In The Field

Knocking the Dust Off

Pressure Wave Cleaning Offers Potential New Option for Power Plants

By Sarah Stankorb

Two workers feed a hose-like lance capped with a plastic balloon into a power plant's heat recovery steam generator (HRSG), maneuvering around tight spaces between tall bundles of tubes caked with yellow debris. Meanwhile, an engineer sitting at a computer at the other end of the lance has mapped out the HRSG on a grid. The computer controls the delivery of an ethane-oxygen mix through the lance to inflate the balloon. When the balloon is positioned at the proper grid coordinates, the engineer ignites the gases inside. The pressure wave rattles the HRSG components with a boom and dislodges debris, which settles to the bottom of the HRSG.

This new process, called pressure wave cleaning, shows promise for reducing plant operational costs and enabling less expensive, more reliable electricity.

Cleaning Tubes: An Important Job

People who like their music turned up loud have probably noticed their windows rattle with the beat. They're enjoying the vibratory force of a pressure wave, which is similar to that caused by the ignited gases in the HRSG. In this case, the wave vibrates tubes just enough to rattle off debris.

Over time, power plant performance depends on keeping tube bundles clean in both coal-fired boilers and HRSGs. Tubes in HRSGs pick up heat from the plant's combustion turbine for reuse in spinning steam turbines. When those tubes become fouled—by ammonia, sulfur, or rust—the resulting back pressure can damage the turbine and increase heat rate, leading to lost energy and higher generation costs.

According to EPRI Program Manager Bill Carson, tube bundles typically need cleaning after a few years in service, and traditional methods include chemical cleaning and groom ice cleaning. Many plants' permits prohibit disposal of wastes from chemical cleaning, and groom ice cleaning requires significant work hours and resources to build scaffolding and complete the job. Considering that each approach can have drawbacks, EPRI is examining the effectiveness of pressure wave cleaning to provide utilities with another option to consider.

Pressure wave cleaning requires no labor-intensive scaffolding construction. Swiss company Bang & Clean developed the technology and in 2015 successfully tested it on an HRSG at ESB's Dublin Bay Power plant in Ireland. GE has licensed the technology in the United States.

EPRI has played a key role in bringing the technology to the United States and facilitating industry collaboration. In 2015, ESB personnel presented on their field experiences at EPRI's Boiler Reliability Interest Group meeting attended by dozens of utilities, and the group recommended that EPRI spearhead a project to test the technology in the United States. In subsequent tests in an HRSG at TVA's Southaven Combined-Cycle Plant, inspections by TVA and EPRI indicated that no component damage occurred.

Successful Demonstrations in the Southeast

Jacob Pursley is an operations technician and HRSG system owner at a power plant in the U.S. Southeast. A few years ago, a round of groom ice cleaning helped the plant to reduce problems with back pressure. "We pulled out a few tons of debris from each unit, and we thought, 'Hey, we're good to go,'" recalled Pursley.

But after three months offline during a rainy fall and a major outage, fouling again accumulated on the HRSG tubes, and back pressure increased to unprecedented levels. "I was concerned that if we went back in there with ice cleaning, had all the people in there, put up all the scaffolding, racked up all the man hours, and banged up all the tubes again—would we get the results we needed?"

After reviewing EPRI data on pressure wave cleaning, Pursley and the plant's management team decided to test GE's PressureWave Plus™ technology. The previous round of groom ice cleaning required 20 work days (10 days, two shifts each day) to clean three modules in each HRSG. Using pressure wave cleaning, the team also cleaned a fourth module that could not be reached by scaffolding, completing the entire job in 14 work days (one shift each day)—including two days for a vacuum truck to remove debris.

"The safety side of it is that nobody is inside the HRSG when it's going on, and you have none of the hazards with constructing scaffolding inside the HRSG," said Pursley.

With chemical and ice cleaning, personnel must enter the HRSG to perform the cleaning, increasing risk of injury. (To EPRI's knowledge, there have been no reported injuries as a result of these methods.)

With respect to efficacy, tests at Pursley's plant demonstrated that pressure wave cleaning can reach deeper into tube bundles and clean sections unreachable by other methods.

"Our units are near design level now," says Pursley. "It's like we just put in two brand new HRSGs."

The Work Ahead

A preliminary finding from these and other field tests since 2015: In the near term, it appears that pressure wave cleaning does not result in cracking or other adverse metallurgical impacts in tubes, liners, and other HRSG components. With the Colorado School of Mines and other partners, EPRI will follow the development of this technology and continue field testing to confirm that there are no such short-term effects. It will also examine potential long-term effects on component integrity and plant reliability.

Pressure wave cleaning must be done when the plant is offline, but that could change.

"There is potential for online cleaning in conventional boilers," said Carson. "EPRI will be looking into that with Bang & Clean."

EPRI also will examine pressure wave cleaning for air heater baskets, electrostatic precipitators, wires, and other boiler surfaces.

"It's premature to say that pressure wave cleaning is superior to other methods," said Carson. "EPRI is still researching the technology and its possibilities. But early results show that it could offer the industry new options."

Key EPRI Technical Experts

Bill Carson

Technology At Work

Maximizing Reliability of Instrumentation and Controls

EPRI Collaborates with Chinese Nuclear Utility to Transfer Insights from Successful Reliability Program

By Scott Sowers

An EPRI report documents an innovative program at China General Nuclear Power Corporation (CGN) that has significantly reduced the frequency of unplanned reactor shutdowns related to instrumentation and control (I&C) equipment failures. The product of a two-year collaboration between EPRI and CGN, the study offers insights and lessons to nuclear operators worldwide.

I&C equipment serves as a nuclear power plant's central nervous system, measuring and controlling various parameters for safe, reliable operations. While most printed circuit cards that reside in the equipment continue to work well, the nuclear industry has observed that more circuit cards are failing, leading to unscheduled shutdowns, lost revenue, and other operational problems for power producers.

"Failure rates have increased primarily due to component aging and improper storage and handling," said EPRI Technical Leader Stephen Lopez.

A New Program to Reduce "Scrams"

Beginning in the late 1990s, CGN plant workers noticed an increased frequency of unplanned shutdowns, or "scrams," attributable to failing circuit cards and I&C equipment.

"I&C reliability was the main contributor to scrams in our nuclear power plants," said Ma Shu, a chief engineer with CGN. "We discovered that these issues created 70% to 80% of our unplanned outages, many of which occurred at peak demand."

To reduce these scrams, CGN developed and implemented an I&C aging management program, with positive results: While there was an average of nearly six unscheduled shutdowns per year in the late 1990s as a result of I&C equipment failures, no such incidents were reported from 2003 to 2013.

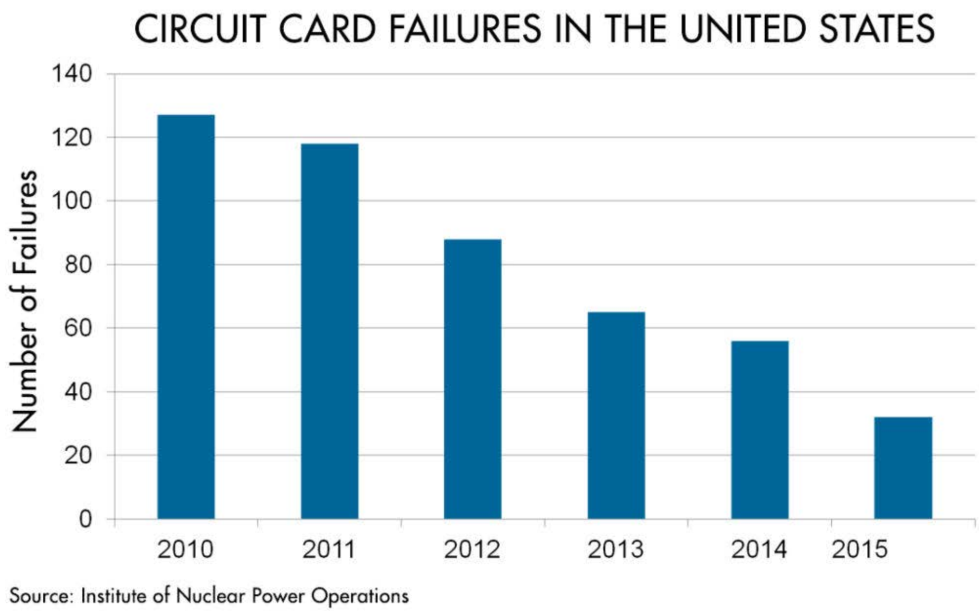
The program categorizes components based on how essential they are to reliable operations along with their aging characteristics, then tracks failure rates throughout the life of the equipment. Different strategies are assigned to each category and stage of equipment life to help prioritize testing, monitoring, and maintenance. CGN also developed technical standards and technologies to diagnose degradation and faults in circuit boards and other I&C components, including power supplies, fuses, and relays.

The program's other key aspects include:

- A database for tracking equipment status, test history, and operating experience
- Monitoring plant environmental conditions, such as temperature, humidity, and radiation
- Preventive maintenance and replacement of critical equipment with spare parts

After CGN joined the Instrumentation and Control Program in EPRI's Nuclear Sector in 2014, EPRI researchers made a series of visits to China to learn how the program reduced I&C-related reactor and turbine trips and to collaborate on technology transfer.

"The best way to reduce circuit card and circuit card–related I&C failures is to study reliability, develop a program that monitors components and mitigates failures, and then implement and track the program," said Lopez. "CGN dedicated funding to long-term planning and resource development that supported new laboratory testing facilities and highly qualified staff to operate and manage them. Another strength is CGN's use of metrics to benchmark the performance of its reliability program against other such programs."



Since EPRI launched its Gold Card project, the number of circuit card failures has significantly decreased.

"It's our honor to become a member of EPRI. We are delighted to see CGN working with EPRI on technical collaboration," said Ma Shu.

EPRI has been examining I&C reliability and circuit card issues in nuclear plants for more than a decade. Published in 2010 and updated in 2011, EPRI's "Gold Card" report provides information on degradation mechanisms and failure risks for I&C circuit cards, along with best practices to prevent failures.

The nuclear industry has used the Gold Card report and other guidance to improve circuit card reliability, as demonstrated by declining circuit card failures reported to the Institute of Nuclear Power Operations (see chart). CGN has used the EPRI guidance to enhance equipment storage, refurbishment, and processes to control electrostatic discharge. As another example, FirstEnergy has applied it to reduce "infant mortality" failure (occurring shortly after components are installed) and to improve its circuit card refurbishment process (see p. 34 in the Winter 2014 issue of *EPRI Journal*).

"Through the exchange of information and technology, EPRI continues to help address challenges facing the nuclear industry by bringing together its members and diverse scientific and technical communities," said Lopez.

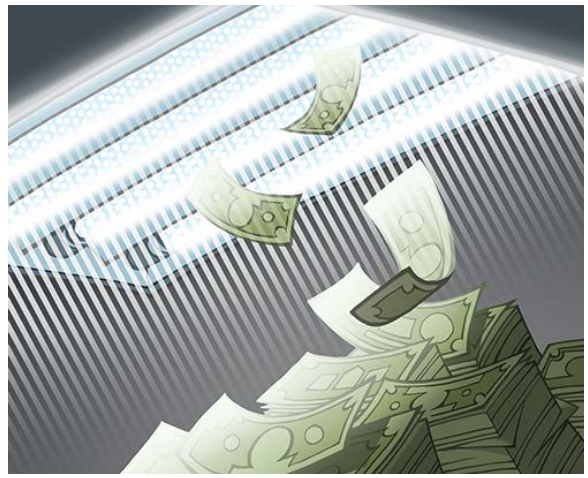
Key EPRI Technical Experts

Stephen Lopez

R&D Quick Hits

Gigawatt-Hour Savings in Store?

Study: LEDs Can Replace Fluorescent Lights with Equal Performance and High Efficiency



An EPRI study indicates that utilities should consider linear light-emitting diode (LED) lamps and troffers for rebates and incentives in their energy efficiency programs to replace linear fluorescent lights in the commercial sector. The switch offers significant energy savings with adequate light levels and payback.

Researchers scanned the LED market for potential fluorescent light replacements and examined 20 products in EPRI's lighting laboratory, measuring light output, efficacy, illuminance, energy savings, and payback. LED lamps offered energy savings of 25–61% relative to fluorescents. LEDs in dimmable troffers provided 28–36% savings at full output and 47–53% savings when dimmed to match the fluorescents' luminous flux.

Based on energy savings, LED lamp payback is 1–5 years, while payback for the more expensive troffers is 10–12 years. If LEDs last longer than fluorescents as manufacturers claim, reduced maintenance costs could shorten payback.

Because of varying LED product designs, the authors recommend that utilities vet products before providing rebates. They point to additional potential energy savings when dimmable LED troffers are combined with networked controls and demand response programs.

For decades, linear fluorescent lights have dominated U.S. commercial and industrial lighting. Replacing them with LED products offers the potential to save thousands of gigawatt-hours per year.

R&D Quick Hits

Driving Cleaner Air in the Tennessee Valley

EPRI Study: Driving EVs and Off-Road Electric Equipment Could Improve Air Quality

By 2030, deployment of electric vehicles and off-road electric equipment can lead to modest, but widespread, emissions reductions and air quality improvements in the service area of Tennessee Valley Authority (TVA), according to an EPRI study.

Using an EPRI model and TVA market data, researchers projected that in 2030, electric vehicles would account for 9% of vehicle miles in the TVA region, and various types of electric off-road equipment would capture market share ranging from 17% to 85%. Based on this, they modeled the impacts on air quality and emissions. Main findings:

- Ozone decreases across the region, including reductions of up to 1 part per billion in urban areas. This is significant given the stringency of the National Ambient Air Quality Standards.
- Nitrogen oxide (NOx) emissions decrease by 3%, with 44% of the reduction coming from off-road electrification.
- Volatile organic compound emissions decrease by 5%, with 65% of the reduction coming from off-road electrification.
- Particulate matter emissions decrease by 1%, mainly in urban areas and along interstates in eastern Tennessee, with 79% of the reduction coming from off-road electrification.

Electrification more extensive than that modeled in the study could reduce emissions more significantly. The TVA results mirror those of a 2015 EPRI-Natural Resources Defense Council study that quantified nationwide air quality benefits from increased vehicle electrification.

R&D Quick Hits

What Might the Electricity Mix Look Like in 2030?

EPRI Models 13 Scenarios to Examine Key Uncertainties

Between 2015 and 2030, coal's share of the U.S. electric generation mix could decline significantly, while natural gas's share is likely to grow, according to a recent EPRI study.

Using EPRI's U.S. Regional Economy, Greenhouse Gas, and Energy (US-REGEN) model, researchers examined 13 scenarios, including low and high natural gas prices, flat and increasing electric load, low-cost utility-scale solar photovoltaic technology, refurbishment costs for aging coal- and natural-gas-fired plants, potential paths to implement the federal Clean Power Plan, and other policies to reduce CO_2 emissions in the U.S. electric sector. Key insights:

- Between 2015 and 2030, coal's share of the U.S. generation mix could decline from 33% to less than 25% if natural gas prices remain low, new federal climate policies are enacted in addition to the Clean Power Plan, or aging coal units face significant refurbishment costs.
- New natural gas generation remains a significant part of the U.S. generation mix in most scenarios, including those with a stringent CO_2 emissions cap, and is expected to grow significantly in some scenarios. The main risks are high natural gas prices and targeted regulation to reduce dispatch or deployment of natural-gas-fired units.
- Relative to natural-gas-fired generation, renewable generation from utility-scale wind and solar power remains economically uncompetitive in most scenarios without CO_2 policies, even with a 17% reduction in capital costs for onshore wind between 2015 and 2030. This result is driven by the assumptions of low natural gas prices, expiring tax credits, and no further increases to state renewable portfolio standards.
- Existing and new nuclear generation are expected to be competitive in scenarios with significant CO_2 reduction requirements or high natural gas prices.

R&D Quick Hits

Time to Plan for the Future Workforce

Knowledge related to nondestructive evaluation (NDE) in nuclear plants needs to be preserved and transferred to a new generation of workers, or it will be lost, an EPRI study concluded.

A 2016 survey of major NDE personnel providers for the nuclear industry found that:

- About half the workers are older than 45, and about 25% are older than 55.
- Since 2014, the size of the workforce has declined by 3% each year.
- Trainees and workers with entry-level certifications account for 6% of the workforce—not enough to fill the gap left by retiring workers with higher level certifications.

Over the next 10 to 20 years, half of the NDE personnel will potentially leave the workforce. To sustain safe, reliable operations of the nuclear fleet, the authors say that it is essential for industry stakeholders to collaborate on recruitment of new personnel for NDE careers.

R&D Quick Hits

Go with the (Better) Flow?

Study: Highly Fluid Concrete Can Reduce Time and Labor of Nuclear Plant Construction

Self-consolidating concrete offers potential to significantly reduce time and construction costs associated with placing concrete for nuclear power plants, according to an EPRI study.

Photo of construction of Vogtle Unit 3 courtesy of Georgia Power.

When conventional concrete is placed, technicians must temporarily liquefy it with vibrators so that it flows around obstacles and fills forms. This is particularly labor-intensive work in building nuclear plants' complex structures with reinforcing steel. Developed in Japan in the mid-1980s, self-consolidating concrete contains chemicals that promote fluidity and stability and has been used successfully in commercial and industrial buildings and nuclear plants in the United States and China. When placed in one area of a concrete form, it flows throughout the form without the use of vibrators, potentially reducing time and labor.

Laboratory tests determined that it has slightly higher compressive strength relative to conventional concrete, given comparable water-cement proportions. Self-consolidating concrete exhibited slightly more shrinkage and slightly less splitting tensile strength. In test molds for power plant foundations and walls, self-consolidating concrete flowed freely through complex structures (see video).

As with conventional concrete, researchers found that careful selection and proportioning of ingredients can help avoid problems such as segregation. Different mixtures may be needed for different plant structures.

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