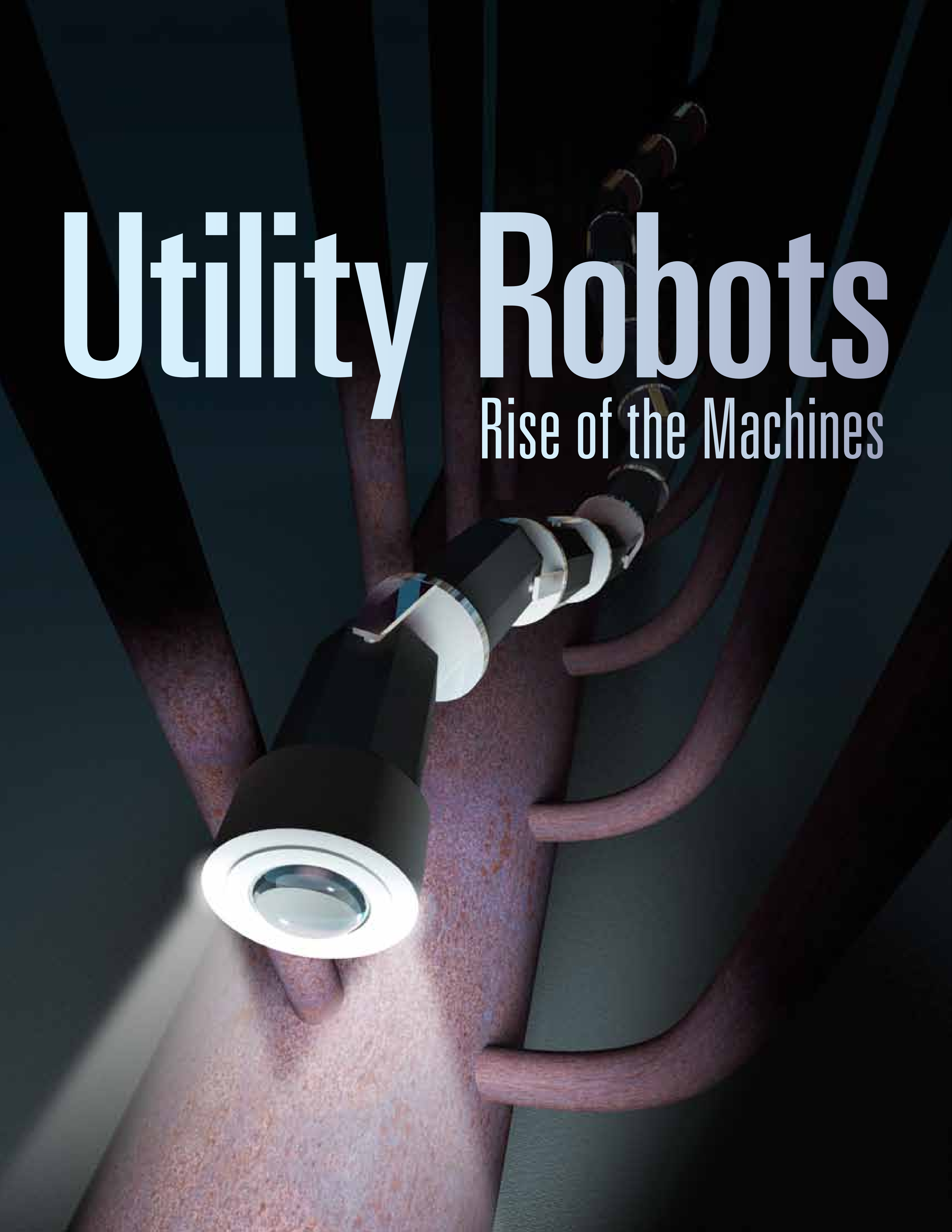
Utility Robots

Rise of the Machines



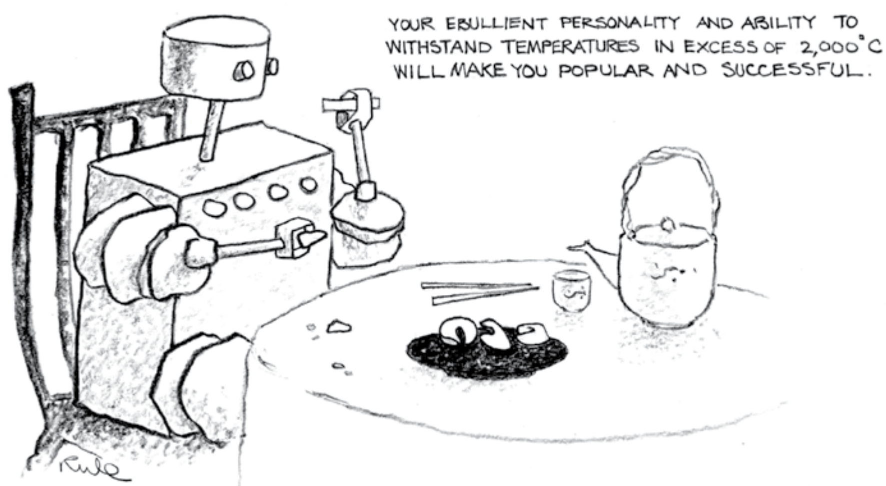
They don't look like the Terminator or come from the Forbidden Planet. But robots are becoming important allies to the power industry, performing tasks that are too risky, remote, or complex for humans to handle efficiently. The industry is starting to pay attention to the possibilities: in October 2010, the first International Conference on Applied Robotics for the Power Industry brought together robotics experts and power company representatives from 22 countries to facilitate the development of suitable machines.

EPRI has long recognized that robots can perform critical functions and has been developing robots for power plant and high-voltage environments since the 1970s. One early power line robot, TOMCAT (Teleoperator for Operations, Maintenance, and Construction using Advanced Technology), featured a large remotely operated arm for work on live transmission wires.

EPRI designed TOMCAT to be an all-purpose machine, but robotics trends now call for smaller equipment to perform specific functions. EPRI's current work covers a wide range of applications and makes use of the knowledge of research and industry partners to investigate promising technologies while lowering development costs. Today's projects put robots inside major plant components, on suburban streets, and on high-voltage transmission lines.

THE STORY IN BRIEF

Robots are the power industry's allies for complex inspection and data collecting missions.



Taking the Heat

Robots make good detectives, and they are particularly adept at performing work that involves squeezing into tight spaces, such as the vertical and horizontal tubes of a heat recovery steam generator (HRSG). In a combined-cycle plant, these tubes transfer heat from the combustion turbine's exhaust gas to water flowing through the tubes to generate additional steam for electricity production.

The closely bundled tubes are typically 50–70 millimeters (2–2.75 inches) in diameter and extend 12–18 meters (40–60 feet) between the upper and lower headers. Physical limitations pose big challenges for close inspection. When the tubes perform poorly or fail altogether, the causes can be complex and difficult to uncover.

So inspection requires something flexible and agile. Accessing the tubes inside the bundle presents a particular challenge for nondestructive evaluation (NDE) because the ultrasonic and eddy-current equipment used to detect problems must be in contact with the tubes. Robots are good candidates, and a so-called "snake" robot has been developed to crawl around in the tight environment. EPRI is working with Carnegie Mellon University to improve the robot's agility, speed, and efficiency and to add capabilities to perform NDE.

The goal is to improve the robot's ability to inspect the hard-to-access center of the tube bundle. Designers also hope to be able to introduce the robot for a complete inspection through a single entry point in the HRSG header, avoiding the time and cost of cutting and closing multiple entries. Other modifications would allow the robot to climb vertical tubes more easily and to direct its inspection camera straight down the tube bundle.

The team plans to alter the robot's "gait" so that it can maneuver through different tube configurations and remain stable when encountering obstacles. To increase its range of motion and prolong its operation in the field, researchers are looking to reduce the weight of the robot's tether while adding other safety features. Over time, EPRI plans to add more NDE capabilities for a wider range of problems and solutions.

Seeing the Light

Light-emitting diode (LED) technologies use energy more efficiently than conventional lighting and promise a longer lifespan, resulting in lower operation and maintenance costs. Since 2009, EPRI has been conducting an LED energy-efficiency demonstration to assess the technology for street and area lighting.

EPRI designed a robot, called Scotty, to help researchers collect data from the 20-plus U.S. demonstration sites. Scotty takes precise measurements of light levels on the street so that researchers can determine, among other things, how much and how fast the light intensity deteriorates over time. It's not an easy job. Researchers want to collect photometric data near the ground and to do so in a precise grid. In

Scotty, a mobile light-measurement robot, performs accurate, timely, and repeatable measurements of LED light levels.

Ti, a transmission line inspection robot, can traverse 60 miles (96.6 km) of line at least twice a year, collecting high-fidelity information that utilities can act on in real time.

the past, researchers manually inspected the equipment, made light measurements, and recorded the data.

Scotty, a four-wheeled, remote-controlled robot, is proving to be a faster, more exacting surveyor. Guided by a global positioning system (GPS), Scotty traces designated paths, measures lighting levels, and transmits the readings to a remote computer five times per second. The robot completes a job in minutes rather than hours. It can measure all types of lighting, allowing direct comparisons of LED systems with more conventional options.

Thanks to Scotty's precision, researchers are making measurements at a 2-foot (0.6 m) spacing, providing much more detail than the conventional 10-foot (3.1 m) spacing. The robot also keeps human inspectors off the streets, where they may be exposed to speeding cars and other hazards.

Living the High(-Voltage) Life

Transmission lines present a substantial and expensive challenge for human inspection and maintenance. They stretch hundreds of miles, often through remote areas.

As the technology is refined, momentum is growing to use robotic inspection for transmission line components. In a survey conducted during last year's robotics conference for the power industry, 32% of the respondents said they used robots for live-line work, most often for replacing parts or cleaning insulators. Inspection and preventive maintenance applications could greatly increase the use of robots on the high wires.

EPRI is refining a prototype, called Ti, to develop an inspection robot that can reside permanently on a transmission network, traveling up to 40 miles (64.4 km) on a line in four months. The robot will then reposition itself on another wire or be moved by a line crew. Along the way, the robot will identify right-of-way encroachment and any vegetation that threatens the performance of the line, plus monitor and report problems with transmission line components.

EPRI researchers are now analyzing data from laboratory tests to improve Ti's design. The current prototype can run at up to 3 miles (4.8 km) per hour and inspect, on average, 15 segments of 138-kV line each day.

Ti incorporates high-definition infrared cameras and image-processing technology and can compare images taken at different times to track equipment deterioration well before failure. Researchers expect to add a light detecting and ranging (LIDAR) sensor to provide close measurements of the relative positions of the conductor, vegetation, and other structures. Ti's use of GPS technology enables utility operators to quickly pinpoint trouble spots.

Ti will also transmit data collected from sensors already installed along the transmission lines to check on the performance of insulators, conductors, and compression connectors. This use of sensors can be critical, particularly in regions that experience strong winds or frequent lightning.

Creating inspection robots for the nation's transmission network will continue to be a key focus. EPRI will unveil a new transmission robot at the Utility Products Conference and Exhibition in San Antonio, Texas, in January 2012.

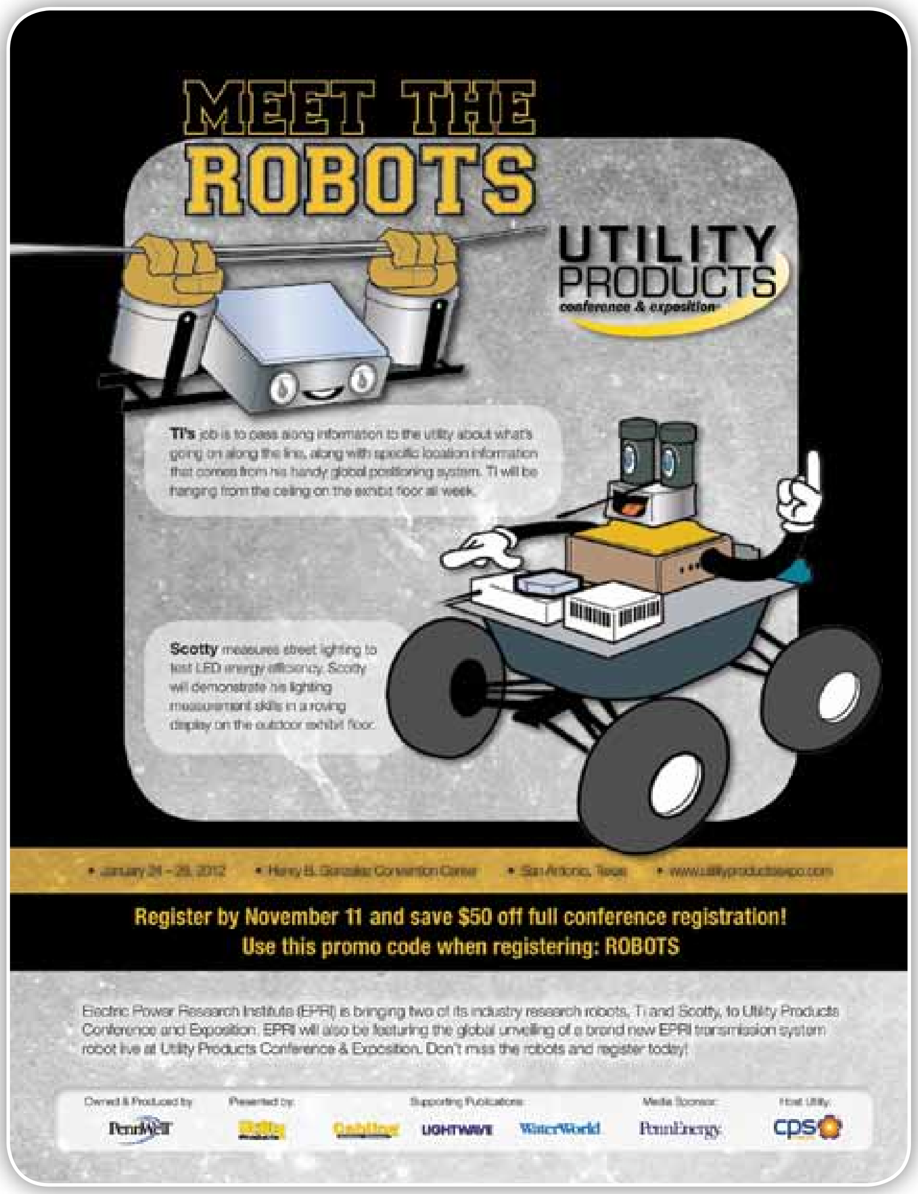
Nuclear Reactor Drain Line

The interior surfaces of carbon steel drain lines in a boiling water reactor (BWR) are susceptible to corrosion by the deoxygenated water that flows through the pipes. If not detected early enough, corrosion can thin pipe walls and cause failures that could lead to an unscheduled shutdown or other problems. EPRI is developing a series of robots to inspect and evaluate reactor drain lines for various BWR designs.

Drain line examination presents key challenges. The lines are surrounded by extensive hardware at the bottom of the reactor, making access difficult. Moreover, the configuration of drain lines and adjacent equipment differs by BWR plant design.

In 2007, EPRI conducted a field test to demonstrate the first robot's ability to remotely assess the wall thickness of a BWR drain line. The reactor's piping configuration was typical of BWR reactor Models 5 and 6. The robot used two rotating ultrasonic transducers to measure the thickness of the drain line pipe. Data analysis showed that the drain line was in good condition. Since then, three other reactors have deployed the same robot design to inspect drain lines.

A second-generation robot was designed for a drain line configuration typical of BWR Model 3 reactors. In these reactors, the drain line follows a complex path on top of an I-beam and through pieces of hardware, such as a control rod drive mechanism and in-core flux-monitoring tubes. The complexity of the operation prompted researchers to build a detailed, full-scale mockup of the piping configuration, including obstructions. Testing the robot



EPRI robots will receive star treatment at the Utility Products Conference and Exhibition in San Antonio in January 2012; two are pictured here in an advertisement.

on the mockup allowed engineers to fine-tune the robot, identify likely problems, and train the inspection team.

In 2011, after two years of development, the new robot was put to use during a reactor's planned maintenance shutdown. The EPRI–utility team encountered a navigation problem because the mockup did not correctly reflect a spacing gap, but after some modification, the robot completed its mission and provided the data necessary for the plant owner to certify that the drain line was in good operating condition.

Inspection of Concrete

EPRI is also designing a robot to facilitate the inspection of large concrete structures. The "concrete crawler" will have to be able to move over curved concrete wall surfaces, be rugged enough to withstand outdoor use, and run on a battery that can last three to four days. Why? Because the crawler will be checking large structures such as cooling towers, containments for nuclear reactors, and hydropower dams, said Maria Guimaraes, a project manager in EPRI's Nuclear Sector.

Currently, inspectors assess the integrity of such concrete structures with manually applied NDE equipment, using scaffolds that must be moved around the structure to gain access. As concrete structures age, the need for evaluation increases. "Right now, it takes a long time to inspect a cooling tower," Guimaraes noted. "With a robot, it could be safer, simpler, and less expensive."

The concrete crawler will carry test equipment and collect data for later analysis in the lab. Forty companies responded to a request for proposals for the concrete crawler projects this past summer. EPRI is evaluating the proposals and plans to conduct field tests next year.

This article was written by Ucilia Wang. Background information was provided by Andrew Phillips, aphillip@epri.com, 704.595.2728, and Maria Guimaraes, mguimaraes@epri.com, 704.595.2708.

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Maria Guimaraes is a project manager in EPRI's Nuclear Sector, specializing in the aging and inspection of concrete structures. Before joining EPRI in 2009, she worked for Aalborg Portland in Denmark, developing new cements that have reduced CO_2 emissions. Guimaraes holds a B.S. in civil engineering from the Universidad Nacional del Nordeste in Argentina, an M.S. in the same field from Newcastle University (UK), and a Ph.D. in civil and environmental engineering from the Georgia Institute of Technology.