial restoration of degraded pipe. Research into improved cathodic protection systems could lead to fewer instances where repair is needed.

"To further reduce the need for repair, the industry is carefully evaluating the use of corrosion-resistant materials as a long-term replacement for steel piping," said Lupia. "Those can include high-density polyethylene (HDPE), stainless steel, or other corrosion-resistant materials." HDPE pipe has been used by the waterworks and natural gas industries for nearly 40 years. In the United States alone, there are more than 700,000 miles of HDPE gas lines. HDPE is not susceptible to corrosion, doesn't need cleaning, has comparable installation costs to steel, and has lower maintenance costs.

HDPE has limited approval for use in the nuclear industry, especially for ASME Class 3 (safety-related) applications. That may soon be changing. Based in part on EPRI research, the American Society of Mechanical Engineers in 2007 approved Code Case N-755, which details rules for installing HDPE in Class 3 systems. The Nuclear Regulatory Commission (NRC), however, has not yet approved HDPE for broad application.

EPRI has also worked with two U.S. utilities on their Requests for Regulatory Relief (RRRs) for using HDPE in Class 3 applications. In October 2008, the NRC approved the RRRs for specific buried pipe installations at the Catawba and Callaway nuclear plants. Duke Energy's Catawba nuclear station has now become the first U.S. nuclear plant to use HDPE to replace a water system, changing out carbon steel buried piping used to supply water to and from the diesel generator jacket water coolers with 12-inch-diameter HDPE piping. AmerenUE's Callaway plant replaced 30-inch-diameter carbon steel buried piping in the Essential Service Water system with redundant 36-inch-diameter HDPE piping. The first two sets were installed in December 2008 and April 2009, respectively.

"I think the NRC has a positive perception of HDPE, but it is brand new," said Tim Eckert, EPRI program manager. "It has taken some time for people to accept that a highly engineered plastic can provide the high quality needed in these nuclear applications."

Buried Pipe Integrity Group

Recognizing the importance of buried pipe to long-term operational viability, many utilities have designated staff as buried pipe program managers. "If we do our job well, our plants can remain safe, cost-effective generation sources for decades to come," said Lupia. To help these individuals and their utilities address issues connected with buried piping, EPRI created the Buried Pipe Integrity Group (BPIG) in 2008. More than 80 nuclear reactors are represented by the members of BPIG.

The group shares operating experience on buried pipe and identifies opportunities for more-effective buried pipe management. One approach EPRI takes is to consult with representatives from the water and petrochemical industries to adapt the knowledge others have gained over the past century with respect to coatings and cathodic protection. For example, natural gas transport lines are commonly designed to accommodate internal inspection using devices called "pigs" that can be inserted into the pipe. The technology is not directly applicable to nuclear plant pipes, but there are important lessons to be learned.

"The gas pipeline industry is dealing with one pipe that runs for miles in a straight line," Eckert said. "We typically have a spaghetti bowl of buried pipes all intertwined within each other, so signals are easily confused. We are looking to see how well these techniques can be applied to multiple pipes together in one small, common area."

"As an industry, we need to be committed to ensuring the integrity of the buried piping at all our nuclear power sites," said Jones. "Collectively, we have more resources available to give engineers the tools needed to predict where there will be a problem and to upgrade the systems before leaks occur."

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Types of Buried Piping

The 2007 NRC/Brookhaven National Laboratory paper *Risk-Informed Assessment of Degraded Buried Piping Systems in Nuclear Power Plants* lists the types of systems found at nuclear plants. The list was compiled through a survey conducted using data in *Welding Research Council Bulletin 446, Design and Repair of Buried Pipe*, as well as a review of 12 license renewal applications submitted to the NRC. The report identified 16 piping categories, including service water, diesel fuel oil, fire protection, emergency feedwater, and condenser recirculating water. Some categories had several subsystems. The service water category, for example, includes emergency service water, auxiliary salt water, salt water, nuclear service water, residual heat removal service water, plant service water, high-pressure service water, and intake cooling water.

The full 174-page report is available from the NRC at http://www.nrc.gov/reading-rm/doc-collections/nuregs/contract/cr6876/cr6876.pdf. In addition to detailing the types of buried piping systems, it also discusses how to detect and evaluate pipe degradation.