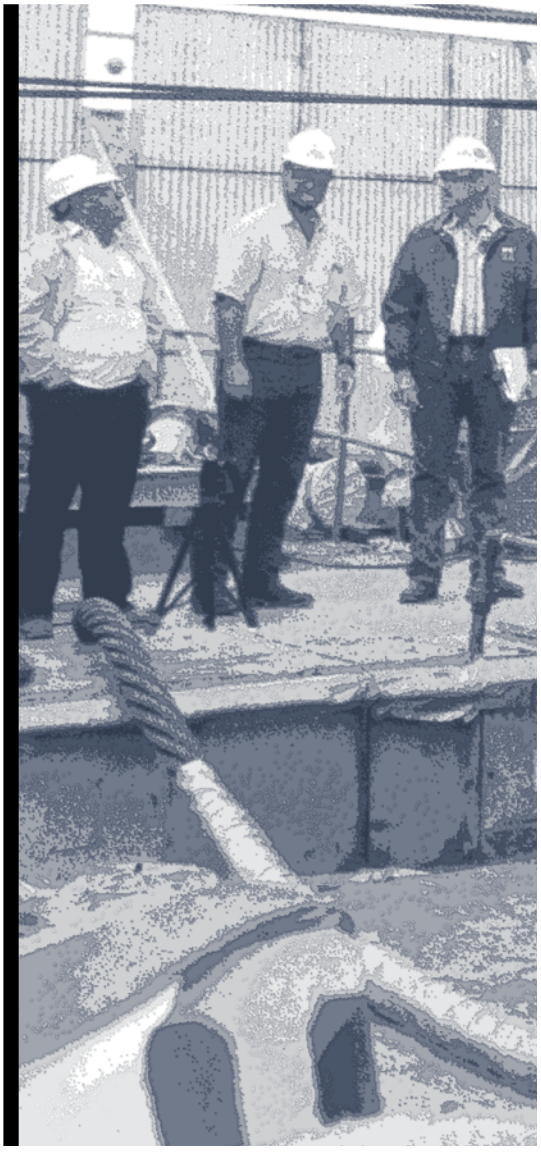
Condition monitoring and proactive repair or replacement can head off major downtime and expense

MAIN GENERA CHALLENGES



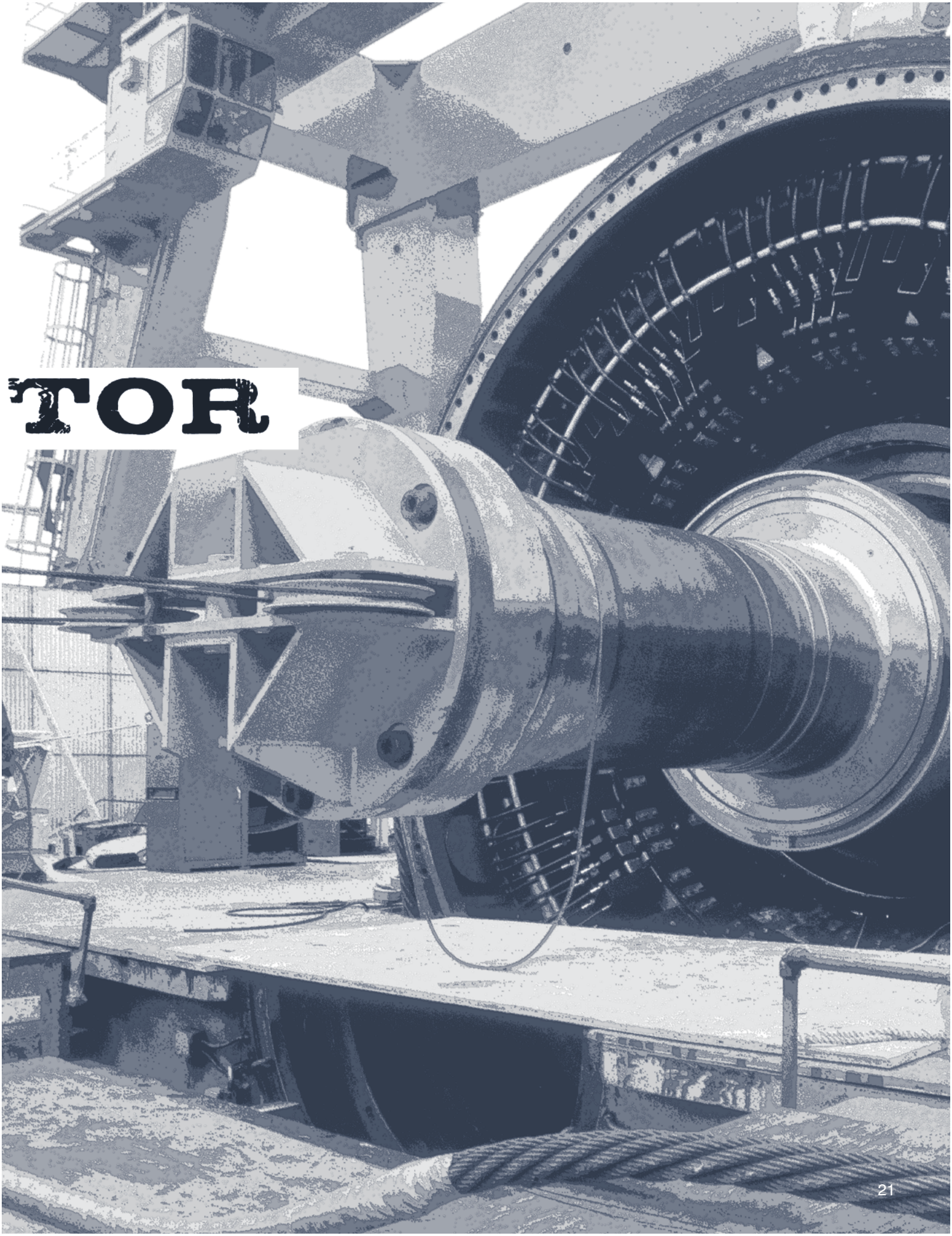
Output from U.S. nuclear plants grew steadily from the 1970s through the 1990s. But early in this century, that trend was interrupted by a significant increase in lost power generation. One of the major causes: main generation problems. Four predominant problem areas were identified: generator rotors; excitation systems (particularly the voltage regulator); stator cooling water; and hydrogen leakage.

To assess the problem and develop strategies for dealing with it, the Institute of Nuclear Power Operations analyzed the problems in two Topical Reports (TR4-38 and TR6-51) and conducted main generator review visits at 14 nuclear stations in 2004 and 2005. Among the industry experts who participated in some of these visits were Randy Bunt, a Southern Nuclear Operating Company project engineer; Russell Chetwynd, a turbine generator component engineer at Southern California Edison's San Onofre Nuclear Generating Station; Bob Tomala, a senior turbine generator engineer at Exelon Corp.; and Jan Stein, an EPRI senior project manager.

The Nuclear Professional asked these experts about ways of identifying and resolving main generator problems.

Q There was a marked increase in main generator problems about six years ago. Why?

Bunt: The major factor is the age of the machines. Most came into service at the same time. Also, plants are running longer between outages and major maintenance. The curve of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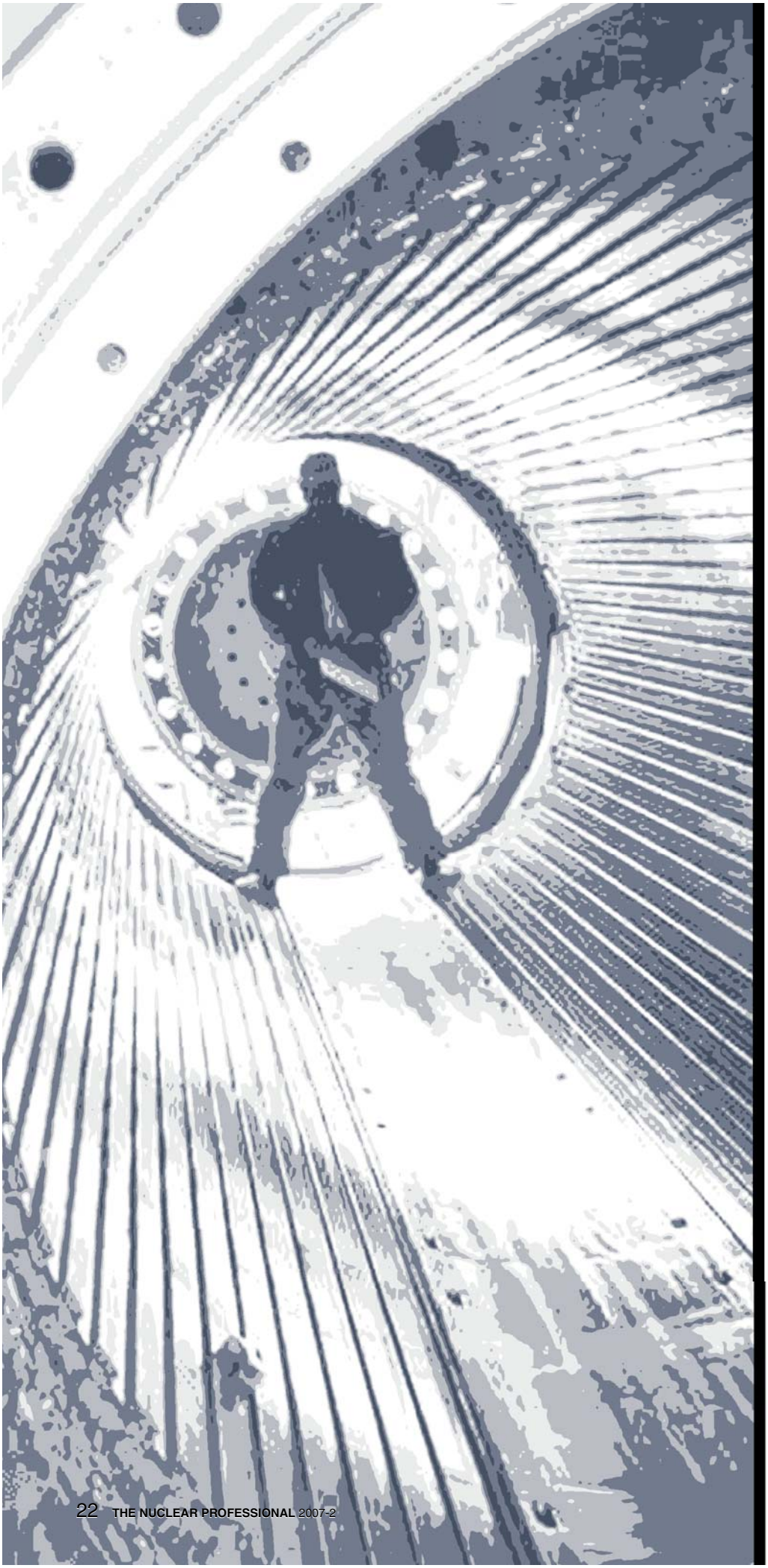

main generator events almost parallels the curve of capacity factor increases. There's another factor, too. Nationally, the experience level of station personnel is lower, and the number of people allocated to a job is fewer. Consolidation of the fleets has created a larger base supported by fewer people. Finally, outages are shorter, and most generator activities are not performed online.

Tomala: I agree, it's the age of the fleet. We're starting to see the failure of the weakest links from the construction of these machines – the first components that have the least amount of margin in their design. I also believe that some of the decline in generator reliability is a result of increased inspection intervals. The reasons for extending intervals are the time required for full disassembly and inspection of the main generator, outage scheduling constraints, and budgetary constraints. Much of this is the result of the increased competition within the power industry.

Chetwynd: With deregulation, there was a change in the general business of the electricity system. The electricity distribution grids are now run separately from the power plants. Sometimes, the way the grid is operated can put more stress on the system, and this directly affects the generators.

Q How widespread are these problems in the U.S. nuclear fleet?

Chetwynd: There's something called the "bathtub" curve – a generator reliability curve. In the early years of their lives, plants are expected to

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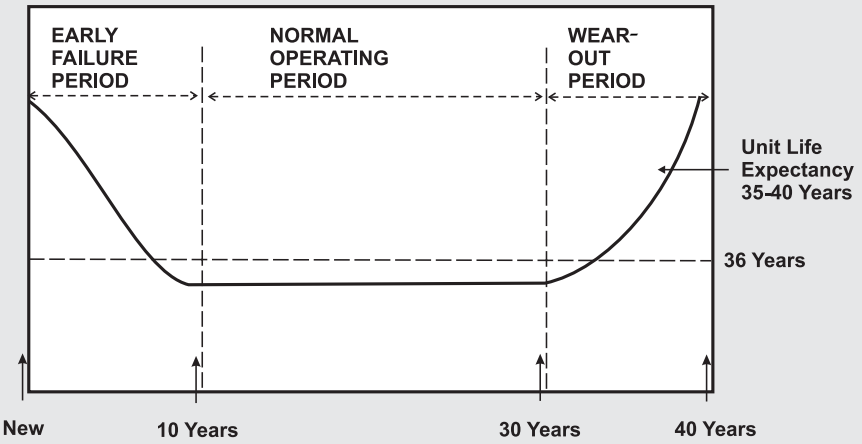

have problems, but they have a large staff that is used to dealing with these problems. Then, for the next 20 years or so, things go fairly well, the problems are sorted out and the plants reduce staff. But after about 20-30 years of operation, things start to wear out.

The key is to recognize that aging is occurring and that all plants have essentially the same kind of equipment, regardless of vendor, and thus much the same kind of problems.

Tomala: Certain issues are associated with various manufacturers, but generic issues are widespread. What concerns me the most, because we understand it the least, are the effects of interaction with the electrical grid. There's not as much excess capacity on the grid as in the past, due to today's competitive marketplace. Less spinning reserve is available, so perturbations can't be accommodated by excess capacity. We're starting to see dings and hits coming back through the electrical system, and they're having a mechanical effect on the machines.

EPRI's Jan Stein issued a report on a study of grid effects on generators. It made a dent in where we need to go, but there is a lot left to understand about what's happening technically.

Stein: Generator problems start with a few plants, and then grow to impact a large part of the fleet. If you don't have a problem, you should be prepared for one.

Q To what extent can these issues be attributed to equipment performance? To operations?

Bunt: Voltage regulators are in the 25-35 year age bracket, and most are on the verge of end of life. Exciters have been very reliable over the years but are also reaching their end of life.

Rotor problems are probably more related to operating issues or maintenance. As plants upgrade, it changes the stress on the machine. When you increase output, you change the sequence for loading electrical demand on rotor components.

Part of the issue with cooling water chemistry is the design of the system. That design makes it prone to operation in less-than-optimal conditions. If stator water gets into the transition region between high and low dissolved oxygen levels, it can cause plugging or erosion, depending on other parameters. Particular parameters need to be monitored, and historically this wasn't done rigorously.

Tomala: Equipment performance is the major factor in all four areas. In this day and age, we are so driven by operating procedures. These procedures can be a good barrier to operational-related problems.

Chetwynd: For hydrogen leakage, the operations/maintenance factor is greater than the effect of equipment degradation. Aging equipment starts to leak more, but if it's managed better, leakage problems can be controlled.

Stein: Rotor problems are mainly an equipment aging issue, as are exciters and voltage regulators. Water leaks are an equipment aging issue, while chemistry problems are an operations issue. Hydrogen leakage is mostly an operations problem. But if the generator wasn't put together correctly, it can leak.

Q What is being done to address these problems? What can be done?

Chetwynd: If you have good monitoring equipment, such as flux probes, you can see rotor problems coming

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"… This is the benefit of being proactive. If you let [thermal damage] get away from you, it can cost roughly $15 million for a new winding – and a couple of months or so of downtime." – Russell Chetwynd

– you can stay ahead of equipment problems. If people are monitoring and management is prepared to invest proactively, you can address rotor problems. Initially, we were reactive and didn't anticipate the problem. But when we saw it, we promptly invested in spare and rewound rotors.

With stator cooling water, you have to be able to monitor the dissolved oxygen in the water as well as the temperature at which you're operating. If the temperature starts to increase, you've likely got a cooling problem. If you jump on it, you can avoid having to buy a new winding by stopping thermal damage to the insulation. This is the benefit of being proactive. If you let it get away from you, it can cost roughly $15 million for a new winding – and a couple of months or so of downtime.

With hydrogen, there is a myriad of places it can leak. You're more likely to have problems if you don't look for them. Experienced maintenance people say, "I don't like the look of that gasket, we'll put in a new one."

Monitoring and life cycle management are the ways to deal with aging. A preventive maintenance program is good for the first 20-30 years, but it won't work to get you to 50-60 years. That's where life cycle management is critical.

Bunt: Deciding which inspection and type of inspection to perform requires a knowledge of the history and operation of the plant. It's based on indicators, monitoring and past inspections. It goes back to having knowledgeable people who plan maintenance and take care of the health of the machine.

For cooling water, monitoring the chemistry is the critical element. You're less likely to know the baseline conditions because you can't physically see the places that have corrosion. You have to be prepared for replacement if you believe you're susceptible.

Getting a monitoring system with constant data can be expensive, so some plants hook up monitoring tools, such as flux probes, when another indicator shows a problem.

Hydrogen leak mitigation schemes may not be adequate. Prepare before you get leaks.

Stein: Employ condition monitoring while the unit is running. And question anything out of the ordinary, find out what is the root cause. When planning an outage, you should look at all the monitored information, know what to look for and have a contingency plan for fixing it.

It goes back to life cycle management. If you have a 30-year-old rotor and you know other people have had problems, you should plan for a replacement before you have a problem. You could take an old rotor and refurbish it, and keep it as a spare.

Tomala: We may not be moving quickly enough on exciters and voltage regulators. I'm not comfortable that we have our arms around the issue and have a successful long-term plan to keep them running.

We have continuous dissolved oxygen monitors for our stator cooling water on some of our units, and other plants are starting to do this. It allows continuous on-line monitoring of the quality of the cooling water.

We do inspections of hydrogen coolers, eddy-current testing, and, at some plants, we do a bubble test. Everyone should be doing air tests at the end of an outage before hydrogen is added. Manufacturers recommend looking for pressure to drop over 24 hours and calculating the leak rate. Because of efficiencies and shorter outages, we do snoop leakage inspections over the machine while monitoring pressure decay.

Q What is the role of engineering in dealing with main generator problems?

Tomala: Engineering is the hub of anything that goes on at the plant, whether it's corrective action recommendations or root cause evaluation. Everyone looks to engineering. System engineers are doing the monitoring. Even if operations personnel collect data, the engineering department does the trending. Engineering establishes the preventive maintenance scope and intervals. Engineering gets involved in

evaluating repairs and deciding on the right approach. It identifies improvements and is tasked to get those improvements communicated to – and approved by – management.

Many new monitoring capabilities are available today, for example; but monitoring systems compete with other station priorities. A lot of these systems fall into a low-probability but high-consequence type of failure and are hard to cost justify. You need to push to get some of these monitoring improvements. You need to focus on convincing management of the need and benefits of such devices.

Chetwynd: Senior management has to decide where to spend its money. Engineers responsible for generators have to be persuasive about why they need the money.

Stein: Engineering has to have the knowledge to put all the warning signs together. It can be very confusing. It's not like a car, where a light goes on telling you that you should change the oil. Engineers see the symptoms and they need to make a diagnosis. Once they have a diagnosis, they have to develop a plan to address it. They have to be prepared for the problem.

Bunt: You must have good fundamental knowledge of how equipment works, a network of mentors or peers that you can ask questions of, a good working knowledge of how things come apart and go together, and where technical information is located. All of these are tools that a quality engineer would use in his or her job, no matter what equipment is supported.

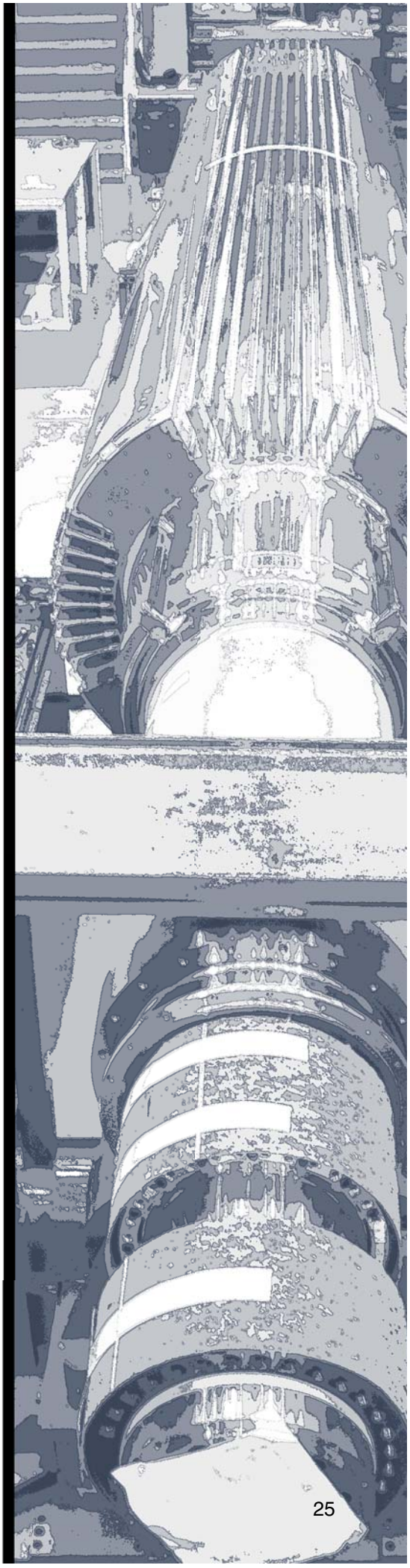
Q What resources are available for addressing main generator problems?

Chetwynd: EPRI has a turbine generator user group, which meets twice a year. I'm the chairman of that group. We swap experiences and thus learn from each other. There's also a turbine engineer network – it's almost like a

INPO VISITS LOOK AT MAIN GENERATORS

INPO is performing one-week, in-depth main generator review visits, with teams comprised of an INPO lead and up to three industry peers. Teams review key programs associated with the main generator and support systems, including preventive maintenance, on-line condition monitoring, outage inspections and testing, operational contingencies, and life cycle management. The industry experts referenced in this article have each participated on at least two review visits.

Specific recommendations and strengths from main generator review visits are available on the Evaluations page of the INPO member Web site. For additional information, contact Geoff Seguin, (770) 644-8780, *seguingc@inpo.org*.



blog. Someone sends an e-mail – I've got this problem, what do you think is going on? – and waits for replies.

The expertise is out there, and communications we have really help. If you're not a player, you won't get help. After INPO review visits, senior executives will sometimes encourage middle management to get more engineers out to these conferences.

Tomala: The guide prepared by the INPO main generator working group for use during the site visit reviews is a template for a good generator program. It addresses all aspects of generator systems – material condition issues, different monitoring requirements, preventive maintenance and operational good practices.

Once we were aware of this guide, we encouraged its use and review by all system engineers.

Stein: EPRI has two meetings a year where we discuss turbine and generator problems. The generator manufacturers have user groups that meet once a year, and there are the professional societies. There are opportunities to share information. But one problem is that system engineers often don't have time to attend these meetings, and they may not be encouraged to attend by their management.

EPRI is working with INPO to develop a hydrogen system maintenance guide. It will be published by the end of this year. The guide will include predictive maintenance tasks and their frequency, where leaks occur and what is acceptable.

Bunt: I'm a big proponent of industry involvement – user groups and Web conferences.

Q What impact does the industry's aging workforce have on resolution of generator problems?

Chetwynd: The aging workforce is an issue. If management is to spend proactively, you have to put a strong case for why your equipment needs to be replaced. The better you understand your equipment and can communicate this to management, the greater your chance of getting investment.

Referring to the "bathtub" curve, if you were working during the early years of the plant's life, you're better able to deal with the back end of the curve, 20-30 years into the plant's operation. You know where to look for problems and how to find them quickly.

If young engineers don't have experience in root cause analysis and troubleshooting, they need to go out and get training.

Tomala: The aging workforce concerns me. We're seeing it within equipment manufacturers as well as utilities. We're starting to lose a lot of corporate knowledge and history.

We need to recruit and hire young workers into the industry and we need more of an apprenticeship system. That's not always happening. ■

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