AHEAD OF HIS TIME?

THE CAROLINAS AGC, *ENR* MAGAZINE, AND OTHERS HOPE THAT LEONHARD BERNOLD'S GENIUS WILL BE REWARDED BEFORE IT'S TOO LATE. HIS INVENTIONS PROMISE TO REVOLUTIONIZE THE INDUSTRY

IS IT A BIRD? A PLANE? NO…IT'S PIPEMAN.

Dr. Leonhard Bernold vividly recalls when he first knew for certain that his invention, the Pipe Manipulator (or PipeMan, for short), really worked. Carolinas AGC member Justis Everett, owner of ABE Utilities Inc., Raleigh, N.C., believed in PipeMan enough to field test it for two sunny fall days in 1999. "Conditions were a researcher's dream," says Bernold. "We had the same crew, same location, and same great weather for both days. It was perfect." Providential, some might say—for, certainly, few if any construction innovations have been more valuable or more worthy of being manufactured.

In a nutshell, PipeMan is a remote system that lays, manipulates, and connects pipes with O-ring joints. Best of all, it completely eliminates the need for workers in the trench! From a safe location, the operator controls a robotic excavator attachment with a joystick and receives information about pipe alignment from a line-and-grade laser, two video cameras, and a flat-screen monitor.

PipeMan's biggest advantages include needing only a three-person crew (as opposed to the five-person crew needed with conventional pipelaying methods); no shoring or shielding; and dramatically reduced excavation and backfilling. Also, the obvious time saved results in cost savings on labor and equipment. To date, the per-unit cost of pipelaying with PipeMan is about 32 percent less than with conventional methods. Though PipeMan is not yet manufactured, it could be soon with just a little more help from contractors or others interested in seeing the technology produced.

In ABE's field test, the crew laid nine 8-foot-long, 36-inch-diameter concrete pipe sections by conventional means, following OSHA-approved trenching methods, and laid another identical series using PipeMan. Everett was amazed and delighted with PipeMan's greater safety, simple operator training, added efficiency, and dollar savings. "When you know all the things that can go wrong and find, by experience, something that works, you're reluctant to mess with it," says Everett. "But PipeMan beat out my skepticism. I loved it and so did our foreman, Don Hayes, who has been laying pipe with me for 25 years."

AGC member Justis Everett, owner of ABE Utilities, Raleigh, N.C., lays nine sections of pipe using the Pipe Manipulator, or PipeMan—an invention of Dr. Leonhard Bernold, who is an expert in robotics and associate profes - sor of civil engineering at North Carolina State University (N.C. State). Pipe Man provides a "better, cheaper, faster" and safer new pipelaying method for utility contractors.

Two other AGC members, Barnhill Contracting Co., Raleigh, N.C., and Harry Pepper and Associates, Jacksonville, Fla., have field tested different models of PipeMan. "All the field tests are so crucial for our research," says Bernold. "I can't thank these contractors enough for their support."

THE QUEST FOR FUNDING

"Sounds great," you say. "Where can I buy PipeMan?" Well, not so fast. There's a catch. But the catch has nothing to do with the technology's usefulness or its demonstrated ability to produce: It's simply that—even now, two years after its brilliant trial run with ABE Utilities—PipeMan still isn't for sale. To be considered for manufacture, it needs just a couple more field tests, which will require more funding and/or more contractors to donate work hours and equipment time.

Bernold's research began auspiciously enough in 1994 with $50,000 from the Federal Highway Administration, succeeded in 1996 by a three-year, $300,000 grant from the National Institute for Occupational Safety and Health. But recently, funding has dried up. It's dried up despite the importance of PipeMan's objectives, despite the fact that it works, and despite the acclaim and honors it has received,

Intelligent rebar placement with planned rebar staging [for beam-joist floor] increased productivity 30 percent. Color taps on bundles show where to stage bar on formwork.

Dr. Leonhard Bernold shows Brad Barringer, president of BRS Inc., Richfield, N.C., a later model of PipeMan in the Construction Automation & Robotics Laboratory (CARL) at N.C. State. Bernold founded both CARL and the university's Center for Construction Technology & Integration (CT&I).

R. Kelly Barnhill, Jr., P.E, of the AGC firm Barnhill Contracting Co., Raleigh, N.C., tested an earlier prototype in the company's equipment yard. "All the field tests are so crucial for our research. I can't thank these contractors enough for their support," says Bernold.

including *Engineering News-Record*'s Award of Excellence in 1999.

MEET DR. LEONHARD BERNOLD

Certainly, Bernold's credentials and prolific output of inventions are not the problem. He holds a B.S. in civil engineering from the Swiss Institute of Technology, and a Ph.D. in construction engineering and management from the Georgia Institute of Technology, Atlanta, Ga. He has taught at the university level for 15 years, including 10 in his current position as associate professor in the Department of Civil Engineering at North Carolina State University (N.C. State), Raleigh, N.C. However, for purposes of this article, the most relevant office Bernold holds is that of director and founder of the Center for Construction Technology & Integration (CT&I) and the Construction Automation & Robotics Laboratory (CARL) at N.C. State. CT&I takes a multidisciplined approach, integrating CARL's research and development with the knowledge of industry, government, and many branches of academia.

ACADEMIA: THE DARK HORSE IN CONSTRUCTION TECHNOLOGY RESEARCH?

Yet, though no one would question Bernold's credentials, Allen Gray, director of the Carolinas AGC Utility Division (and one of Bernold's most fervent supporters), believes the fact that Bernold conducts his research at a university tends to work against him.

"Academics doing construction technology research have it especially rough," notes Gray. "Traditionally, people in the industry just expect the manufacturers to take care of the research, which is unfortunate. Universities tend to approach problems with long-range goals in mind, thinking about what will be best for the industry, workers, and the public. In the long run, this approach really serves everyone's self interests, including manufacturers (although corporations don't always see this). Corporate 'bottom-line thinking' asks 'Can we immediately make money off of this?'or 'Will it compete with our existing product line?'—products they may have a lot invested in researching, developing, and marketing."

THE CENTER FOR CONSTRUCTION TECHNOLOGY & INTEGRATION

CT&I's mission is to address the challenges of the construction industry in three major areas: maintenance and construction of infrastructure and other projects, hazardous site remediation, and information processing. As an independent organization, CT&I researches and develops ideas of concern to its members. It welcomes as members all U.S. and foreign organizations (including, of course, contractors) that have an interest in the Center's mission.

One of CT&I's most loyal members is the Carolinas AGC. "We believe the construction industry should jump on this," says Gray. "CT&I is really one of a kind right now. Other schools [besides N.C. State] have construction programs, but none systematically encourages collaboration between many different disciplines (the way the Center does)."

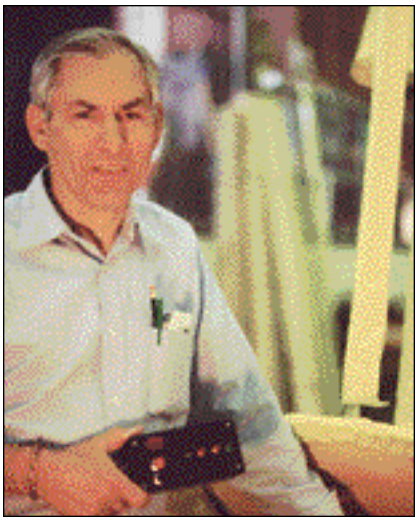
CT&I'S INVENTIONS AND RESEARCH

A number of CT&I's ideas are far past the brainstorm phase. For exam-

(continued)

A Black Box Technology sensor on the tip of a crane senses whether or not the hoist line is in a nonvertical position.

In CARL, Allen Gray stands beside the Equipment-Mounted Buried Utility Detection System (EM-BUDS), which works by attaching to excavators, trenchers, or auger drills.



Brad Barringer inspects the simple T/R/E control for EM-BUDS.

ple, the center's Black Box Technology, is a full-fledged product, patented, manufactured and sold by Elliott Technologies Inc., Apex, N.C. (For more information, call 919-303-6230.) Several others, like PipeMan, are ready or almost ready for production. What follows is a bit more on some other research and inventions by Bernold and his colleagues that your company may one day depend on.

BLACK BOX TECHNOLOGY

The crane monitoring system Black-Box Technology (BBT) can be used to train crane operators and to troubleshoot mechanical problems in old and new cranes. The technology was developed by CARL and Elliott Technologies Inc., Cary, N.C., with funding provided from the North Carolina Department of Transportation.

When attached to a crane, the BBT system senses critical data, such as load, truck incline, and boom angle. Beyond these measurements, which are also monitored by LMIs (Load Moment Indicators), BBT detects dangerous operations such as dragging and extraction. If threshold limits are reached, which place the operator and crane at risk, an alarm sounds, and data from the attached sensors is saved to a "black box," (similar to those in airplanes) that supervisors can review. A supervisor can inspect for operator misuse of equipment and equipment malfunction. BBT detects equipment misuse before any damage is done, thereby facilitating preventive maintenance.

"One of the main benefits is psychological," says Bernold, "because crane operators feel monitored. With BBT, they won't do things they might otherwise have done to cut corners, sacrificing safety for speed. It also prevents errors in judgment by giving better information on which to base decisions. BBT measures things that no product currently on the market is measuring."

EM-BUDS

EM-BUDS works by attaching sensors to excavators, trenchers, or auger drills in order to confirm the location of marked metallic utility lines and wires and to detect unmarked ones. Unlike commonly used hand-held devices, the equipment-mounted EM-BUDS puts the antenna right in the trench to accurately predict utility depth. Having undergone redesign based on field tests, EM-BUDS is now more rugged, easier to use, and ready to be tested on real construction jobs.

"You don't use EM-BUDS in lieu of the other technologies to locate facilities, but it adds a much-needed extra precaution to the process," says Gray, who has seen the EM-BUDS demo. "Because lines are too often mismarked, or not marked at all, companies don't know where the facilities are. EM-BUDS could be a true life-saver when there's a breakdown in the one-call process."

Bernold notes that by preventing damaged lines, the EM-BUDS will not only save lives, but also reduce the hidden "consequential costs"—damaged lines. "These indirect costs are often quite high," says Bernold. "Take a case where the 'official' cost (which includes only costs to the fire and police departments) of hitting a gas line is $35,000. Once you realize that a mall is shut down for one evening, the cost goes up to around $350,000. Then there are the lawyers' fees, and soon you're up to $2 million."

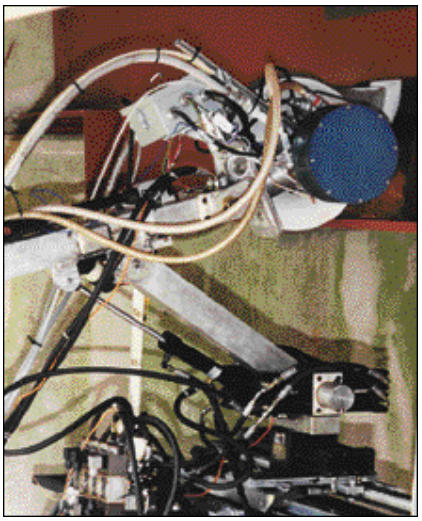
An early version of EM-BUDS was tested by Barnhill Contracting Co., with funds provided by the Federal Highway Administration's Office of Pipeline Safety.

TELE TRAINER

With Tele Trainer, equipment trainees use computers to learn controls, but it's not just a simulation—they actually manipulate real equipment. Tele Trainer consists of computer-integrated heavy construction equipment, two PCs linked to the Internet, and a human-computer interface at a remote location with joystick, audio, and video. To use Tele Trainer, the trainee sends signals to operate the equipment, and the "artificial coach" gives feed-

(continued on page 30)

The truck-mounted Robotic Bridge Maintenance System is field tested.



The robot removes paint from a bridge beam using carbon dioxide (dry ice) pellets with a centrifuge developed by Oak Ridge National Laboratory.

The Drill Shaft Inspection System.

back, letting the person identify and correct mistakes. "In effect, the Tele Trainer lets two people 'fit into the cab,'" says Bernold. "It recognizes things that a trainer could see only by being in the cab. With Internet II—the next-generation Internet tested by universities—real-time stereo images allow depth perception that makes this training idea even more effective."

Tele Trainer may also present new entrepreneurial opportunities for contractors and uses for idle equipment. "Imagine that Johnny Dig has a company and hooks up equipment he's not using (say, over the weekend, maybe) to the Internet," says Bernold. "People could dial into the Internet, pay $50, and operate the equipment."

MORE, MORE, MORE!

Bernold and his colleagues have many more construction innovations in various stages of development. Here are just a few:

Robotic Bridge Maintenance System (RBMS). RBMS has four main capabilities: remote inspection, spray washing, paint removal, and painting. The system removes the operator from direct contact with the paint removal process, contains lead-based paint, and allows tele-operation of the entire bridge maintenance procedure. Big benefits: this system constitutes a relatively simple modification to existing equipment and is easy to transport. The gantry table and robot mount to the peeper crane with four bolts and four quick-connect lines.

The Drill Shaft Inspection System (DSIS). This alternative to dangerous and difficult traditional drill shaft inspection methods eliminates the need for a human at the bottom of a drilled shaft. The main component of the DSIS is a capsule that has all the equipment needed for proper inspection: a) a remote video system that can operate in Bentonite slurry, b) an underwater positioning system for maneuvering the capsule, and c) a device for measuring the bearing capacity of the soil at the bottom of the shaft. The capsule is controlled remotely by an operator at the surface.

Computer-Aided Process Planner. This innovation augments the ability of human experts in process planning—the act of preparing a detailed plan for the production of a project unit. In one field test of the automated process planner, productivity in placing rebar for floor beam was found to improve 30 percent.

Controlling back injures. Bernold's CARL has teamed with N.C. State's Ergonomics Lab and the Duke University Medical Center to develop technological and managerial interventions to decrease the incidents of back injury for the average worker in a small construction company. These interventions include simple engineering solutions (process modifications or simple workplace modifications), more advanced engineering solutions (development of tools, lifting devices, etc.), administrative controls (managerial intervention and on-the-spot corrections), and education and training (exercise sessions, classes on proper lifting techniques, etc.).

Data entry using voice recognition for multiple users. Speech recognition as a means of entering data and commands has many intriguing benefits for many applications in construction, especially those for which the computer user needs to keep her/his hands free, as in establishing a project cost estimate with a quantity take-off program. CT&I continues to research the formidable challenges involved in developing voice recognition technology for multiple users.

FOR MORE INFORMATION

About the Center for Construction Technology & Integration (including information on becoming a member), the Construction Automation & Robotics Laboratory, or any of the aforementioned inventions contact Leonard Bernold.

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