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CCJ COMBINED CYCLE Journal

User Group Reports

HRSG FORUM WITH BOB ANDERSON

The inaugural Forum, held at EPRI's conference center in Charlotte, received favorable reviews from attendees who shared their thoughts with the editors. Two topics of great interest to participants: (1) How innovations in steelmaking are changing the way pressure-part materials behave—and not necessarily for the better. (2) Experience with drones for boiler inspections shows how quickly these unmanned aerial system tools are becoming an industry standard.

W.T.U.I. 1990 2017

The world's largest conference supporting gas-turbine owner/operators, the all-volunteer Western Turbine Users attracted to Las Vegas in March more than 1100 attendees from 20 countries and 41 states. CCJ's coverage begins with these highlights:

Presentations and discussion included repair of casing leaks at the horizontal joint, valve inspection, repair, and maintenance, varnish solutions, diaphragm dishing, re-rounding of casings, rotor straightening, high-speed balancing, experience with PAG lubricants, inspection of blade roots, OEM maintenance guidelines, casing crack repair

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'Barry Dooley,'

Said the voice at the other end of CCJ's editorial phone.

Dr R Barry Dooley, a member of this periodical's Editorial Advisory Board, was in the Midwest sharing his extensive knowledge of cycle chemistry with users responsible for maintaining generating assets in top condition and had a few minutes to update the editors on recent observations.

Dooley, a senior associate at Structural Integrity Associates Inc by day, gives generously of his personal time. He serves as executive secretary of IAPWS (International Assn for the Properties of Water and Steam) and leads that organization's efforts in the development of Technical Guidance Documents (TGD) on various aspects of cycle chemistry and best practices. Dooley also chairs, or is a member of, steering committees for user organizations dedicated to heat-recovery steam generators in the US, Western Europe, ANZ, Russia, and Canada.

The water doctor called shortly after chairing the European HRSG Forum in Amsterdam, which attracted about 80 attendees from 19 countries. Open discussions on flow-accelerated corrosion, he said, revealed several examples of misidentification of FAC. This is something he also finds at meetings of the other HRSG forums and user groups.

Dooley went on to say that in the last six months, at plants investigated by him worldwide, there have been four examples of misidentifying FAC as single-phase in LP evaporators—when the damage clearly was two-phase. This is important, he continued, because there are different cycle-chemistry solution approaches for each.

Dooley stressed once again these three cycle-chemistry points for controlling FAC in combined-cycle plants:

- Operate only in the oxidizing mode—AVT(O) or OT—to eliminate the possibility of single-phase FAC. No reducing agent should be added to the steam/water cycle.
- Operate within a tight pH range, one approaching 9.8, to mitigate/eliminate two-phase FAC.
- Monitor total iron to determine the optimum chemistry. Acceptable ranges for total iron in feedwater and drums of combined-cycle plants are included in the IAPWS TGD "Corrosion Product Sampling and Analysis. . . ." Download the document at no cost from www.iapws.com.

The Amsterdam meeting also revealed three examples of plants not properly addressing damage/failure. One was a thermal-fatigue problem in a drain pot, the others were corrosion fatigue in tubes and drums.

Dooley said, "the approach has been concrete for over 30 years that the first step is to take a sample of the failure/damage" so the mechanism can be identified. Next, identify the possible root causes (could be multiple). Then provide a solution to address the most probable root cause.

The last step involves identifying the geography and history of the damage/failure, and the operating spaces. The mechanism only can be eliminated by addressing the problem at the root-cause level, he said The key message delivered in Amsterdam was that every effort should be made to remove samples of damage and failure when it first occurs. Examples emerged of multiple failures when the first was not removed for examination.

Dooley then transitioned to recent experience with film-forming products (FFP), a subject of great interest to owner/operators today. He mentioned IAPWS' recent efforts regarding FFP: Publication of a TGD, "Application of Film-Forming Amines in Fossil, Combined Cycle, and Biomass Power Plants," in November 2016, plus an international conference on the subject in Lucerne (May 2017).

Dooley noted that while there have been many problems associated with the use of FFPs worldwide, in all of the cases investigated by him, the issues were traced to plant personnel not comprehensively addressing or understanding baseline conditions before applying the FFP, and/or not knowing the complete composition of the FFP applied. Guidelines are provided in Section 8 of the IAPWS TGD.

CCJ COMBINED CYCLE Journal

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Recent D-11 outage experiences:
The good, the bad, the ugly

Perhaps the biggest benefit of user-group meetings is the access they provide to the experiences of others. You can't come close to learning all that you probably should know by simply working at your plant—even if you're the most diligent person on staff. It's important to expand your knowledge horizons by gaining exposure to things you might not imagine could happen, but have. This improves your ability to make informed decisions.

The Steam Turbine Users Group (STUG), like most independent user


G1


G2


G3


G4

The Good

Hydraulic actuators were cited as the "most overlooked" powerplant component. Actuators in Fig G1 await proper crating (Fig G2) for shipment offsite to overhaul shop. Speaker recommended a complete overhaul of actuators at every steam-turbine (ST) major; inspection and refurbishment of hydraulics (servos, fast-acting solenoids, etc) at every ST minor.

Takeaway from the user sharing his experience was that Rexroth (Bosch Rexroth Corp) makes a good actuator but it's difficult to find an experienced and competent overhaul shop. RPM LLC, a subsidiary of Mechanical Dynamics & Analysis (MD&A), was cited as a preferred shop by one user who said the company has repair kits for all Rexroth ST valve actuators. The user went on to stress the importance of proper packaging for shipment to protect the actuator from damage.

Proper tooling is required to both protect turbine components and assure timely completion of outages.

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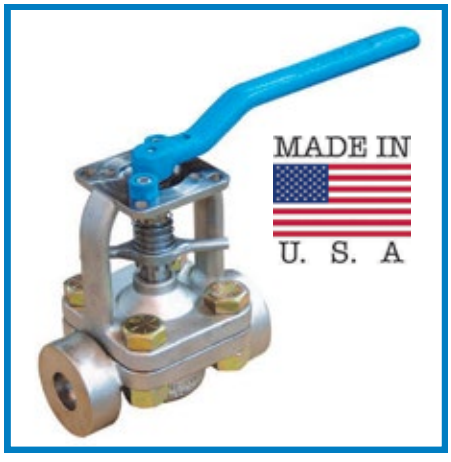

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organizations serving the electric power industry, is managed by a steering committee of veterans who relish learning, promoting safe work practices, sharing experiences, and righting wrongs (box).

Be sure to attend the 2017 meeting, August 28-31, at the Sheraton Grand at Wild Horse Pass, Chandler (Phoenix), Ariz. Visit www.stusers.org for details.

The information below, based on a discussion of D-11 outages at the 2016 STUG conference, is not a typical CCJ article, but rather a few photos and explanatory captions of the many experiences shared by users. It's a good way to learn.


G5


G6


G7


G8


G9


G10


G11


G12

Examples: Fig G3 is a stand for properly supporting the outer shell of a D-11 HP turbine. The user sharing recommended not putting components on bare ground.

The diaphragm lifting tool in Fig G4 sits on the horizontal joint and removes all diaphragms with one crane lift, saving a great deal of time over the alternative—a series of individual lifts. Store diaphragms in a rack such as that shown in Fig G5, which can accommodate both inspection and light maintenance.

Generators got some air time in the STUG sessions. Fig G6 illustrates a user's recommendation for assuring a complete seal around the end bell by drilling extra holes for sealant entry (arrows). Fig G7 shows a reference chamber on the generator for faster verification of hydrogen leak test—four hours versus 24 previously.

Cranes can be a significant line item on an outage budget so there's financial upside to minimizing the number required and their time onsite. A utility engineer demonstrated a rigging technique to flip a HP casing with one crane; follow Figs G8 through G12.

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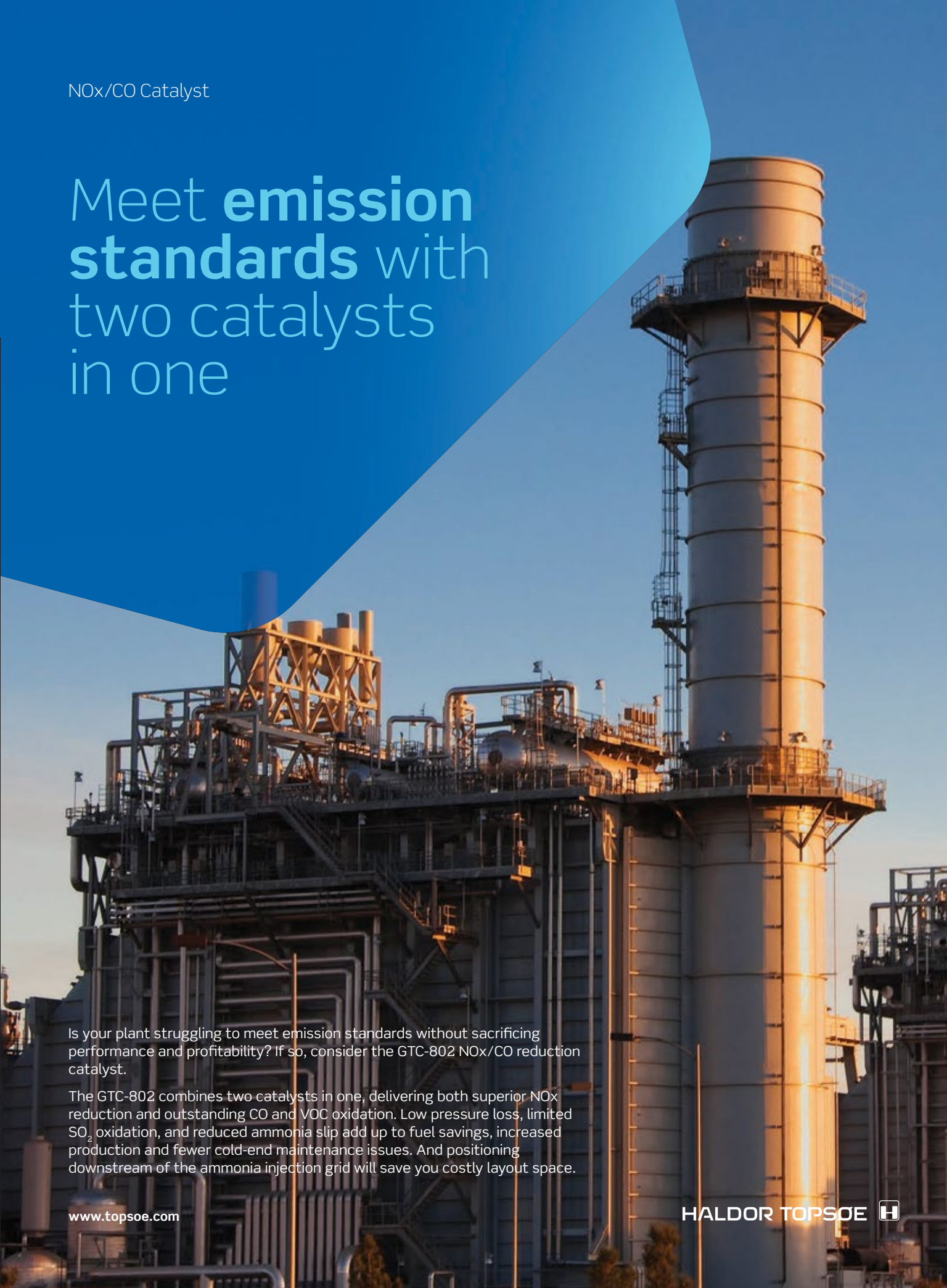

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Here's how this type of session is conducted: A participant without prepared notes comes to the front of the room, flashes a photo up on the screen, and says something like, "Know what this is?" or "What's wrong—or right—with this picture?" Impromptu discussion ensues, instant sharing of information proceeds across the meeting room. If you're not sure what the exchange of ideas is all about, just sit there, listen, and learn. And ask questions. CCJ

STUG
STEAM TURBINE USERS GROUP

2017 Conference and Vendor Fair

Sheraton Grand at White Horse Pass
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John McQuerry, *Calpine Corp*
Lonny Simon, *OxyChem*

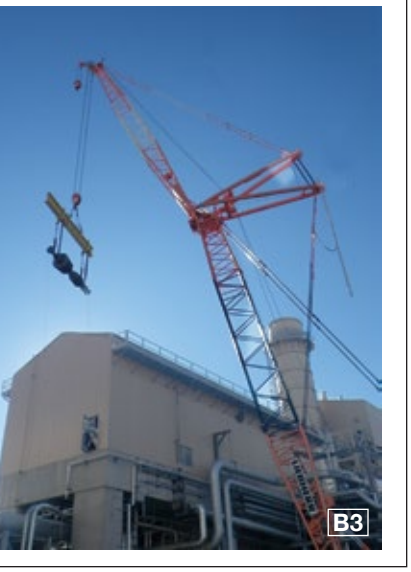
The Bad

No overhead crane was provided for turbine casing and associated lifts. The outdoor steamer is on the other side of this 90-ft-tall building (Fig B1) and the only way to access it is to reach over the top of the structure with a 600-ton crane, shown at rest in Fig B2 and at work in Fig B3. A crane like this can cost half a million dollars for a major outage.

Bolts visible in balance chamber for the combined stop/control valve are prone to failure (Fig B4). Speaker recommended their replacement every outage. When the bolts break, the balance chamber drops down and rests on the control valve, impeding its operation.


B1


B2


B3

"Walk your lines," a user told the group, using Fig B5 to show electrohydraulic control oil lines retained with U clamps (arrows). Vibration can wear lines at these points and cause leaks. On rounds, be on the lookout for obstructions and wear and insert "softeners" where appropriate.

Broken shaft (coupling) on electrohydraulic-control-oil (EHC) pump can be a real nuisance (Fig B6). To access the damaged part and replace it, you have to pull the motor located alongside the cylindrical oil conditioning unit in Fig B7. In cases where the pump and its suction strainer are installed in the oil reservoir, a forced outage may be necessary. The speaker recommended installing a longer shaft between the motor and pump to make the coupling accessible.

Failed O-ring in an EHC line to the actuator for a D-11 interceptor valve forced a 500-MW unit out of service. Control oil was found leaking from the connection. Root cause: The wrong-size O-ring (at top in Fig B8) was used.

Hose alert. No photo provided by a user who suggested that his col-

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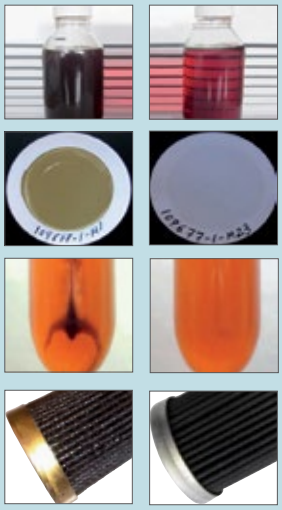

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B4


B5


B6

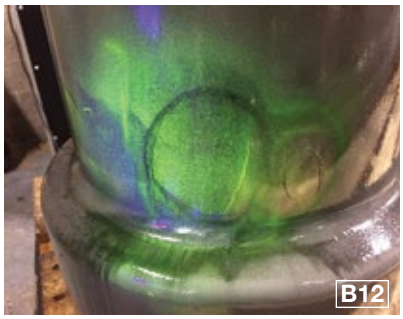

B7


B8


B9


B10


B11


B12

leagues check the blue hoses at the discharge of their D-11 EHC pumps. If Aeroquip AQP he recommended replacing them. The background: The OEM's Technical Information Letter 1659 states, "GE does not recommend or approve the use of hoses or other flexible components in the high-pressure hydraulic tubing system."

However, on many of the latest combined-cycle units with the EHC reservoir at the end of the lube-oil tank and with vertical pumps, GE used hoses. In some cases, these were Aeroquip AQP, which the supplier does not now recommend for use with phosphate ester fluids. Also, one station was said to have reported blistering of Aeroquip FC-636 EPDM hoses.

Jacking of the D-11 HP turbine case. A user reported flexing of the HP turbine's outer casing when just using the OEM's jacks at the corners. He suggested this alternative: Weld I-beams at the corners and in the center of the shell and add two jacks in the middle (on each side of the casing) to get a proper cover lift (Fig B9).

Galling of control-valve bonnet nuts can be mitigated by use of nitrided washers to take the wear (Fig B10).

Walk-around alert: Inadequate special tooling is illustrated in Fig B11. This is an unsafe practice.

Disc inspection of combined stop/control valve revealed nine linear indications (Fig B12), suggesting the casting was not properly heat-treated. Ultrasonic inspection and hardness checks of these components should be incorporated in manufacturing specs and monitored.

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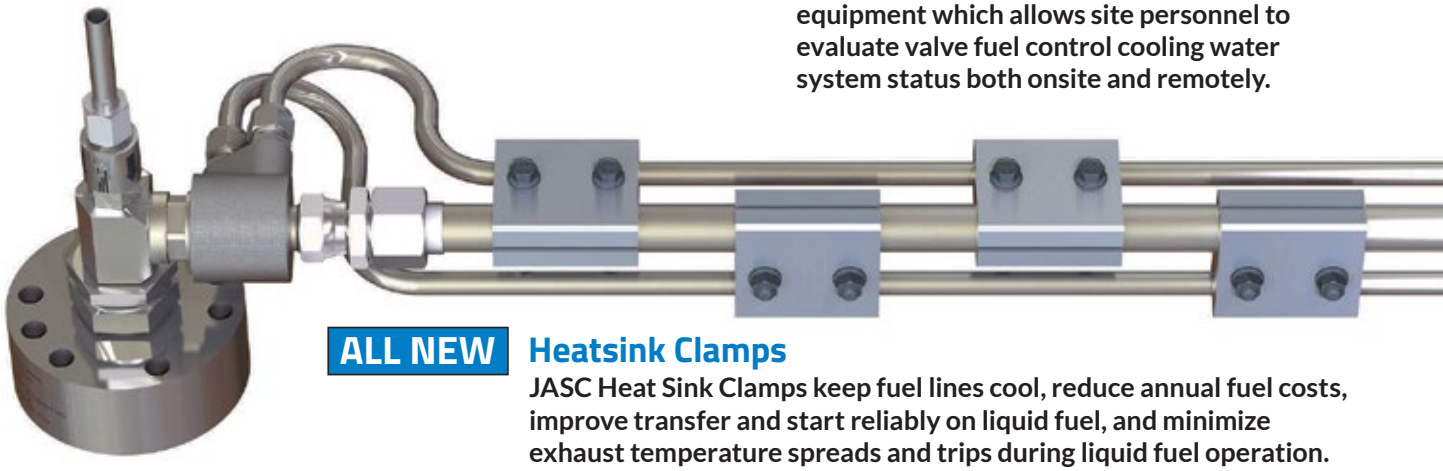

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JASC INSTALLATIONS


U1

U2


U3

U4


U5


U6

The Ugly

Poor supervision, or the lack thereof, is a primary reason equipment is damaged and personnel get hurt during outages. Fig U1 shows the damage to the body of a stop valve caused by arc-cutting to remove the galled pressure-seal pulldown ring in Fig U2.

Gaskets should be *replaced* after breaking joints, never reused. Spiral-wound Flexitallic gaskets have been an industry staple for high-pressure steam systems for decades, but close inspection before use is highly recommended; they are relatively easy to damage (Fig U3). Because they can be difficult to acquire on short notice, particularly in large sizes, the speaker recommended buying three if you need two. Also, users at other meetings have suggested special due diligence before accepting gaskets made in China, which have been said to have a high failure rate.

Welding joints (Fig U4) to prevent leakage is not an acceptable solution. However, the speaker mentioned the need to weld in a half-pipe at the horizontal joint of an operating nuclear plant's steam turbine as an emergency fix. The half pipe was equipped with a drain.

Stellite liberation from valves continues to be an industry problem. Fig U5 shows a piece of stellite liberated from a HRSG valve that was found in the drain pot.

Parts stored outside during an outage should not be placed on bare ground and should be protected against the elements (Fig U6).

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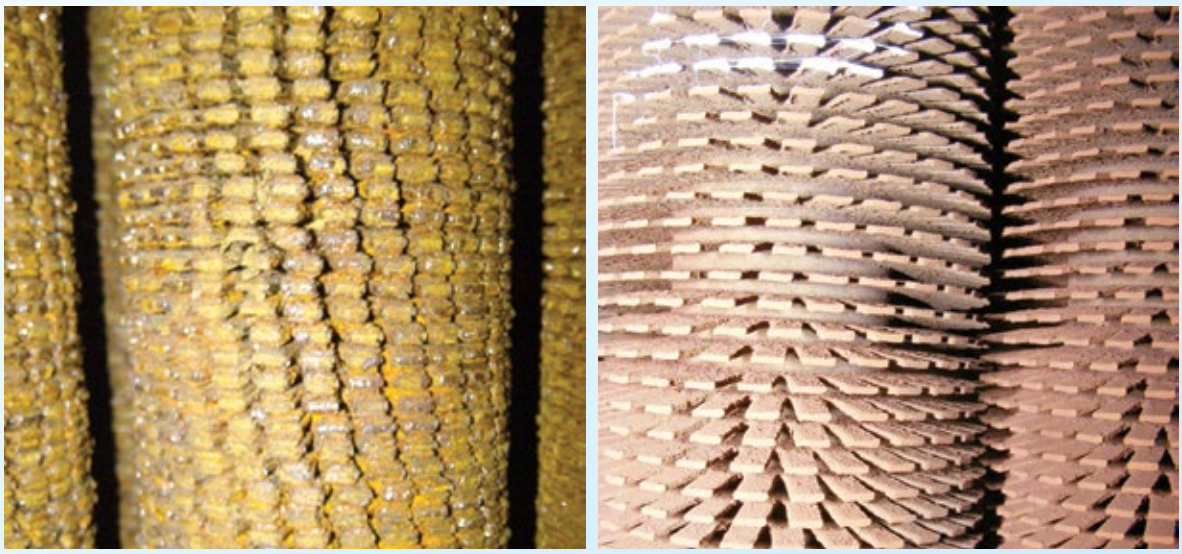

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Monitoring the health of main- and reheat-steam piping

By Thomas F Armistead, Consulting Editor

Out of sight, out of mind is a prescription for disaster in large powerplants that depend on hundreds of feet of high-energy piping (HEP). Turbine/generators and boilers, the equipment that does the money-making work get the most attention and care, while the pipes that connect them are sometimes ignored—at great risk (Fig 1).

Example: In June 1985, a 30-in.-diam reheat steam pipe ruptured at Southern California Edison Co's Mohave Generating Station (Fig 2). Sixteen people were horribly scalded; six of them later died. The tragic incident caught the power industry's attention and triggered a desire to focus on piping to ensure personnel safety, according to Matt Freeman, director of strategic business development for the fossil plant services business unit at Structural Integrity Associates Inc (SI), a consulting firm to the electric power industry.

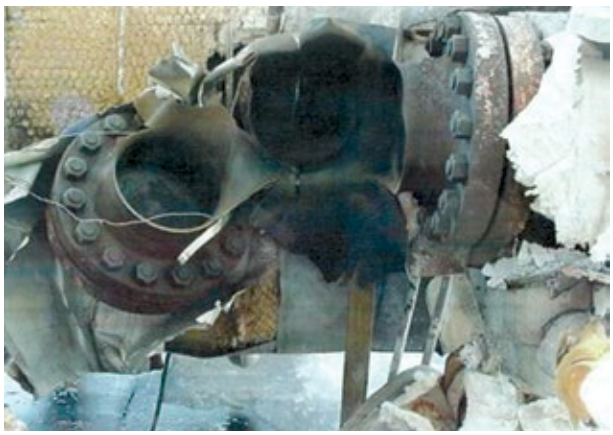
The initial industry responses to the incident ranged from deer-in-the-headlights paralysis to an obsession with smothering the threat through comprehensive, scheduled plant inspections. Operating staff increased monitoring of their plants: Some inspected all welds on a ramped-up schedule, others inspected selected welds, and still others turned a blind eye and hoped it wouldn't happen in their plant.

In the last five to 10 years, codes have caught up with the need, Freeman says. ASME B31.1, for example, requires newly constructed plants to have a program to monitor insulated piping. In older plants, monitoring of HEP has been increased in response to insurance requirements or just to ensure safe and continued plant operation. Whether an incident results in a fatality or not, it could knock a plant offline for an extended period.

High energy is high stress

High-energy pipe is under sustained stress, and stress shortens material life—that's a given. "The metal never forgets," says Scott Rau, senior associate at Structural Integrity. "No matter what you do to your system, every time you start it, every time you stop it, every time you change the temperature, the metal remembers that." Eventually, the metal will say, "I've had enough." The task for plant operators is to figure out when that point is close.

Operators need a way to judge when an HEP system is approaching the end of its life so the weakened piping can be repaired or replaced. SI recommends establishing a formal, corporate-sponsored HEP program before damage occurs. "The most successful programs are driven by the top," says Freeman. If plant operators see that the CEO or a vice president has bought into the program and signed off on it, it is more likely to succeed.



1. Reactions to a rash of piping events since about the 1980s gave rise to wide-ranging, inconsistent practices for managing the serviceability of high-energy piping

The program must measure the HEP system's exposure and vulnerabilities to predict when and where failure may occur. With that information, operators can create a plan and a budget to monitor the system and respond to threats as they are identified.

Several data systems that can support this program are commercially available. Whichever system is selected, the most important thing is to base the HEP program on verified data, which can identify the age, location, and nature of the various welds, elbows, and other vulnerable points in the piping system.

Basing the program on the data and the operators' knowledge of the HEP system, Structural Integrity recommends a "building-blocks" approach that predicts the onset of wear-out and identifies items to minimize the impact of early and random failures. An initial prediction of wear-out may be approximate, but as the predicted date of wear-out draws nearer, it can be refined and focused through a combination of non-destructive evaluation (NDE) of the pipe and refined lifetime calculations, which can lead to repairs being made before failure occurs.

First things first

The foundation for the program is data, so getting a comprehensive inventory of HEP system components is the first priority. The records should include drawings, fabrication records, inspections, repairs, replacements, and other facts to provide an accurate picture of the system's configuration, history, and needs. Engineers then can evaluate the system to estimate when it can be expected to wear out and define the urgency at which wide-scale inspection, more precise analysis, component replacement, or remediation should occur.

To set priorities for system maintenance and safety, operators must draw on their industry experience, the data, observations during walkdowns, and other available information, and then balance these factors with an assessment of risk that includes stress analysis, identifying high-stress locations where damage is most likely to occur.

For example, creep in the pipe redistributes the stress from what it was in the original installation, and that can dramatically affect the stress in other locations in the system. Taking all the

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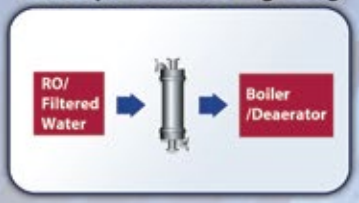

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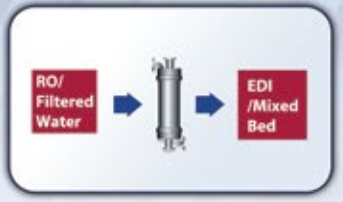

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2. Cold-reheat pipe failure is a typical accident

3. Creep crack is at a girth weld

known factors, including the plant's tolerance for risk, into account, personnel can create an inspection plan.

Periodic, multi-disciplined inspections provide a clear picture of the piping system and allow early detection of potential problems. Inspection intervals are guided by stress analysis, lifetime assessments, and the sensitivity of the inspection method. A relatively insensitive method—such as conventional shear wave—can detect macrocracks in piping, but if none is detected, a shorter inspection interval will likely result. Important to keep in mind is that undetected microcracks could propagate to a macrocrack in a relatively short period, possibly a year or so.

If a more sensitive technique—such as linear phased array or time-of-flight diffraction is used—then microcracks can be detected. Hence, in combination with other life-assessment calculations, a longer interval can be specified before reinspection. Advanced nondestructive inspection technologies—such as focused annular phased array—are able to detect incipient damage, potentially allowing longer intervals before subsequent reinspection—again depending on other factors from life-assessment calculations.

The more highly refined inspection technologies give greater confidence in the life prediction and setting reinspection interval, but they require additional inspection time and more skilled operators to collect and analyze data.

1. Major damage mechanisms affecting high-energy piping

Creep, a progressive damage mechanism that develops over time, is caused by the sustained application of stress at high temperature (more than 800F).

Fatigue, a progressive damage mechanism that develops over time, is caused by repetitive and fluctuating thermal or mechanical loading.

Creep-fatigue is the interaction of creep and fatigue mechanisms. It can reduce life to 20% of that predicted independently.

Corrosion-fatigue, or corrosion-assisted fatigue, describes cracking initiated by fatigue and crack growth accelerated by corrosion and oxidation.

Flow-accelerated corrosion refers to the thinning of steam/water-cycle components, such as HRSG headers and tubes, caused by dissolution of the protective oxide layer under certain chemical and flow conditions.

Asset management

Stress analysis and detailed engineering analysis are the keys to effective management of your HEP system. Confronted by an extensive system with potential for catastrophic failure, operators may be tempted to lavish resources on inspection. However, the goal of good asset management is "to get the optimum use out of the piping system without having to pour exorbitant amounts of dollars into it," says Rau. Stress analysis and detailed engineering analysis support that goal, allowing the operator to predict the remaining useful life of the system.

A stress analysis requires extensive system information: a dimensioned isometric drawing, a map of both field and shop welds, detail drawings and walkdown data of supports, spool-piece drawings, and terminal-point thermal displacements. Augmenting this is information on system loads: the weight, internal steam or water pressure, and thermal expansion, which is the primary contributor to the stresses that govern component life.

As a system goes from cold to hot, the pipe will expand significantly, stressing the supports in addition to the thermal stresses on the pipes. "The thermal-expansion load conditions are a prime mover in trying to predict the life your system. It's where all the uncertainty comes in," notes Rau.

Pipe supports must hold the weight of the system while allowing thermal expansion with minimal restriction. Thermal expansion may cause pipe lengths to grow 12-24 in. To accurately model the piping system, the loads and displacement constraints of the supports must be accurately simulated using the data of their settings, and readings recorded in periodic walkdowns, to detect trends and alerts to maintenance needs. Computer modeling is essential for accurate assessment. Several commercial software packages are available, but only a few can simulate what is really happening: creep (Sidebar 1).

Deadly creep

With long-term exposure to elevated temperatures (more than 25,000 hours), permanent deformation—growth—of the pipe will occur. "The material will actually permanently deform with exposure to stress and to elevated temperatures," continues Rau. Bends and sweeps originally installed at 90 degrees won't be 90 degrees anymore; pipe lengths will increase.

"You're going to have more pipe out there after you've operated that system for an extended period of time." When doing lifetime calculations, stress differences of 10-12% have "significant impact on what life predictions are," he emphasizes. Doing good stress work is extremely important to ensure the accuracy of life predictions.

For predictions of high-temperature component life, creep is the most critical aspect. Alloy steel will void over time, so creep cavitation is an obvious means for qualitative condition assessment and life prediction. For low-alloy steels, the Neubauer system classifies creep damage in a range from Level 1-Undamaged to Level 5-Macrocracking (Fig 3). Voids begin at Level 2-Isolated, and at greater life fraction will become Oriented, Level 3.

P91 and P92 materials develop voids over their life, similar to low-alloy steels, but they don't tend to exhibit an "oriented" stage, so they

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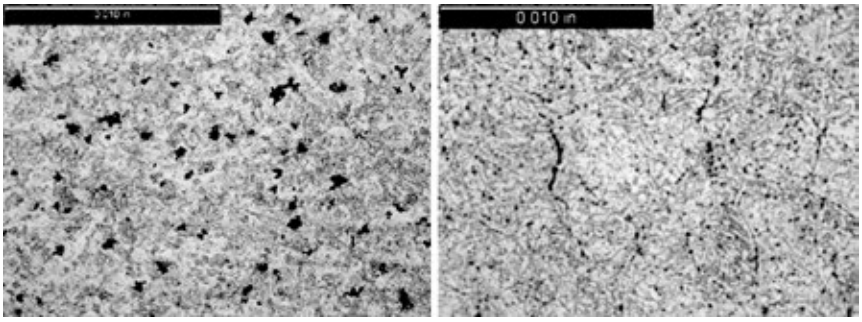

4. Creep-cavity morphology is different for P91 (left) and P22 (right). The Grade 91 material in the photomicrograph is near end of life and exhibits larger cavities and lower density than the P22, sampled after 70% of its life was consumed. Note how the creep cavities are aligned in the P22 but not in the P91

progress from isolated voids to macrocracking in a relatively short period of time.

While the isolated voids are present for a large fraction of the life, they are difficult to detect because they are invariably sub-surface and cannot be found with even the most advanced ultrasonic technology. Hence it becomes even more important to understand stresses and perform accurate component life predictions for creep-strength-enhanced ferritic (CSEF) steels.

Main and hot-reheat steam piping typically is made from these materials. Pipes in older plants generally use low-alloy P11 and P22 steel, while P91 and P92 CSEF steel is more common in the latest facilities. Pressures for main steam piping are typically 2500 psig (3500 psig for supercritical cycles) and for hot reheat, 500 psig, with temperatures of 1000F for conventional subcritical plants up to 1050F-1100F for today's combined-cycle plants.

The creep strength of CSEF steel is significantly greater than that of low-alloy steel, so the pipe wall can be thinner and more flexible, allowing fewer supports. CSEF steel is an advancement over low-alloy steel, but it has some vulnerabilities of its own.

Perhaps the most significant is the potential for degraded strength, more similar to that of P22 steel, if heat treatments are not performed properly. In this so-called "soft" condition, P91 can be very susceptible to premature failure. Even if the heat treatment is correct, CSEF steels are also sensitive to impurity elements, which can influence long-term creep behavior.

Structural Integrity recommends obtaining a full chemical analysis to determine all levels of the minor elements in this grade of pipe. For another, early detection of creep damage in CSEF steels is difficult because P91 develops fewer creep cavities than low-alloy steel, and they tend not to align on grain boundaries (Fig 4). Damage typically accumulates below the surface—except in components with high surface stress, such as branch fittings and areas of high bending stress, which drives the damage to the outer surface.

Ultrasonic techniques reliably detect creep damage in CSEF steels only at the microcracking stage, which often occurs late in life. Also, as described earlier, the Neubauer classification for creep damage in low-alloy steel does not apply to P91 because of the lack of an oriented phase of cavitation.

The bottom line: CSEF steel piping has advantages over low-alloy steel, but requires greater care and oversight in manufacturing, installation, and life management.

2. Damage susceptibility in piping systems

System	Creep	Fatigue-related	FAC	Corrosion
Cold reheat	Low	High	Low	Medium/low
Feedwater	Low	Low	High	Medium
Hot reheat	High	High	Low	Low
Main steam	High	High	Low	Low

Damage whodunit

Creep is one of several damage mechanisms, which may interact, that affect low-alloy and CSEF high-energy piping. It is a progressive damage mechanism that develops over time because of the sustained application of stress at high temperature. Fatigue is another progressive damage mechanism; it results from repetitive and fluctuating thermal and mechanical loading. Interacting as creep-fatigue, they can reduce pipe life significantly more than what would be predicted of them operating independently.

Corrosion is another major threat to pipe integrity. Corrosion-assisted fatigue accelerates cracking initiated by fatigue with corrosion and oxidation. Certain chemical and flow conditions in feedwater piping can dissolve the protective oxide layer in carbon-steel pipe in a damage mechanism known as flow-accelerated corrosion.

Dissolution of the magnetite layer on the surface of the steel is the principal aggravating factor in making FAC a major damage mechanism for feedwater piping, which is less exposed to damage from the mechanisms mentioned above because of its lower operating temperature.

Fatigue is the greatest single threat to cold-reheat piping, while high temperatures and pressures make hot-reheat and main steam pipes most susceptible to creep (Sidebar 2). Variables, in addition to pressure, that increase susceptibility to creep damage include the following:

- Metallurgical damage susceptibility, which can manifest as low creep ductility.
- Pipe ovality.
- Seam peaking (the pipe angle, if the pipe is not perfectly round).
- Seam location.
- Dead loads.
- Bending.
- Weld type and configuration.
- Weld characteristic—such as actual chemistry, fluxes used, weld procedure, grain structure, carbide content, and porosity content.

Looking for trouble

Subsurface creep occurs in both girth and seam welds (Fig 5). It is not usually ID- or OD-connected, until close to final failure. Creep damage on hot-reheat seam welds typically initiates where the weld deposits from the ID and OD overlap. Girth-weld creep damage initiates subsurface, but may be biased to the ID or OD depending on weld configuration and stresses. Because creep damage initiates subsurface it requires the application of volumetric inspection techniques.

Since other damage mechanisms may initiate in many different places, detecting and characterizing that damage requires a variety of NDE methods with different capabilities.

For general piping assessment, surface-coverage techniques like replication and magnetic-particle testing are common. Magnetic particle testing is specifically for detecting large surface indications that may be related to original fabrication, fatigue that has initiated at the surface, or subsurface damage (creep, for example) that has propagated to the outside surface.

Replication, which is basically taking an image of the material microstructure in the field, is used at specific

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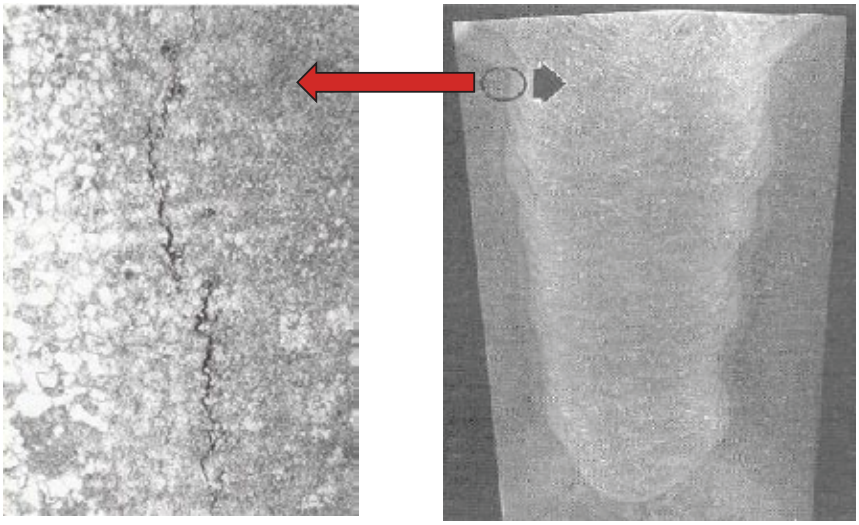
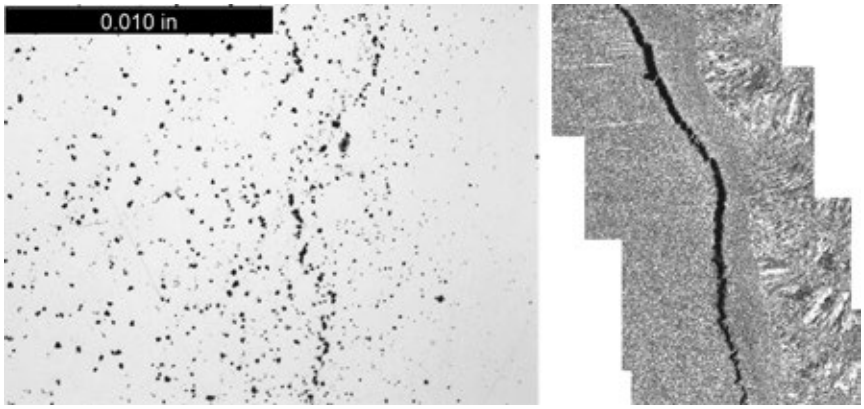
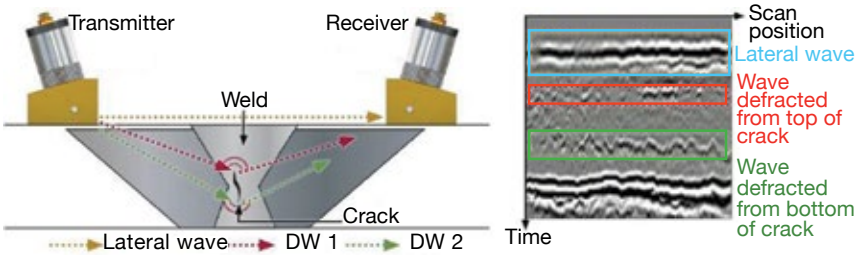


5. Creep voids are difficult to detect because they usually are sub-surface



6. Comparing the appearance of microcracks (left) and a macrocrack (right) in Grade 91 material. Note that there is no alignment of microcracks on grain boundaries



7. Operating principle of crack detection with time-of-flight diffraction is described at left; an example of data collected from inspection of service components is at the right. TOFD relies on the detection of diffracted tip signals and provides a true measure of flaw size rather than an estimate

locations where creep damage might be suspected or to provide metallurgical disposition of indications detected by other techniques without the need to take a physical (destructive) sample to a materials lab.

Sampling involves removal of a portion of the material and often requires a local repair. It provides sufficient material for detailed laboratory analysis of chemical composition, microstructure, and/or material-property determination.

For volumetric testing, radiography has long been a trusted method for post-fabrication inspection, but it can disrupt plant operation because it requires personnel to leave the test area.

NDE developments

Advanced ultrasonic techniques, mentioned earlier and profiled below, are replacing radiography; they are less invasive and do not require clearance of personnel. Plus, radiography is best suited to detection of large flaws—such as those that occur during fabrication—rather than micro-scale flaws that occur as a result of service damage (Fig 6). Here are the methods you should be aware of:

Linear phased array is popular, but it cannot routinely detect microcracking and is quite sensitive to the orientation of the cracking relative to the ultrasonic beam. LPA can scan long lengths of pipe, as the transducer is moved along the pipe, with good volumetric coverage. Scan results can be used to detect and characterize fabrication- and service-induced flaws in welds and base metal.

LPA also can identify locations for supplemental testing by one or more of the methods that follow, or potentially by surface replication, to detect early-stage creep. It electronically sweeps a beam of ultrasound through a series of angles, or can create a different beam angles where required, allowing for good volumetric coverage at the transducer location.

Time-of-flight diffraction is less sensitive to the orientation of damage, and has detection capability similar to that of LPA. TOFD can be used to rapidly scan full lengths of seam welds and provide comprehensive volumetric coverage. It also can detect and characterize fabrication and base-metal flaws, define macroscopic creep damage, and identify areas for supplemental testing—for example, with linear or annular phased array (APA). Supplemental testing is good because different methods produce a variety of views and insights on the damage.

Focused annular phased array ultrasonic imaging is highly sensitive and capable of detecting both micro- and macro-damage, but can only be applied over a limited region. APA provides distinct enhancements over conventional pulse-echo and TOFD inspections, electronically shifting the focal spot to different depths. As a result, its focused beam is highly sensitive, with improved resolution for flaw characterization. However, it cannot steer and vary focal depth as LPA does.

APA is often time-consuming because the small spot size dictates fine pulse increments and scan raster spacing, hence its use as a complementary technique to obtain higher-resolution data.

In sum, none of the advanced ultrasonic techniques described above can be applied universally; each has its own strengths and limitations. For example, to evaluate seam weld damage TOFD and LPA are routinely used for general scanning of the weld volume, with APA used to provide higher fidelity data at key locations along the seam. **CCJ**

Mark V goes haywire, shuts down F-class gas turbine's lube-oil pumps

You're an experienced operator/technician, perhaps with 10, 15, 20, or more years of powerplant service. You've seen it all. Nothing would surprise you. So you think.

Here's a case history likely to tame your unbridled confidence.

A GE F-class unit equipped with a Mark V control system is humming along at base load, no issues, reliable unit, nothing much for operators to do. Next instant: *All* lube-oil pumps—AC- and DC-powered—are forced out of service. Bearings are destroyed in a heartbeat (last reading on bearing-metal thermocouples was 950F) and rotor grinds to a halt severely damaging the compressor and turbine sections.

Say what?

Abel Rochwarger, chief engineer at Gas Turbine Controls (GTC), consulted with the owner/operator and learned that the network connecting the turbine control panel (TCP) and human/machine interface (HMI) had malfunctioned, forcing logic (sidebar) without human intervention. Tens of signals were "forced" within the space of 0.1 sec.

A team of customer and GTC personnel analyzed the root cause and in this case deemed it irrelevant. Instead, the team engineered a solution to prevent the control system from ever shutting down the lube-oil pumps again without operator intervention.

Rochwarger told the editors that GTC was unaware of any other instance in which "this behavior of 'self-inflicted logic forcing' had occurred and forced all lube-oil pumps out of service." He continued, suggesting units that have not yet implemented a protection scheme for the lube-oil system against a TCP failure should consider the following recommendation:

If the TCP starts to do "strange things," such as unexplained logic forcing, immediately put one lube-oil pump in "manual." To protect against an AC failure, start the emergency pump, too (it should latch and stay on). Shut down the unit immediately. If the cooldown sequence does not engage, turn the unit manually.

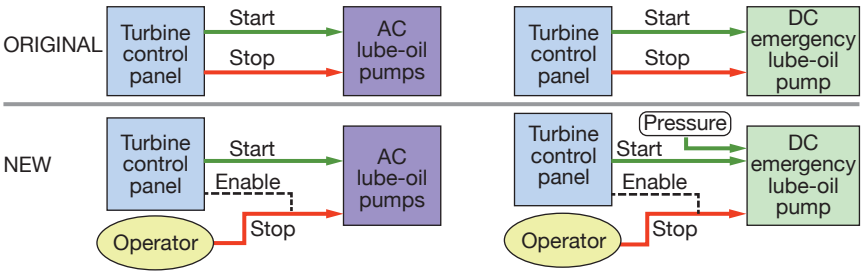
The chief engineer cautioned against accepting the results of a root-cause analysis as a vaccine against all ills. He said, "Eliminating the proximate cause of this failure does not necessarily eliminate all other potential situations that may result in the same scenario. The fact that the TCP failed to protect in this instance suggests that there might be other—today unknown—sets of circumstances in which the TCP would not keep the lube-oil system running when needed.

"The initial assessment indicated that the network connecting the HMI to the TCP was 'overloaded with signal traffic' beyond its design capacity. The underlying problem: One TCP version did it."

Rochwarger challenged those who might say "problem resolved" with the following question: How can you be certain there are absolutely no other combinations of circumstances that would result in a similar condition? He pointed to the fact that later versions of the TCP, such as the Mark VI and Mark VIe, are based on their predecessors, as the OEM points out in its literature.

This raises a second question: Could this possibly mean all TCP generations that followed the Mark V may have carried over the design patterns that allowed the "self-inflicted logic forcing" to happen?

The point stressed by Rochwarger is not to split hairs on what may or may not happen, but to eliminate the possibility by changing the controls paradigm. Until the event described above, the TCP controlled the starting and stopping of the AC and DC lube oil pumps (and seal oil pumps if installed). The controls paradigm he suggests and the one implemented for the affected customer (refer to simplified conceptual diagram):



Protection scheme applicable to all generations of GE F-class turbine control panels

Backgrounder

Logic forcing is a feature in modern (electronics based) turbine control panels allowing the operator to force the logic state of a digital (binary) variable to "0" or "1" independently of the following:

- The logic state mandated by the control algorithm (that is, even in contradiction), and
- The status of the unit (online or offline).

This feature may pose a significant risk to personnel and property; therefore, OEMs restrict the access to logic forcing via password protection.

AC lube-oil pumps

- Allow the TCP to start the AC pumps.
- Do not allow the TCP to stop the AC pumps, but enable a manual stop.
- Operator intervention is required to stop these pumps.

DC emergency lube-oil pump

- TCP enables pump to start; lube-oil pressure controls the start.
- TCP cannot stop the pump, but enables manual stopping.
- Operator intervention is required to stop the pump.
- TCP is allowed to cycle the pump to cool bearings when required at zero speed.

The AC auxiliary and DC emergency seal-oil pumps (not shown in the diagram) require similar logic changes if installed.

Wrapping up, Rochwarger said the sequencing, hardware, and wiring modifications required by the GTC alternative are not difficult to implement. The company says its solution offers a higher level of operational safety in case of a TCP malfunction, regardless of the TCP model. Plus, the same solution can be adapted to steam turbines and to synchronous condensers. Finally, a similar controls scheme has been developed by GTC for B/E-class machines—like the Frame 5, 6B, 7EA, 9E, etc—with a mechanical main lube-oil pump. **CCJ**

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Higher cycling costs loom as solar, wind resources grow

Latest reports from one consulting firm, with arguably more experience than anyone else in estimating the costs of cycling fossil units, suggest this: Gas-fired units may be in for elevated levels of pain, if not a death spiral, trying to make ends meet as more renewable resources come online.

This shouldn't be too surprising to owner/operators. After all, virtually every facility has experienced changes to capacity factor, operating tempo, starts and stops, and load ramping as renewables have grown in a given independent system operator (ISO) service territory, or region.

The coming conundrum is that capacity factors and electricity prices are expected to decrease, cutting into revenues, as even greater cycling and ramping impose more cost on the facility. At the same time, aging gas-fired units are more vulnerable to escalating equivalent forced outage rates (EFOR) and risk of protracted outages from significant failures rooted in cycling impacts from years ago.

The analysis presented here is mostly to help executives make data-driven risk management investment decisions. But individual plant managers and specialists need to assess their vulnerabilities within a broader context. Estimating cycling impacts and cost may be more art than science, but few would argue that the consequences can be catastrophic.

PJM focus. The fossil generator's pain in providing the flexibility "behind the scenes" is the grid operator's glory in accommodating higher and higher levels of renewable energy. The former is often the implicit message while the latter is the explicit one for the public.

Capital costs of solar and wind keep declining. Since there is no fuel cost, the marginal cost begins to approach zero, asymptotically anyway. Overall production costs to the grid are lower. Electricity rates remain stable or decline. What's not to like?

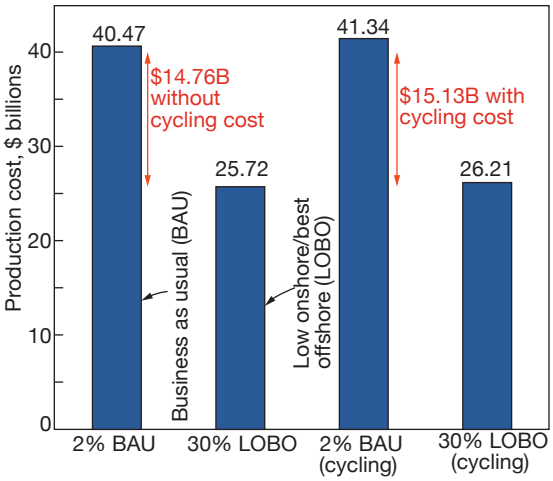
However, each megawatt-hour of flexibility from the gas-fired facility has an increasing incremental cost of cycling attached to it.

A recent monster of a study for PJM illuminates all of this. The "PJM Renewable Integration Study," a 2014 report led by General Electric International Inc, assessed system impacts of increased penetration of wind and solar resources on operation of the

PJM grid. Scenarios of up to 30% renewables by 2026 were investigated.

The report's headline conclusion is this: "PJM, with adequate transmission expansion and additional regulating reserves, will not have any significant issues operating with up to 30% of its energy provided by wind and solar generation."

Here's the critical sub-conclusion for gas-fired asset owner/operators: "Every scenario examined resulted in lower fuel and variable operations and maintenance (O&M) costs, as well as lower average locational marginal prices (LMP). The lower LMPs, when combined with reduced capacity factors, resulted in lower gross and net revenues for the conventional generation resources."



1. Total production cost declines dramatically as renewables penetration grows in PJM scenario modeling, but projected additional cost for cycling—around $500 million—will be borne in some way

The report goes on to note that the increase in variable O&M costs from added starts, stops, and ramping of conventional units is "small relative to the value of the fuel displacement," and did not significantly affect the overall impact of renewables generation (Fig 1).

That's cold comfort to fossil-fired plant owners and operators as any added cycling damage compared to other conventional fossil resources (Fig 2).

One of the recommendations included in the report is that PJM should explore the reasons for ramping constraints on specific units, and determine whether the limitations are technical, contractual, or otherwise, then investigate possible methods of improving ramp-rate performance.

It's easy to envision other potential consequences and solutions:

- PJM could add monetary incentives, such as capacity-type payments, so conventional resources can continue to serve.
- Conventional resources could be consolidated into a few hands to control prices bid into the PJM market under flexible-resource operating modes.

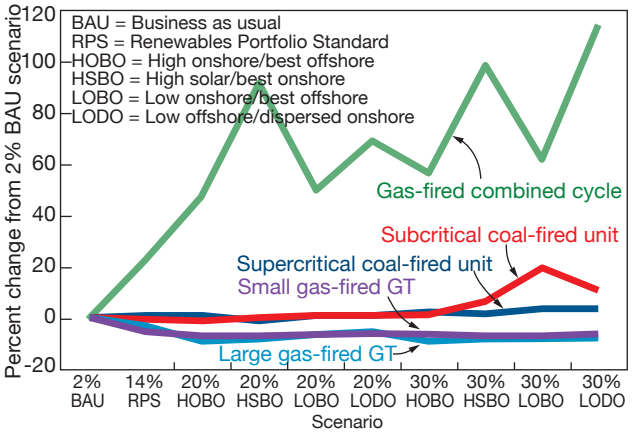
Although the report's principal investigator is GE, Intertek AIM Engineering Consulting, Santa Clara, Calif, provided the analysis on the impact of cycling on variable O&M costs. Intertek acquired Aptech Engineering Services in 2009; CCJ editors are familiar with Aptech's cost of cycling models and assessments dating back to 1986.

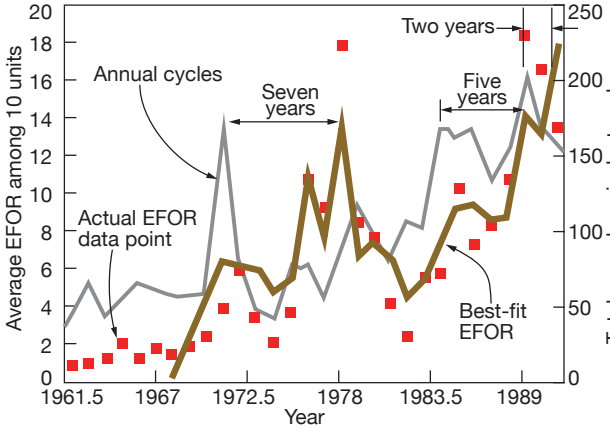
Similar stories abound. Some version of the PJM scenarios is unfold- costs in a declining revenue environment are bad for survival. In addition, conventional generators may have to compete with emerging grid-scale storage facilities for some of that flexibility, especially in the short-duration frequency regulation market. And what happens if gas prices begin to rise? Ominously, gas-fired combined cycles were shown to have the greatest change in

Variable O&M cost (in $/MWh) for cycling scenarios

Asset type	2% BAU	14% RPS	20% HOBO	20% HSBO	20% LOBO	20% LODO	30% LOBO	30% HSBO	30% HOBO	30% LODO
Subcritical coal	1.14	0.61	1.78	0.51	0.69	0.59	1.09	1.46	2.52	1.01
Supercritical coal	0.09	0.11	0.21	0.15	0.15	0.14	0.99	0.31	0.34	0.46
Combined cycle	1.80	2.69	6.29	5.19	4.77	4.68	5.43	7.55	6.76	5.81
Small gas-fired GT	1.65	1.74	0.41	0.52	0.51	0.60	0.92	0.87	0.51	0.82
Large gas-fired GT	3.32	3.41	1.88	2.68	2.19	2.42	1.56	1.52	1.85	2.02

2. Gas-fired combined cycles are substantially more vulnerable to net cycling damage than other generation options as renewables pentrations grow. Trends are based on GE simulations and assumptions made regarding how combined cycles are expected to operate as more renewables are added. Features of combined cycles in service—such as whether they originally were designed for primarily baseload operation, as most were during the bubble, or include the "flex" features of more recent units—were not accounted for. In the table, small GT refers primarily to aeroderivative units, large GT to the largest frame units





3. Average EFOR rises with years in service and total annual equivalent cycles, as indicated by historical data for 10 fossil-fired units. According to Kumar, similar trends appear in analyses of hundreds of combined cycles found in the NERC database and affirms the creep-fatigue interaction

ing in most other markets and regions around the country. In a presentation, "Impact of cycling on availability," at the 2017 501F Users Group conference, Intertek's Nikhil Kumar analyzed three markets from different parts of the country: California, Iowa, and Texas.

He presented graphs on national trends, including the rise of gas and the fall of coal over the last 15 years, growth in the average number of starts per year and in average annual operating hours for peaking and combined-cycle units, and relative increases in hot, warm, and cold starts. These trends are familiar to most CCJ readers.

Collective unit operating data in the three markets studied also were presented, all of which validate quantitatively what readers know anecdotally: gas-fired units cycle more as renewable penetration rates grow. One interesting feature of the data is that conventional units struggle more to follow the wind in Iowa because the resource is much stronger than, say, in Texas. Fossil units in Texas have experienced less cycling following renewables than in Iowa or California.

The researchers suggest that accumulating cycling damage be measured not only in equivalent operating hours but in equivalent hot starts, the latter meaning that each cold and warm start imposes the equivalent of multiple hot starts on the unit in terms of thermally

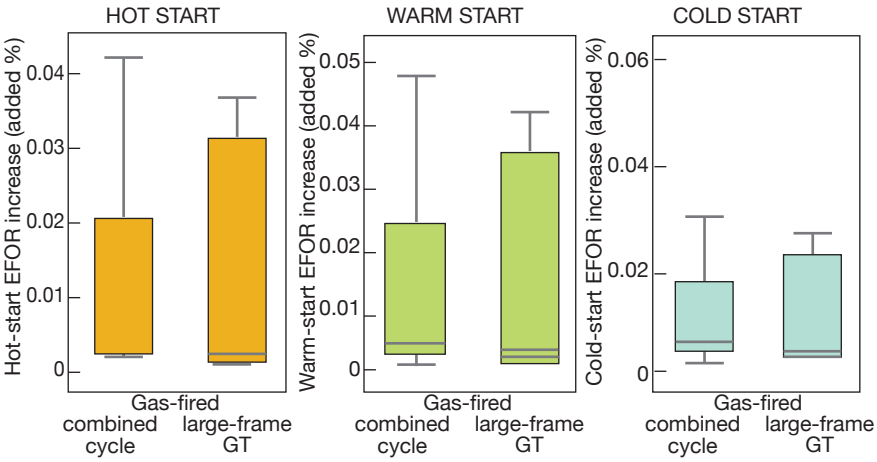
induced cyclic stress, fatigue damage, strain softening, and other mechanical properties—especially in thick-walled components.

The most important point perhaps is that combined-cycle owner/operators need to take a page from recent history and understand how EFORs rise as units age (Fig 3), and the direct relationship to total annual equivalent operating cycles. While the trend lines are clear, the actual damage mechanisms are difficult to identify. For combined cycles, each hot, warm, and cold start has an incremental impact on the EFOR (Fig 4), and a cost associated with it.

Bottom-line impacts. In a follow-up interview, Kumar noted that one of the most important takeaways is that new combined cycles must be designed for greater ramping and cycling flexibility. Despite the flexible unit designs being offered by the OEMs, Kumar argues that combined cycles are still being built without the requisite features for deep cycling and quick ramping. Utilities displacing coal capacity with new gas capacity are especially prone to short-sighted baseload operations design.

As an example, Kumar points to a new plant designed with an HRSG reheater drain line which makes a 180 deg turn and then flows straight up before reaching an HRSG blowdown/drain tank (Fig 5). The tank inlets are located 12-15 ft above the grade of the lower HRSG headers. Such designs allow water to accumulate at low points which then lead to damaging temperature gradients on thick-walled pressure parts under frequent cycling.

Many combined cycles built during the now famed bubble years of 1997-2003 will experience a double whammy of sorts, Kumar stresses. First, the vast majority of these plants were designed



4. Each cold, warm, or hot start incrementally adds to the risk of EFORs escalating as years of service climb. However, the range envelope is large because damage mechanisms are difficult to correlate directly to future outage events. Data are from 50 combined cycles and 25 large-frame simple-cycle units

5. Combined cycles designed primarily for baseload operation feature situations like uphill drains, which allow condensate to accumulate when the unit is offline, and lead to damaging thermal gradients upon restart. Roughly 20% of the combined cycles operating today may not be equipped to cycle, according to Kumar

for baseload operation during a period of intense competition, queues ordering major components from primary vendors, and cutthroat bidding among project developers vying for long-term power purchase agreements as independent and merchant suppliers. These plants often lack one or more of the following:

- Automated drain systems.
- Auxiliary boiler to raise steam during startup.
- Stack damper.
- Steam bypass system.
- Nitrogen or inert blanketing on the condensate storage tank to prevent oxygen ingress.
- Condenser steam dump.
- HRSG drain thermocouples.
- Reheater attemperator outlet thermocouples.
- HRSG stress indicator.
- Tight control and monitoring of feedwater chemistry.
- Steam sparging for reheat and superheat steam temperature control.
- Sophisticated inspection and monitoring capabilities.

The second "whammy" is that these units are hitting the 15-20-yr point in the aging cycle. Intertek's data covering hundreds of units over decades of operation clearly shows that such units are more vulnerable to escalating EFOR and, importantly, high-impact outage events which can force a unit out of service for months.

One vintage 1995 combined cycle Kumar mentioned, operating in the Pacific Northwest, suffered a high-cycle fatigue failure from a crack that originated at the root of a corrosion pit in the steam turbine rotor, ultimately forcing the unit out of service for five months. Official testimony from the owner/operator revealed that "the fact that the rotor has not failed completely in spite of the extensive cracking suggest that the conditions observed were not recent events but had been in existence for some time." In other words, the damage accumulated over long periods of time.

Ultimately, Kumar says, grid operators and plant owners will have to make some tough decisions about how to retain the flexibility necessary to accommodate ever increasing renewables penetration. For plants, the decisions will depend on whether they are regulated, merchant, or under long-term PPAs and the degree of cycling and on/off operation they are expected to accommodate.

One challenge to making the requisite investments is gas-fired plants change owners at a dizzying pace. Who can justify investments for operating flexibility under short-term ownership horizons?

Grid operators will have to adapt and adopt mechanisms for conventional fossil resources to be properly compensated for their flexibility. Most ISOs already have various financial products to encourage flexible operation—such as frequency-regulation payments, capacity payments, day-ahead bidding, ramping products, resource adequacy payments, etc. Another one Kumar thinks should be considered is a special payment for operating at ultra-low load for extended periods.

Like most things in life, grid operation with 30% renewable penetration may not, on paper, pose significant issues from the perspective of the grid operator, but only if in the real-world facilities providing the necessary flexibility, hidden from public view, are appropriately compensated. **CCJ**

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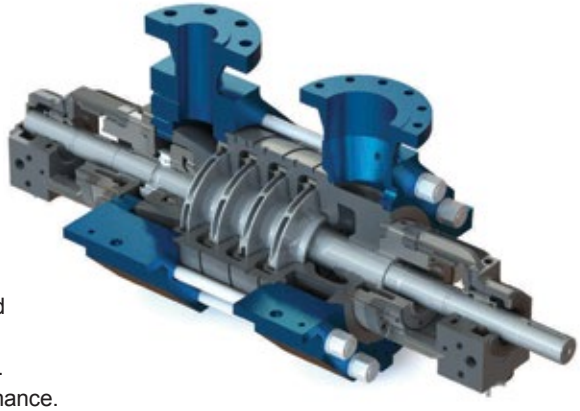

Multistage pumps are manufactured by a number of companies for high pressure medium flow applications and are critical to combined cycle plant operations.

These machines are critical to operations but have presented great challenges related to overall reliability. They are often incorrectly installed and the plants may not have the specialist resources available to diagnose problems that stem from multiple areas. Engineering, manufacturing, installation and operation are all critical to proper performance.

Hydro's study of this type of equipment and the issues encountered, has resulted in the development of engineering solutions and processes to ensure successful repair and installation of multistage pumps. Our engineers and technical staff have extensive experience with a broad range of pump equipment. This diverse engineering expertise, and use of the latest manufacturing and design technologies are why so many combined cycle plants rely on Hydro. We invite you to rely on us too.

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Benefits of solar + storage expand for small Ohio municipal utility

The changing nature of electric supply

Special to the COMBINED CYCLE Journal

Jason Makansi, chairman, Editorial Advisory Board

GRID TODAY

What started with the objective of diversifying supply resources for the village of Minster (Ohio) municipal utility has blossomed into what soon could be a full-fledged solar + storage microgrid with the capability of islanding for extended periods of time.

The 4.2-MW solar photovoltaic (PV) facility paired with a 7-MW/3-MWh battery storage unit (photos) has received much attention from the industry, and many accolades since it went online over a year ago. It is considered by some to be the first solar/storage facility serving a municipal utility in the US.

Perhaps more importantly, it is one of the first to demonstrate what grid-scale storage enthusiasts have been proclaiming for years: If you "stack" the financial benefits, you can earn a decent return on storage capital investments.

Minster Village Administrator Don Harrod confirms that projected benefits to the utility have been exceeded in the first 18 months of operation. So much so that negotiations are underway for a second phase, which will add islanding capability, another 4 MW of solar, and 7 MW of storage; and a third phase with 19 MW of storage.

At the same time, though, Minster's facility partners have to wrestle with unexpected challenges in the PJM grid market.

"Our goal four years ago was simply to diversify our generation supply with some solar, but as we got into the project, we found several other significant benefits," Harrod noted. That was essential, because after the project was initiated, the state of Ohio terminated its solar renewable energy credits mid-stream, squashing project economics.

According to S&C Electric Co, supplier of the integrated lithium ion (Li-ion) battery unit, power conditioning hardware (PCS), and grid interconnects, as well as the battery management and integrated system automation and software, the storage unit is designed for three functions: power-factor control, peak-load management, and Reg D frequency regulation in the PJM market (sidebar).

Harrod confirms that all three functions have been "exercised" and proven in commercial operations. The S&C design, coupled with third-party forecasting, identifies Minster's two-hour peak periods and displaces grid-supplied power with battery-supplied megawatt-hours.

This is critical because Minster's peak-demand charge for the next year is based on the highest of five two-hour demand levels experienced during PJM's coincident peaks the previous year. "Sure enough," Harrod said, "the system correctly forecasted

Village of Minster (Ohio) buys power under a long-term PPA from this third-party owned and operated solar (left) + storage (right) facility, which stacks financial benefits from three functions: power-factor correction and voltage support, Reg D frequency regulation in the PJM market, and peak-load shaving

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March 5-7
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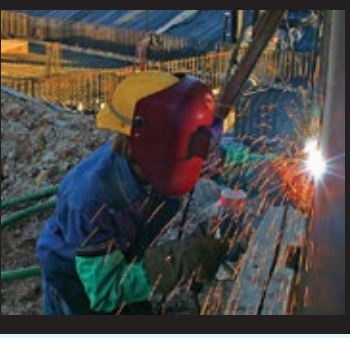
"We offer carefully chosen presentations on topics designed to help owners/ operators and maintenance professionals be more successful."

– Bob Anderson




What 2017 attendees say:

"Unique, very interactive"

"There are a lot of people here from power plants and corporate."

"It's hard to beat Bob Anderson and this forum for information-sharing and getting people involved."

"HRSG Forum has helped me a lot— I know HRSGs but this is where I get the practical information I need."

Key topics from this year's forum:

- Drones for HRSG Inspections
- Optimum Cycle Chemistry Control of CCPP/ HRSG & How to Achieve It
- ASME Code Issues Relating to Advanced Materials & What You Should Know about P91
- Design Challenges for 600°C (1112°F) HRSGs
- Automatic Control of HPSH / RH Drains Using Ultrasonic Technology

Registration Opens Summer 2017 at www.hrsgforum.com

three of the five peaks last year, one of which was the highest for the year, which reduced our demand charge."

Regarding power-factor control, Minster's system is fed by two lines from its wholesale supplier, Dayton Power & Light Co. One line has adequate voltage, the other less so. When supply is switched from one line to the other, the voltage drop can be considerable, and a potential reliability issue, especially for the village's two primary industrial loads. One of those is the largest Dannon Co yogurt-making plant in the US. Together, those two loads demand 10-11 MW.

The utility was facing an expensive addition of capacitor banks to solve the problem. But the storage facility is able to mitigate this challenge as well. "Now, when the lines are switched on us, we don't see the voltage drop in our system." Nor do their large industrial customers, where the drop was apparently visible and potentially problematic.

The third function, frequency regu-

Deciphering grid jargon: What 'Reg D' means in PJM

In the old days, utilities managed their own ancillary services—frequency regulation, for example—and cooperated to keep other utilities whole. Today, in a market like PJM, frequency regulation is another "purchased" service (like capacity and energy). Typically, the grid operator has several tiers of frequency regulation, such as spinning and non-spinning reserve provided by traditional resources.

Regulation and balancing is defined by PJM as a variable amount of generation under automatic control, independent of an economic cost signal, obtainable within five minutes to respond to frequency deviations. The last is called Area Control Error (ACE).

Importantly, regulation requires injecting power and/or "dumping" power. If you can "store" the dumped power, so much the better. In practice, traditional generating units (fossil, hydro) can qualify for frequency regulation if they can respond quickly enough. Batteries and hot-water heaters are good places to store dumped power.

A so-called Regulation A signal has always been used to dispatch traditional generators, which typically are energy rich but limited in their ramping capability. The Regulation D signal was initiated to take advantage of the almost instantaneous response of new technologies like batteries, but which are energy-limited (that is, they can be depleted quickly).

Reg D, in essence, rewards assets that can cycle frequently between injecting power into the grid and taking power out of the grid.

A Reg D participant's ability to meet PJM's requirements is qualified initially through a combination of self-test and tests administered by PJM. Once qualified, the asset owner has to continue bidding into the system and is paid based on how well the asset meets the performance criteria.

Without getting into the considerable financial engineering involved, the formula dings the bidder based on the historic performance score, or the average of last 100 hours of performance scores. In essence, the asset owner's past ability to deliver and take the megawatts promised within the required response time is factored into the bid process.

Typically, regulation needs are calculated 60 minutes ahead of time and participants bid in commitments 30 minutes before the hour in which they will be dispatched.

lation, is managed by a third party, but Harrod confirmed that power was successfully being sold into the PJM Reg D market.

Contractual arrangements. Minster owns none of the hardware; it buys services under a long-term power purchase agreement. The details:

Half Moon Ventures, a private company, owns the solar PV array and the storage system, and is responsible for O&M and performance.

S&C Electric provides regular maintenance and 24/7 monitoring and diagnostics to the storage system under a long-term services agreement.

Viridity Corp handles all of the trades into the PJM regulation market.

LG Chem Ltd, Korea's largest chemical company, supplied the Li-ion batteries, but S&C takes responsibility for them.

American Renewable Energy & Power supplied the solar PV array.

It's no secret that many grid-scale storage projects have suffered from poor contractual arrangements and system design. S&C avoids that by guaranteeing the integrated system. As importantly, the company not only has the decades of experience designing relay and protection systems for electricity distribution, it can factory test all the equipment at full electrical output.

"We don't just test modules, or simulate the software," noted S&C's Jake Edie, during a tour of the company's considerable testing and product display area at its Chicago headquarters facility, "we factory-test the fully integrated system and run it through all possible fault conditions, and test for EMI [electromagnetic interference] and EMC [electromagnetic compatibility] interferences and circuit loadings." Most suppliers don't have these resources, he added.

The PJM challenge. Shortly after the system went live, PJM changed things up in the frequency-regulation market.

The original mode was that battery power would be dispatched on PJM's signal on a 15-min energy-neutral basis, meaning that the charging and discharging of the battery would be equal over each 15-min period.

But PJM found that it needed even more flexibility and accuracy of response. The ISO changed to a 30-min conditional signal, meaning that the grid can keep pushing the battery to completely empty or past fully charged.

Harrod noted that this situation would only affect the utility if the batteries could not be discharged during a peak demand period because of interference from Reg D obligations. However, the more aggressive dispatch and operating mode does affect the battery system lifecycle.

Edie also said the challenge could be addressed with system modifications. "We could add more air conditioning to the system, because the batteries generate more heat on deep discharge; add battery capacity, or operate the system a little differently."

The last option could impact the way revenue is earned. Revenues from PJM depend on how quickly and accurately participants can follow the signal, and each participant earns a "score" for this capability. When you bid into the market, you not only are bidding with your "price" but your performance score as well.

Changes to Reg D rules have generated controversy, according to an April 20 article in *Utility Dive,* and a complaint to FERC issued by the Energy Storage Association (ESA), which alleges that PJM changed Reg D rules without FERC review or approval. One of those changes was the elimination of energy neutrality, which caused "daily pegging" to remove excess generation from the system. The other was to cap the amount of Reg D resources PJM would procure. According to ESA, the changes disregard the favorable characteristics of limited energy resources that the Reg D signal was designed to respect. **CCJ**

Materials issues, drones, cycle chemistry, attemperators among first-meeting highlights

By Steven C Stultz, Consulting Editor

They gathered in part because of Bob Anderson's reputation and experience in the design, operation, and maintenance of heat-recovery steam generators and combined-cycle plants. But they gathered also to discuss key topics with people like Barry Dooley, Jeff Henry, Joe Schroeder, and others who have dedicated their professional lives to these complex, hard-working systems and components. They assembled to share experiences, discuss operations, review achievements and lessons learned, and anticipate challenges.

As one participant said, "Many of us know the technologies, but many of us don't. And that's very good! It's a blend that works. And we're all looking for practical knowledge that we can take home with us.

"You sometimes get lost in the theoretical," he continued. "But the need for hands-on experience is something we all share, regardless of current job or background. That's how we keep our systems and this industry going. It's how we save time and money, and protect our investments and jobs."

EPRI hosted the inaugural event at its large conference facility in Charlotte, NC.

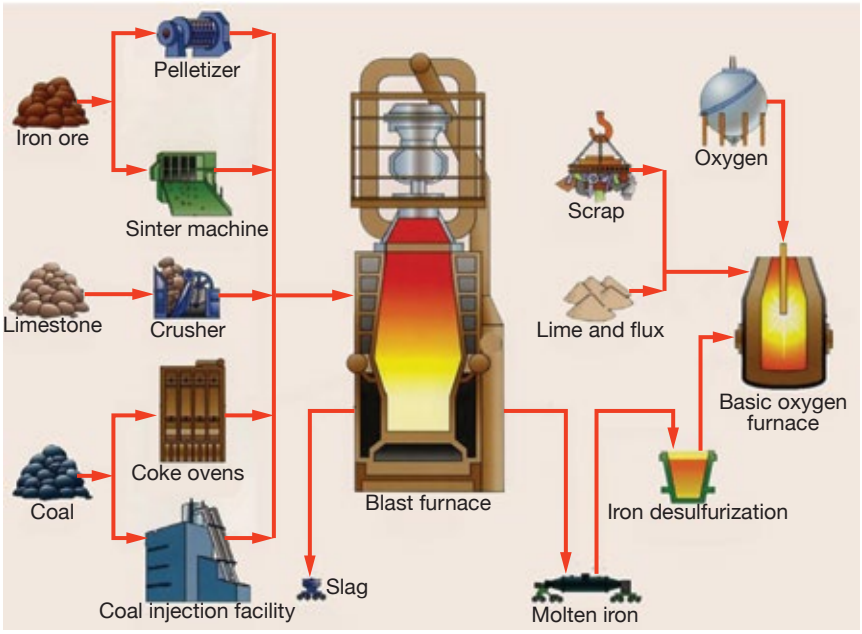
In a brief opening statement, Bob Anderson welcomed the participants and thanked the host and sponsors (Sidebar). Then it was time to get to work.

HRSG FORUM WITH BOB ANDERSON
March 5 – 7, 2018
Hyatt Regency, Houston, Tex

The steels, they are a-changin'

It could be the *price of progress,* the unintended consequences of well-intended actions. They can be expected at times. But the keys to managing them are awareness, detection, and observation.

One compelling takeaway from the HRSG Forum was "How *innovations* in steelmaking are changing the way pressure-part materials behave." As attendees listened intently to Jeff Henry, Applus+ RTD and chairman of ASME Section II, the details unfolded



1. The way it was. Steelmaking involved the reduction of iron ore in a blast furnace to produce a high-carbon molten iron which was desulfurized and charged into the basic oxygen furnace where alloying elements were added and carbon content reduced

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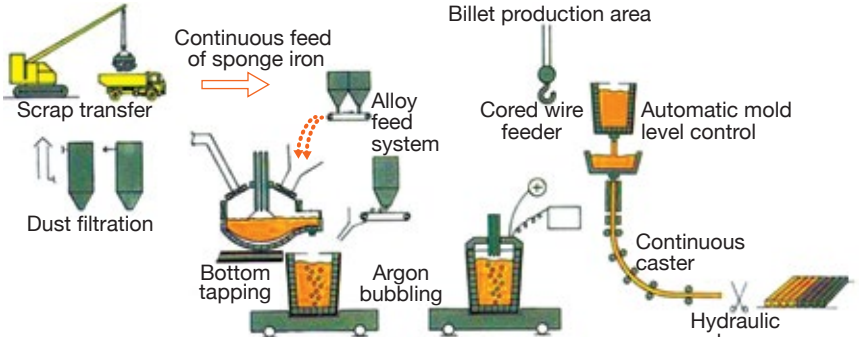
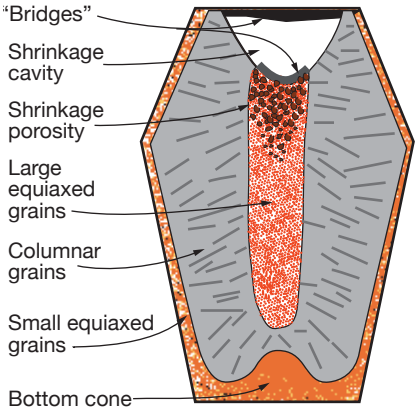


2. The way it is. Modern steelmaking relies on scrap-based processes in which large quantities of scrap metal are charged directly into an electric furnace.



3. Steel ingots cool slowly from the molten state and the cast structure produced is a heterogeneous mixture of varying grain structures with pronounced macro and micro segregation

into a wake-up call. Users should take note.

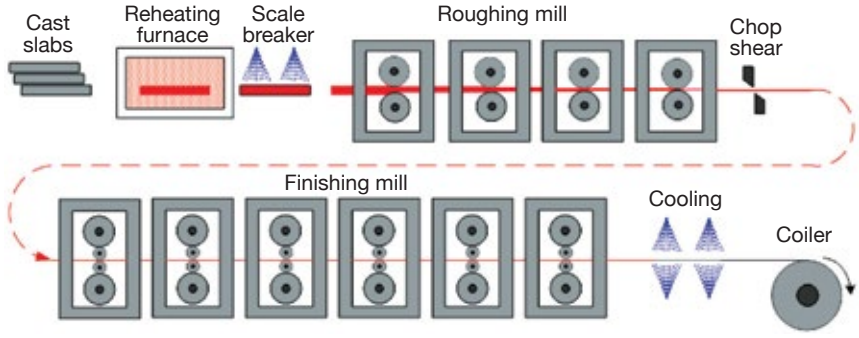
The story goes like this: Traditional steelmaking reduces iron ore in a blast furnace to get high-carbon molten iron. This is desulfurized and charged into a furnace; carbon content is reduced and alloying elements are added (Fig 1). Residuals like sulfur, phosphorus, copper, and tin (even some dirt) exist, but at tolerable levels that are not worth the high cost of removal. At the known and allowable levels, these residuals should not change material behavior. Simple enough.

Now add some more-modern activities. Quantities of scrap metal are charged into an electric furnace, saving time and money (Fig 2). But the potentially pesky residuals are now determined more and more by the scrap content. According to Henry, "The number of residual elements such as copper, tin, chromium, nickel, niobium, and titanium have increased with the greater use of scrap."

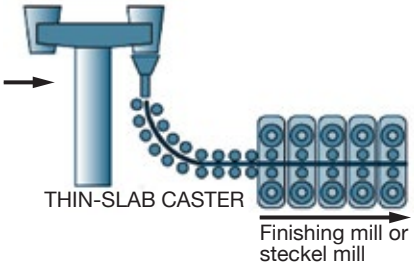
But even residuals are a complex topic. In carbon steel, chromium is residual. In Grade 22, it is alloying.

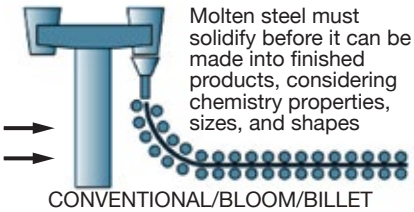
Now more progress. Years ago, hefty ingots were sent out from the mills as the main starting point for steel parts. The industry knew that as these large ingots slowly cooled, their cast structure became a mix of grain structures with pronounced macro and micro segregation (Fig 3). Breaking down the ingots into sheets improved homogeneity. Knowingly, the process chain added several mechanical steps with intermediate heat treatments. This produced a relatively consistent and uniform structure and composition (Fig 4).

But today there's more continuous casting, again saving time and money. Molten metal is solidified into intermediate shapes more closely aligned with the final product. On the positive side, the continuously cast products



4. Production of a usable part from an ingot typically involves multiple steps of mechanical working and intermediate heat treatment to achieve desired size and shape. In the hot-rolling process illustrated here, the heterogeneous metallurgy of the ingot is transformed into a relatively homogeneous product of uniform structure and composition





5. Continuous casting involves the solidification of molten metal into "intermediate" shapes—that is, blooms, billets, slabs—thereby eliminating some of the steps of working and heat treatment required to break down the ingot

cool more quickly, eliminating much of the macro segregation and structural variety. But the effects of micro segregation and finer-scale structural inconsistency remain.

Because the product is now close to final size, the amounts of mechanical working and heat treating are reduced, and some remnants of the original cast heterogeneous structure can move freely into the final part (Fig 5). And let's not forget the pesky residuals.

That's the background, and a few well-intended process improvements.

The evidence

In 2015, a Fluor representative alerted ASME to problems with some carbon-steel fittings and forgings at a work site. Unexpected cracking appeared during normal handling, at or below room temperature (Fig 6). All materials met ASME/ASTM specifications, but subsequent analysis showed poor toughness with brittle trans-granular fracture and nil lateral expansion. Re-normalizing did not restore toughness.

The following year, XGEN engineering's inspectors at a nuclear site had troubling nondestructive examination (NDE) issues with stainless-steel and nickel-based materials. UT was showing false reflectors (indicating cracks). Inspectors were unable to transmit sound to critical areas.

Testing showed highly anisotropic mechanical properties (varying by measurement direction, Fig 7). Analysis also indicated accelerated growth rates for stress cracking in cast and banded structures in some

6. Fluor Corp alerted ASME in 2015 regarding poor toughness of carbon-steel forgings and fittings

well-known alloys.

The alloys

Stated Henry, "Creep-strength-enhanced ferritic (CSEF) steels, such as Grade 91, are examples of what we consider *advanced alloys* for boiler and pressure-vessel applications." He then added, "Implications for advanced alloys could be the most significant, particularly for those at elevated temperatures and under frequent cycling. These materials have more complex metallurgy, so small changes in their composition, heat treatment, or processing may produce significant adverse changes in properties."

So what are we seeing and what are the implications?

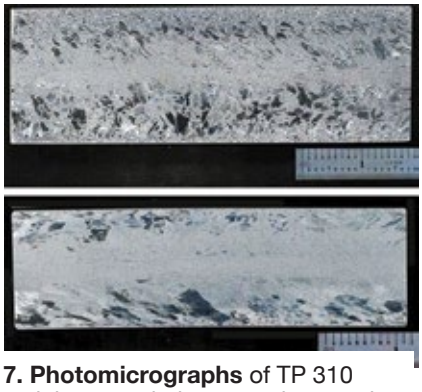
We know there are potential changes in material behavior, but all of this is not yet clearly understood. Again in the past, OEMs filled part of this knowledge area with dedicated laboratories and veteran personnel, but they can no longer fill this role.

Material suppliers (steelmakers) are concerned with delivery and production costs. "Also," Henry added, "Most suppliers will charge a high premium to produce materials with more restrictive requirements for individual purchasers."

The research

Recent work at EPRI has focused on the effect of residual elements on both long-term creep rupture strength and ductility (Fig 8).

One finding might be even more concerning: "Significant differences in both strength and ductility have been found in different heats of Grade 91, all of which had been manufactured in the same manner and operated under exactly the same conditions."

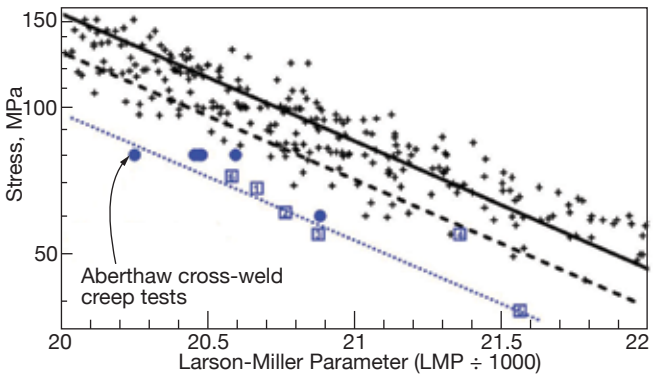


7. Photomicrographs of TP 310 stainless-steel plate reveal non-uniform grain structure

Henry then turned to compositional issues specific to Grade 91, noting ASTM's requirements adopted in the mid-1980s. Details for more restrictive requirements (residuals) are now incorporated in a new Section I code case that was approved in 2016. And in February 2017, the responsible ASME groups voted to *reduce* allowable stress values for the existing Grade 91 steel (Fig 9). Other studies and potential actions are ongoing.

The implications

One message was clear: **don't panic**, but **do** be aware!



8. Negative impact of residual elements on long-term creep strength and rupture ductility, shown here for Grade 91 material, is based on work by EPRI

Although there were many questions and focused discussions during Henry's presentation, there were many "still looking" statements. The primary conclusion: "Effects of fabrication processes on advanced alloys are not yet clearly understood," but we all need to stay informed. We need to observe.

Henry summarized the implications: "There is no question that the concerns raised for performance of Grade 91 apply to all CSEF steels, and to other advanced alloys." All codes will need to consider these "unintended consequences."

In a more pointed remark, he noted that "Action has been taken on Grade 91 not because it is the only advanced alloy adversely affected by the changes, but because it is the only alloy that has received the attention necessary to define *some* of the required actions."

He concluded with a look ahead, and the need to:

1. Better understand these changes.
2. Implement the necessary Code changes.
3. Better define what constitutes critical service.

Closely related topics of personnel safety and plant downtime were also discussed.

Lively dialogue followed on the status, outlook,and use of 91, 91 Type 2, and 92. Topics included ASTM material and product processes, general upgrading of specifications including OEM's lists of supplementary requirements (based on experience), and the troublesome challenge of management's fallback: "If it's not in the Code, we don't need it."

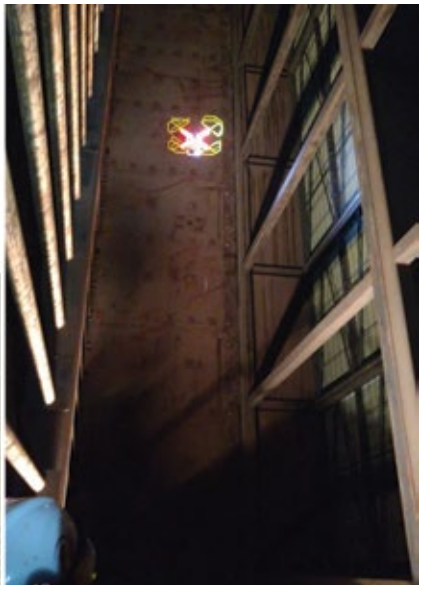
Time will tell.

Parameter	Temperature, F					
	950	1000	1050	1100	1150	1200
ASME 2015 t≤3 in.	17.8	16.3	14.0	10.3	7.0	4.3
ASME 2015 t>3 in.	17.8	16.3	12.9	9.6	7.0	4.3
→		16.1	12.2	8.7	5.7	3.5

9. Responsible ASME groups, voted in February 2017 to reduce the allowable stress values for existing Grade 91 steel

Wheels up in 30

Scott Wambeke, principal HRSG engineer, offered a detailed review of Xcel



10. Unmanned aerial system is used to conduct safe and effective indoor HRSG inspections

11. Plywood platform facilitates take-off and landing in tight space

12. Crashed drone is in for desktop repairs

Energy's new indoor unmanned aerial system (UAS) tools, a/k/a drones (Fig 10). Although the company has used drones outside to survey transmission systems, pipelines, and other difficult-to-traverse systems, Wambeke's team concentrates on what's inside the plant—more specifically what's inside the boiler. He was at the HRSG Forum to explain the experiences, successes, and lessons learned as his crew launched and improved these new inspection tools.

The Xcel team has come a long way in two years of *flying*, beginning in large coal-fired units looking at tube-wall slag and burners. Skill and precision have progressed rapidly, and the team is finding comfort and new applications inside the more restrictive HRSGs.

Wambeke clearly labeled drones as *consumable* inspection tools. In corporate terms the cost is very reasonable. And the savings in time, equipment and labor can be enormous. Scaffolding alone, in a large boiler, can cost up to $100,000 to deploy.

"Our primary purpose is to have a safe, compliant and efficient internal UAS program that saves both time and money," he explained. Wambeke's overview stressed how these systems offer immediate access to information so engineers and maintenance personnel can quickly determine needs and assess what conditions they might be facing. It's a decision-making tool on whether or not they need to expend further time and effort, and where to focus if they do.

It's nearly spontaneous. When called, the UAS team can be up and running quickly (in as little as 30 minutes).

"We've had our challenges," said Wambeke, "and we know that personnel safety is a primary concern." The drones can, for example, be pulled by draft into tube walls, or lose power and just drop. They can also veer toward objects and people, and can move horizontally at up to 50 mph. But Xcel adds a "handler" who is equipped to "swat them down." Think pesky bats.

For the pilot, stress levels can also become high. "Sometimes it's like driving a car in a snow storm," stated Wambeke.

But the immediate and recorded inspection results offer great benefits.

Low expense, high payback

Xcel began with a DJI Phantom 3 Pro, modified with carbon-fiber blades, blade guards, and eventually LED lighting. At times, a simple sheet of plywood served well as a launch site (Fig 11).

Most camera systems are reasonably priced, as are memory cards. Wambeke offered a warning on the latter. "Have multiple cards," he cautioned. "The last thing you want is to lose a memory card in an ash pit or bunker." So the team replaces cards at each landing. "It's OK to lose the drone," he said, "but you don't want to lose the data."

There have been other challenges and a few crashes with various causes including HRSG liner bolt snags, draft-induced collision with catalysts, and the occasional yaw malfunction (software-induced). But tabletop repairs can be fairly simple (Fig 12).

Limitations

Other restrictions become obvious through experience. Examples include:

- Flight time is 10 to 12 minutes per battery.
- Minimum space requirement is normally 6 to 12 ft.

13. Lighting improvements for Xcel drone

- High dust and ash loading can make flight manipulation a challenge (think snowstorm).
- Any draft above 5 mph makes flight difficult in tight areas.
- Standard lighting can be limiting; Xcel has modified and continues to improve theirs (Fig 13).

Built-in challenges

Commercially available drones are designed for outdoor use, and most are equipped with GPS. This positioning system does not work inside a steel boiler. So Xcel is working with others on a possible artificial GPS. They are also working on new object-avoidance software.

Wambeke offered a list of other challenges, including these:

1. Inspector/operator training and stress can be limiting factors, especially with crew members having other responsibilities and with long intervals between flights.
2. Safety consciousness around people is critical, and personal protection is required.
3. Communication between pilot and spotter requires training and coordination.
4. Drifting in elevation and yaw are nearly unavoidable (at present).
5. Maintaining a precise position is difficult, especially with ambient drafts.
6. Compass interference can prevent takeoff; an angle iron near the compass seems to help.

14. Custom-built unmanned aerial system and cage

Next generation

Wambeke gave some specific ideas for the next fleet of craft. These included:

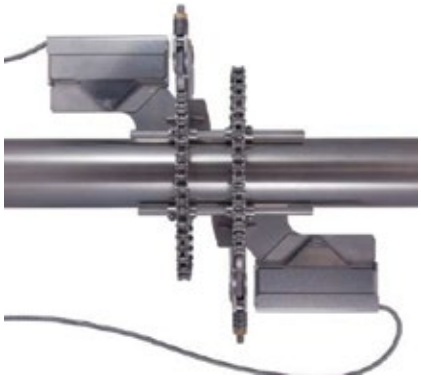
- Continuous lighting improvements.
- New versions of wall-roller attachments.
- Upgraded blade guards and unit cages (Fig 14).
- And eventually, very highly refined, custom-built systems.

Xcel collaborates with universities on some of these developments and shares information with other utilities and users.

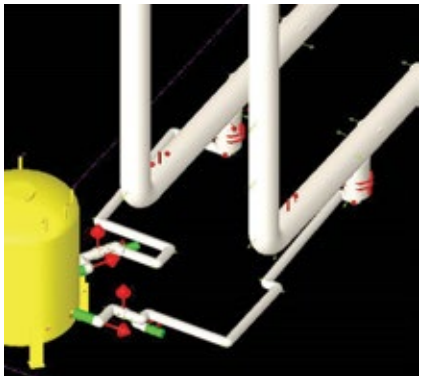
Although the possibilities seem endless, Wambeke stressed that drones are still an inspection tool—not (yet) a service and repair tool. But again, the possibilities seem endless.

Drain systems

Another example of *what's new in the industry* was Glen Wilson, Nooter/Eriksen, offering a timely project-



15. Ultrasonic detection system is calibrated to distinguish condensate from steam



16. Sensors are at the vertical drip pot and drain valves are located near the blowoff tank

based look at installation of an EPRI/Flexim-developed ultrasonic steam/water detection system for control of superheater/reheater drain valves.

The overall objective: Automatically detect and remove condensate from superheaters and reheaters without excessive release of steam, thereby preventing damage to coils and other steam-path equipment. This would reduce damage from tube-metal failures, stretching and bowing of tubes, and a host of related issues.

Riverside Generating Station wanted to use ultrasonic flow meters, with no instrumentation inside the drain lines.

The owner/operator was considering two significant EPRI guidelines, and Nooter/Eriksen suggested the newest (Product 3002005843, "Guidelines on Optimizing Heat Recovery Steam Generator Drains") which would greatly reduce the equipment requirement.

"Simply put," noted Wilson, "the industry has vast experience using ultrasonic meters to measure flow. The application to detect condensate uses the same sensing method, now calibrated to distinguish condensate from steam" (Fig 15).

At Riverside, new sensors were located near the HRSG in vertical piping (Fig 16).

Valves

Next came a discussion on condensate removal. This is a *severe* service involving large pressure drops and flashing liquid; flow capacities vary with operations.

Continued throttling reduces valve life, and discussion turned to the *master/martyr* drain-valve arrangement in which the master valve is opened first and closed last. This maintains reliable shutoff tightness of the master valve by using the sacrificial martyr valve. In this case, the master metal-seated ball valve opens and closes in two seconds with an unobstructed flow path.

The martyr valve, for throttling, can adjust to fairly low flows. As Wilson explained, "The martyr valve will open to a preset position based on current system pressure and then modulate based on presence of condensate at the ultrasonic sensor. Modulation rate may be lower prior to the purge and faster during the purge and after the CT is fired."

The all-inclusive goal is to operate the master valve as little as possible.

Installation

Installation and calibration should be by experienced technicians.

Although more expensive than the

commonly used thermocouples, "ultrasonic sensing element signals can be directly correlated to the presence of liquid or vapor, with fast response to changes in state. Thermocouples respond more slowly and cannot distinguish water from steam at a saturated condition" he noted.

Many questions followed, some stressing again the importance of proper installation. Chairman Anderson added that a downward piping slope is necessary, as water must be able to flow toward the sensor. Therefore, it is best to specify this equipment before construction. Retrofits can be challenging with high and low spots in the drainpipe, but there are now retrofits in full-time service.

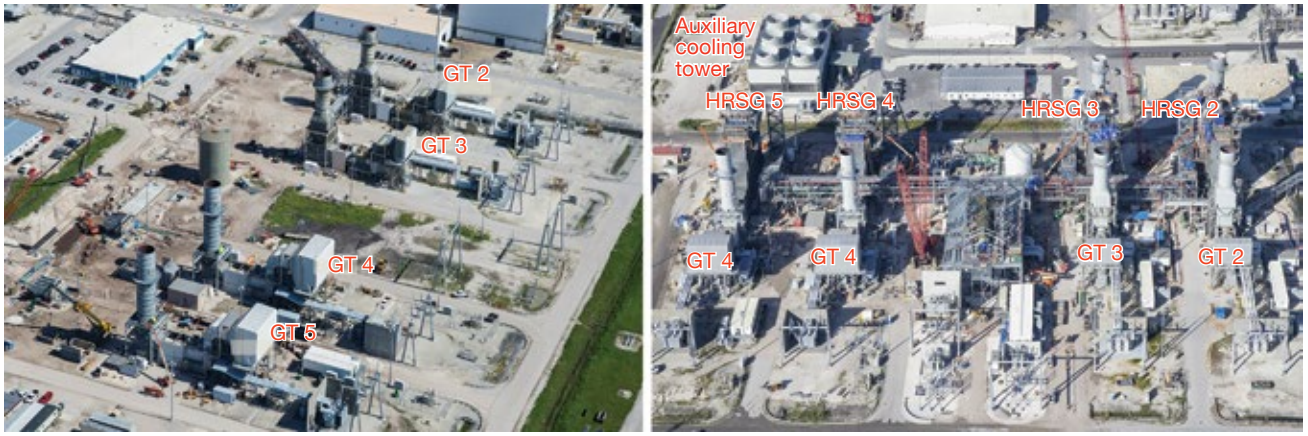
Penetrations and seals

In another site-specific example, the OG&E/Dekomte presentation focused on the 500-MW McClain Power Plant commissioned in 2001. Thermal and visual HRSG inspections in 2014 and 2015 showed several bellows and penetration-seal concerns.

McClain Power's Benn Privett explained the inspection findings, ranging from sediment and debris at the bottom of an expansion joint to severely leaking penetration seals (essentially overheating the surrounding casing).

At McClain, there are 103 seals per HRSG. After initial inspection, Dekomte performed a complete thermal survey.

Side-wall penetration technology was reviewed first, noting various OEM installation types and retrofit options. Discussion then centered on converting OEM bellows to fabric (to increase flexibility), mechanical seals



17. Simple-cycle arrangement of four 7FAs in July 2004 at left and after conversion to combined cycle 16 months later

to fabric, and labyrinths to fabric.

Specific and detailed examples followed, supporting the conclusion that "each site and application requires a tailored solution." These details also showed that "monitoring and annual inspection are critical," to address small issues early rather than major problems later.

The McClain project was 80% complete at the time of the meeting.

Dekomte's Jake Waterhouse then discussed pumpable fiber insulation, defined as a mix of short fibers dispersed in high temperature binders which, upon drying, produces a strong insulation structure with low thermal conductivity. It can be pumped or troweled into place for use in insulation, sealing and duct repairs while the unit is operating.

Simple to combined cycle

Yogesh Patel, Tampa Electric (TECO), discussed the recently commissioned Polk Unit 2 Expansion.

The project began in 2012 with four existing 7FA simple-cycle gas turbines. The result would be a 4 × 1 combined cycle with new diverter dampers, auxiliary firing for an additional 30 MW per HRSG, and one 500-MW steam turbine. Cooling towers were added to support the new auxiliary equipment (Fig 17).

Patel clearly outlined TECO's planning and assessment factors for all major project participants. The common theme was what he called a "blended team arrangement," including hands-on participation by the owner/operator.

Also of interest, HRSG supplier bid criteria included all standard items, then added adaptability to cycling service, and ease of inspection and maintenance. Cycling design elements were therefore critical, as was full-system accessibility.

For example, both front and rear inspection ports, doors, and platforms would be installed. Wide maintenance bays (23 versus 18 in.) were specified. Lower headers also required good access and room was specified under all modules for blowdown and drain inspection.

For resource selection, weaving a thread with Jeff Henry's discussion on steelmaking, raw materials originating in certain countries were not allowed. Patel noted that the entire supplier list was scrutinized and evaluated. Weld qualification tests were mandated for P91 tube-to-header welds.

He then reviewed the construction management team setup, organized in part to strengthen owner/operator personnel for future involvement in field engineering and construction.

Discussion also took place (in general terms) on the cost impact of the added features. Methods of vendor quality control also were noted.

Many questions followed, and much discussion. Some questions returned to inspection space and cycling. As Chairman Anderson clearly acknowledged, "The industry is changing. We will have more cycling and inspections; we need more room."

Cycle chemistry

Barry Dooley, a senior associate at Structural Integrity Associates Inc and executive secretary of IAPWS, presented a global look at optimum cycle chemistry for HRSGs and combined-cycle plants. He consolidated information from aligned HRSG sessions in Australasia, Europe, Russia, and Canada. Dooley and Anderson share the chairmanship duties for these conferences.

A well-known and highly-respected presenter and cycle-chemistry

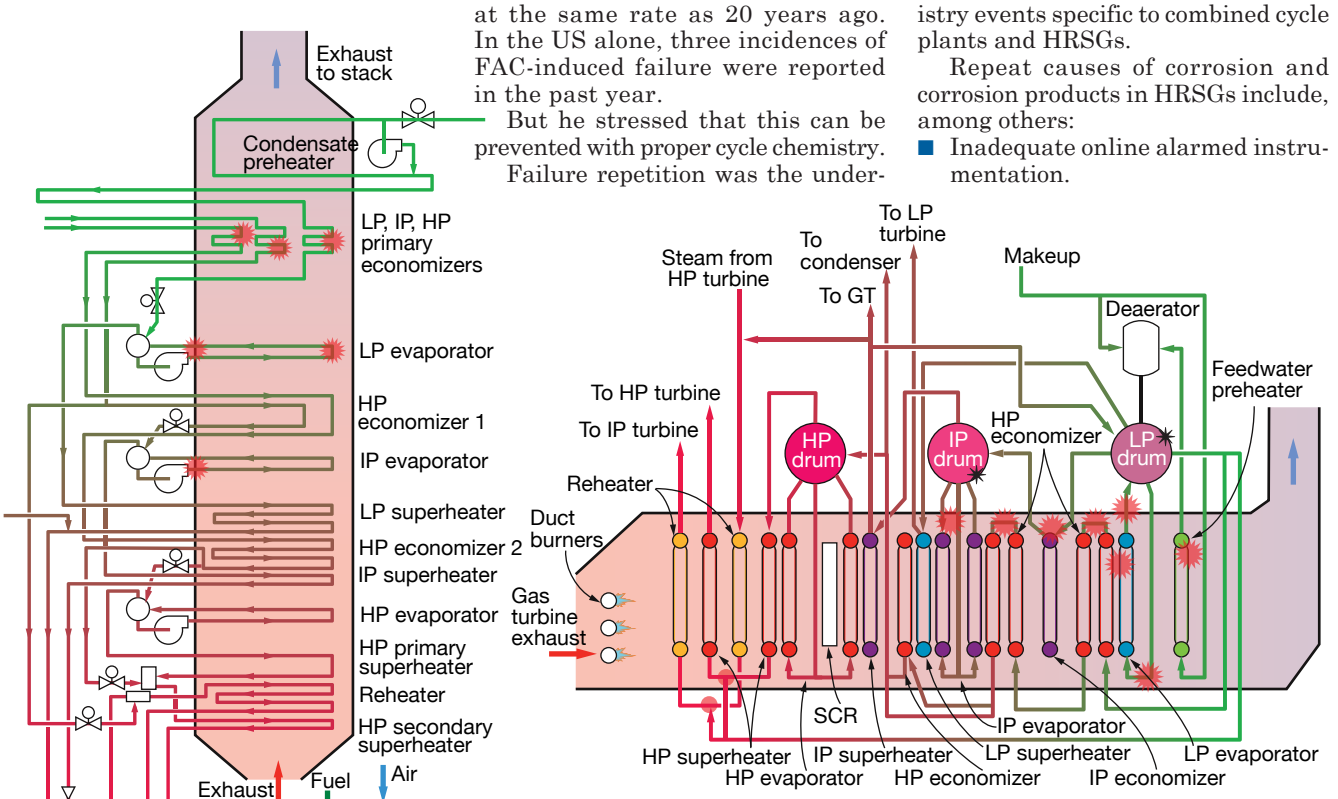
expert, Dooley repeated that flow accelerated corrosion (FAC) is a paramount concern, and proper chemistry must either be designed into or incorporated into each system installation. He also noted, with a sense of frustration, that under-deposit corrosion and FAC are still occurring at the same rate as 20 years ago. In the US alone, three incidences of FAC-induced failure were reported in the past year.

But he stressed that this can be prevented with proper cycle chemistry.

Failure repetition was the underlying theme, and Dooley referenced a summary table of data from 185 plants showing repeat problem situations. He then presented the repeat cycle chemistry events specific to combined cycle plants and HRSGs.

Repeat causes of corrosion and corrosion products in HRSGs include, among others:

- Inadequate online alarmed instrumentation.



18. FAC locations typically identified with heat-recovery steam generators are LP heat-transfer surfaces and to a lesser degree the IP stages

- Drum carryover.
- Not challenging the (site) status quo.
- Lack of shutdown protection.
- Boiler waterwall/evaporator deposition.
- No action plans for repeat situations.

Carryover also must be addressed because it leads to steam-turbine failures in the phase transition zone. "Steam-turbine issues in combined-cycle plants are increasing," he noted.

Dooley also stated emphatically that "air-cooled condenser chemistry absolutely controls the plant chemistry" (CCJ, 4Q/2016, p 56).

For FAC control, he noted the need to identify both single- and two-phase activity, and to distinguish between the two. To emphasize the seriousness and what we do know, Dooley stated that single- and two-phase FAC are still occurring worldwide, and locations have remained constant for more than 15 years. He then gave details and background, along with relevant IAPWS rules for avoidance.

Dooley then pointed out typical FAC locations in horizontal- and vertical-gas-path systems (Fig 18). His discussion featured some common ways to identify both location and type.

Then another rule of thumb: Two-phase is controlled by pH; single-phase is controlled by oxidizing power in the liquid. Proper levels of each were discussed. He also noted that amines and film-forming products must be used with extreme care.

Under-deposit corrosion (UDC) was also explained and reviewed, with specific histories, causes, examples, and treatments.

Relevant IAPWS Technical Guidance Documents (TGDs) also were listed and reviewed.

Chemistry for HRSGs

Mike Caravaggio, EPRI, followed Dooley with "Achieving cycle chemistry excellence in HRSGs." This included current industry statistics, examples of chemistry-related damage to both HRSGs and turbines (for example, FAC and iron transport, hydrogen), and a preferred instrumentation suite. Caravaggio concentrated on what he labeled "practical steps" to achieving proper and obtainable chemistry control.

Topics included the most common tube failure areas (LP economizer and HP evaporator), turbulence and FAC risk, UDC and hydrogen damage, and corrosion fatigue (now increasing with aging of the fleet).

Iron transport and oxygen levels also received high attention.

Caravaggio then presented the case study of a 700-MW plant that has shown dramatic improvement reducing iron transport by using an ammonia and neutralizing amine blend (CCJ, 4Q/2016, p 70).

Concluding thoughts included understanding the damage mechanisms and chemistry control options, performance monitoring, and the critical importance of acting on the measured results. All too often, it became clear, such action requirements are overlooked (or simply ignored).

Water/steam sampling

Manual Sigrist, Swan Systeme AG, followed with specific tools to monitor cycle chemistry, emphasizing refurbishments of existing plant sampling equipment. Systems in legacy powerplants typically have high O&M costs, low monitoring reliability, and can increase risk of collateral damage to major components. Space for new instrumentation can be limited.

For refurbishments, he emphasized the "project concept phase" to define options and obtain commercial justification. Personnel safety should always be included as a valid economic factor.

He then reviewed examples of both refurbishments and new installations, in both cases putting strong emphasis on operator training.

Materials

Jean-Francois Galopin, CMI Energy, held a WebEx presentation and group discussion from Brussels, Belgium, giving a current European perspective. He discussed higher efficiencies and the resulting higher exhaust gas temperatures entering the HRSGs. "We are already operating," he noted, "at the upper limits of Grade 91 materials."

CMI recent involvement includes Bouchain in France and Hamitabat in Turkey, both high-temperature plants now in operation. He is also involved in advanced ultra-supercritical installations.

His discussion covered material selection and design, weldability, steam oxide resistance, allowable stress, and Code approvals (both ASME and EN).

For the highest temperatures, he discussed Super 304H, good for resistance to stress corrosion cracking and stress relaxation cracking. He also covered experience with Grades 91 and 92 headers.

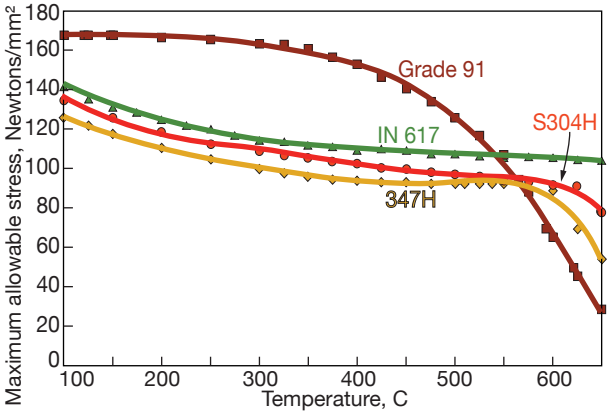
To show variety and characteristics he discussed Super 304H (fine grain structure), TP347H (course grain structure), and high-cost Incoloy 617.

Specific to maximum allowable stress/creep and impact on design, he presented the data for component thickness and cycle fatigue performance (Fig 19).

Other items included header mockups for research, welding procedures and metallurgical aspects for dissimilar welds, and alternative weld locations. In one summary he stated, "Welding procedures and metallurgical aspects of dissimilar welds exist, but long-term thermal cyclic behavior of dissimilar welds is not well established."

He concluded with finite element analysis and a focus on cyclic behavior.

Questions included the pros and cons of horizontal and vertical HRSG



19. Maximum allowable stress curves illustrate the limitations of Grade 91 material as temperature increases

20. Dissimilar metal weld failures can occur between Grade 91 and austenitic alloys, as well as lower-alloy ferritic materials

21. Current reinforcement rules are unacceptable for materials in the creep range where damage is likely in the heat-affected zone. Shown is a Grade 91 seam weld in a hot-reheat pipe with nearly 65,000 hours of service

design, cold metal working and shot peening, and stress-relief applications.

Alloy piping

Kent Coleman, EPRI, discussed issues with CSEF piping, including Grade 91. He first noted several design and manufacturing flaws that have led to premature damage in Grade 91 piping systems including:

- Dissimilar metal welds.
- Improper materials.
- Fabricated fittings and wyes.
- Fabrication/design errors.
- Soft materials.
- Longitudinal seam risks.
- Thermal fatigue at sky vents and drip pots.
- Lower alloy filler metal/base metal with and without heat treatment for attachments and lining lugs.
- Use of high nickel and manganese fillers for improved toughness.

Many of these practices, he stated, "are not prohibited by Code." Similar to the discussions with Henry, therein could lie part of the problem.

For specifics, Coleman stated that "dissimilar metal weld failures can be quite dangerous and can occur between Grade 91 and austenitic alloys as well as lower alloy ferritic materials." Main areas of concern include flow elements, thermowells, RT plugs, bypasses around stop valves (warmup lines), and material transitions (Fig 20).

Coleman also highlighted longitudinal welds (Fig 21), stating that current reinforcement rules are unacceptable for materials in the creep range where HAZ damage is likely.

He also questioned various cross and attachment welds. He then offered some specific suggestions to minimize the problems:

- Require lifting and alignment lugs to be nominally the same composition as the base metal to which they are attached.
- Follow PWHT requirements.
- Protect in a dry environment until PWHT is performed.
- Ensure PWHT on lifting lugs before they are used or stressed.

Tube cleaning, catalyst

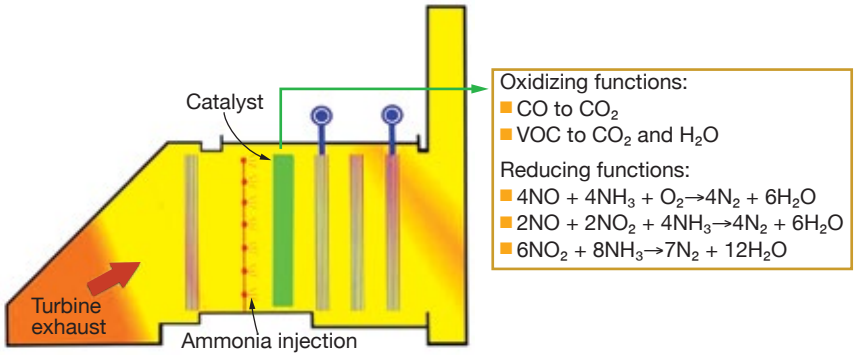
Jacob Pursley, Southern Power, gave a new perspective on HRSG tube cleaning by discussing both CO_2 and an alternative, GE PressureWave Plus™ (developed by Bang & Clean Technologies AG).

Scaffolding is not required; after setup, pressure waves penetrate the tube bundles.

With the unit offline, a lance is placed between the modules and a bag is inflated with a combustible mixture that is then remotely ignited. The pressure waves and tube vibrations remove the deposits. This is performed at various locations.

Pursley explained the process, site history with CO_2 cleaning, and the decision to use this technology.

The HRSGs at Southern's Plant



22. Meteor™, a new extruded-honeycomb catalyst in one layer, features both oxidation and SCR functionality

Rowan F-class 2 × 1 Unit 4 were cleaned by ice blasting in 2015. Corrosion at the time was visible with excessive bridging of rust between the fins. Tubes are in-line. Backpressure was approaching the GT trip point of 24 in. H_2O (original design backpressure was 15 in.). Three tons of debris were removed from each unit. Backpressure decreased by 3 in. for Train A and 2.5 in. for Train B.

But soon after the outage, Train-B backpressure increased to 28 in. Potential reasons were found in areas that had no personnel access (18 in. between modules). Pursley did point out that "previous ice blasting showed good results on the surface but various concerns were raised in the ability to access hard-to-reach areas, as well as depth of penetration." He added, "we did not use a spreading or deep-clean method previously."

Also, during an 86-day outage in 2015, Unit 4 had no dehumidification or layup, and there was rain "almost every week."

For PressureWave Plus, cleaning locations were set in five horizontal and nine vertical spots. There would be at least four *bangs* at each location. The primary target was the middle of Module 4, between HP Economizer 2 and the IP superheater section. Roof-access sky climber ports were installed for the lance rigging.

The results: debris 14.5 tons, back pressure decreased by 8 in.

Both units then were cleaned in fall 2016. The results: Train-A debris 24.8 tons and backpressure decrease 9 in.; Train-B debris another 3.3 tons, backpressure decrease 2 in.

Pursley then gave comparative results (both cleaning methods) for personnel required, backpressures, stack temperatures, and tons of debris.

There were a number of questions including the specific type of fouling, potential impact on seals and baffles, potential impact on catalysts, and theoretical depth of cleaning.

Experience with this technology is growing and under review. An EPRI program or paper is being considered.

Catalyst technology

Brian Helner, Cormetech Inc, presented on Meteor™, a multi-pollutant catalyst technology patented by Siemens. This is a homogeneously extruded honeycomb catalyst in one layer with both oxidation and SCR functionality (Fig 22). It has been "optimized and fully developed into commercial production by Cormetech," stated Helner.

A principal benefit is reduced pressure drop, along with accessibility (less space requirement).

He then presented a case study,

Ennis Power Co in Texas, a G-class combined cycle. Results after one year of operation showed "capability to operate at lower loads while maintaining CO emissions compliance" and faster CO compliance during startup. Field test data verified 99% CO oxidation at the 36% GT load point (previous was 55% to 60%), low ammonia slip, and NO_x within the target value. Inspection showed excellent catalyst condition with clean and open cells.

Further installations are scheduled for spring 2017 and fall 2018.

One general point noted was possible permitting obstacles with substitute technologies.

Controls, monitoring

NETL's Syndi Credle discussed sensors and control technologies for HRSG application. The laboratory's activity for sensors and controls focuses on high temperatures and harsh environments.

Potentially adaptable technologies reviewed included, among others:

- High temperature wireless temperature sensors.
- Temperature sensors for application up to 3270F.

Credle also explained in detail the current industry-involvement process.

PI dashboard

Madeline Dean, Exelon Generation, discussed the PI Dashboard, "Using PI to mitigate thermal transients." PI (plant information) performance equations, with real-time sensors, offer thermal transient calculations for:

- Condensate detection.
- Attemperator leakage.
- Valve instability.

Condensate: The system identifies times when undrained condensate travels across selected thermocouples, identifying large and sudden temperature drops by looking at slope and standard deviation. This helps focus corrective actions on the specific portion of the HRSG.

Attemperator: These calculations identify when water is exiting the attemperator with the valve closed, allowing detection of valve degradation.

Valve instability: Thermal transient calculations will count the number of times a valve changes from open to closed over a specific time interval, providing a specific maintenance alert.

"The Transpara LLC interface," she added, "is the visual end product that can be used on computer, phone or tablet." She also stressed the value of having historical data in an easily searchable and adaptable format.

Other applications discussed were system chemistry and catalyst monitoring for pressure drop and ammonia use.

Online monitoring

Through its acquisition of Alstom's power and grid businesses, GE can now supply and service HRSGs. (GE also has acquired the Doosan HRSG business in Korea.)

With GE's digital background, the presentation by Pascal Decoussemaeker concentrated on turning data into actionable intelligence to improve plant performance. His overall theme was asset performance management (APM).

Typical HRSG failure modes and locations were discussed (Fig 23).

Decoussemaeker then compared traditional single-sensor monitoring with real-time, multi-sensor analysis systems with dynamic alert band, to more easily detect early stages of damage.

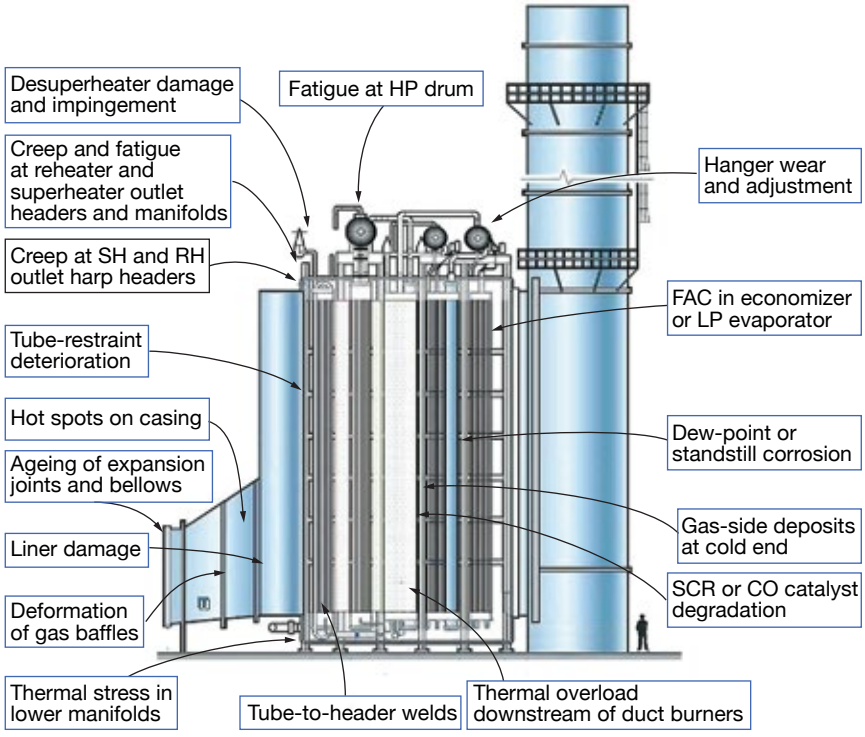
Next, he concentrated on the monitoring of some of the main life-limiting failure modes for HRSGs—such as fatigue, creep, and flooding events. The last, he explained, include desuperheater overspray and condensate flooding of the lower headers or mani-

folds during startup. However, it is not sufficient to just monitor. GE uses these insights to optimize the outage scope in an application called the *Outage Advisor* (Fig 24).

"Operation optimization," he explained, "uses actual versus expected values for thermal performance." This is traditionally applied in monitoring systems to proactively manage plant performance. However, advances in IT also allow using artificial intelligence in completely new ways. In one application, a newly developed signal called "maximum likely demand in the next 30 minutes" was created to optimize the increase of duct-firing activity to free up gas-turbine capacity for rapid response, supporting the ancillary reserve market. This led to an annual fuel saving of $1 million.

"This example shows," Decoussemaeker said, "how the exchange between plant operators and IT developments can lead to differentiators in a changing market environment."

Various questions and discussions followed on how to retrofit life-monitoring systems, factory versus site installation methods for instrumentation, adjustments for cycling operation, and incorporation of site-specific data such as measured material properties.



23. Typical HRSG failure modes and locations

Attemperators

One of the headliners on the Forum program was a panel discussion on HRSG attemperator concerns. Panel members were:

- Tom Freeman, GE Power.
- Joe Schroeder, JES Consulting.
- Ory Selzer, IMI-CCI.

- Justin Goodwin, Emerson Fisher.

Chairman Anderson moderated the panel after introducing the topic and panelists. Ensuing discussions centered around the following topics:

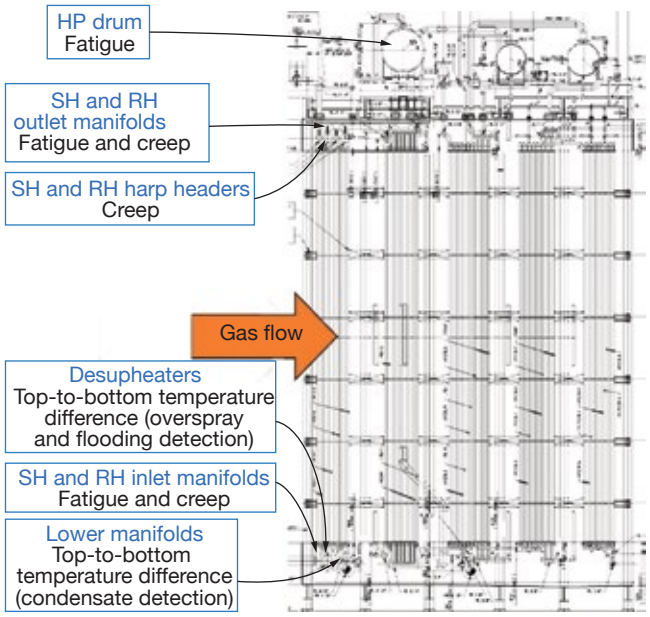
- Tube and pipe failures, steam-pipe distortions and weld cracking.
- Performance problems, including high steam temperatures and overspray.
- Attemperator hardware damage.
- System controls.

Superheater and reheater tube bowing was voted a common problem by the panelists. Anderson began by asking how many people with this problem operated GE 7FA machines. Most indicated "yes." Discussions then centered on reheater and superheater piping length, master/martyr valve combinations, and turndowns.

The panel was asked about attemperator design features (developments) to address fast starts. Selzer opened the discussion with a summary of inter-stage and terminal units in different thermal and operating environments. Goodwin continued, explaining that current operating ranges are not consistent with original attemperator designs. This led to discussion of two-stage setups.

One participant discussed a site's move to Inconel spray nozzles; benefits were noted. Others indicated this might be a good form of "cheap insurance."

The option of reheater bypass for attemperation also was reviewed.



24. HRSG life-monitoring targets

The gas-turbine perspective

Anderson set the stage with a summary of common experience: GT exhaust temperatures can go very high, and the attemperator cannot spray enough water. So, operators turn down the set point to prevent outlet-temperature overshoot. This increases the probability of overspray.

Freeman discussed the original GT design for nightly turndowns, and the differences inherent in cycling operation.

"The world has changed," he said. "Maintenance people want to protect the hardware; dispatch people want to make money and worry about parts life later." He then added, "The money-making piece plays heavily."

Freeman examined three topics. He began with the market perspective, noting that when most existing powerplants were commissioned no one conceived of the world in which they function today. He described this as a global market and mission shift.

Next, he extended this shift to the CT operational profile. Most existing plants were designed with part-load paths that were merely transients on the way to baseload, where units were expected to run for most of their lives.

Often, part-load curves were designed for what was then the new generation of low emissions combustors. But before long the North American market would see dramatic operational shifts. Turndown was becoming a significant factor. And sites were beginning to feel new pressures on HRSG operation and maintenance.

Freeman continued: "GE is rethinking the gas turbine load path [GT load versus exhaust temperature]. The way the load path was configured," he continued, "was to hold temperature rise as a constant as long as possible. Some GE units are 100F hotter on exhaust than counterpart GTs."

A few years back, he said, his gas turbine team was largely unaware of HRSG constraints. "When information began to emerge, it became clear that there were two primary regions of interest: startup and turndown. The startup regime is generally related to independent GT/plant controls and often can be solved with a simple feed forward loop. In GE, that is called OpFlex Advanced Attemperation.

"The more intriguing issue is turndown," he noted. "If you look closely at the operation, the concern often is not at low turndown but rather in the high-energy portion of the turndown, as the gas turbine approaches the isotherm while air flow (inlet gas velocity/IGV) remains fairly high."

He then relayed some more history. "A few years ago, GE was experimenting with a much broader load path range. The low end of the range could be called *cold load path*. Essentially, it becomes a trade-off on giving up air flow more quickly than T-fire (uprating the base firing temperature). Old timers would call it a *simple-cycle load path*. Interest grew because the modern DLN systems were now fairly robust and could provide greater flexibility.

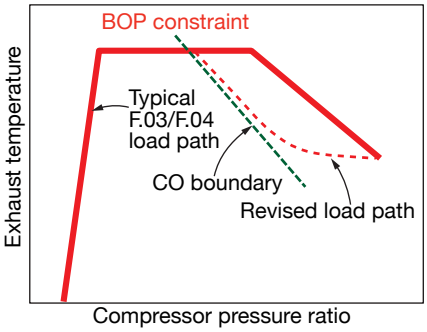
The HRSG high energy corner could be bypassed. Attemperation valves that were running to 100% stroke could be held down around 40%. Thus, GE began to include the optimized load path in the later implementations of the advanced gas path (AGP)" (Fig 25).

He cautioned, however, about locking into any one path.

Freeman summarized the industry situation this way: GE has some methods to mitigate near-term operational boundaries. Yet, he sees the industry as needing to make uprates to the HRSG subsystems.

Looking at industry direction, Freeman predicted increased exhaust conditions and the need to make an improved integrated system decision focused not on status quo, but on where the industry will likely go.

And his summary message to the HRSG community: "Scale up what you are doing. Don't solve for today; solve for tomorrow. If you do an upgrade without understanding where the market is going, then you might end up paying twice." CCJ



Initial examples: 7F.04 in the Northeast and 7F.04 in the Southeast. Attemperation system was undersized for the emerging mission profile. During certain times of year, while the gas turbine could turndown, the BOP limited operation—both before the advanced gas path (AGP) upgrade and afterwards. Question: Can the gas turbine be used to enhance BOP operation? Direct boundary control advantages coupled with advanced DLN operability knowledge opened mission space.

25. Optimized gas-turbine load path to reduce HRSG impact on turndown

Still growing, innovating to better serve aero users

Western Turbine Users Inc, the world's largest independent organization of gas-turbine owner/operators, celebrates 28 years of service to the industry at its 2018 Conference and Expo, next March 18-21 in Palm Springs, Calif (visit www.wtui.com). Sounds like a long way off, but it's not too early to make a note on your calendar and begin lobbying for travel funds. Registration opens November 1, which offers the opportunity to apply 2017 budget surplus to next year's meeting.

WTUI President Chuck Casey, utility generation manager for Riverside (Calif) Public Utilities, brought participants in the March 2017 meeting in Las Vegas up to date on the organization's activities and health—nothing but good news. Casey, who has chaired the meeting since the 2013 retirement of immediate past president Jon Kimble, does an outstanding job of keeping members informed.

His hour-long presentation was crisp and eclectic—including messages of importance and those not so important, WTUI business matters, industry highlights, etc—holding audience interest the entire time. Most importantly, Casey began with a safety message, showing the thousand or so attendees in the cavernous ballroom how to exit the South Point Hotel & Spa quickly if need be.

He stressed courtesy and respect among all presenters and attendees and requested no photography or recording of presentations.

This was WTUI's first trip to Las Vegas since 2001, Casey recalled. In the intervening years, the LM2500 fleet had grown by 300%, the LM6000 fleet by 350%. The LMS100, today an important breakout session for the user group, wouldn't debut at Basin Electric Power Co-op's Groton Generation Station in South Dakota until 2006. Also of note:

Casey

- WTUI membership, 169 in 2001, stands at 1050 today.
- Meeting attendance in 2001 was 713, this year more than 1100.
- Exhibit-hall booth space nearly doubled from 143 in 2001 to 256 in 2017.
- Room rates *decreased* over the years, from $94 to $70.

Casey's day job requires him to keep his hand on the pulse of the industry to help guide decision-making at Riverside Public Utilities. Briefly, he shared knowledge on three of what he considers top non-turbine concerns:

- Cybersecurity.
- Digital assets.
- Customer service and transparency.

And then on three observations impacting turbine asset management today:

- It's less about reliability and availability, and
- More about cycling, turndown, emissions, ancillary services, and shorter outages.
- Relevancy.

Casey next offered a few thoughts on the impacts on the electric power industry of the following:

- Today's focus on the environment, as indicated by installation of the most photovoltaic generation in history last year, renewables reaching grid parity (gas versus wind), and load defection attributed to solar and storage (see article, p 30). Another milestone: Electric production nationwide from gas passed that of coal in 2017.
- Inexpensive natural gas.
- Commercialization of advanced technologies.
- Impact of demanding load swings for conventional generation assets.
- Online devices and smart homes.
- Policies and regulations.
- Rate design.

Casey is not the type to sit back and make decisions based on what others think. He rolls up his sleeves and opens up his wallet to get first-hand experience. The Western Turbine leader brought attendees up to date on what he calls the Casey Energy Center—residential self-generation. Many in the room were aware of his "experiment" from previous presentations. The utility's December 2016 statement he showed revealed the following:

- Average daily electricity usage (utility supplied power) for the month of December in 2017 was 3.7 kWh. That's about half of the 7.03 kWh/day in December 2016; two Decembers ago the number was 6.06 kWh.
- Total consumption for December 2016 was 481 kWh. Self generation totaled 370 kWh. Thus Casey had to buy only 111 kWh.
- In February, March, April, and May 2016 Casey Energy Center produced more power than it needed.

He also put up a chart of rooftop PV production hourly for several days in May 2016. Peak production each day was about 0.5 kWh during the noon hour. The inescapable conclusion from

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Boyd weighs anchor, sails into retirement

The greater aero user community wished Alvin Boyd fair winds and following seas in his retirement, which began when President Chuck Casey closed the 27th annual conference of the Western Turbine Users Inc at noon, Wednesday, March 22.

Boyd learned how to operate a lathe and handle a wrench in the US Navy, mustering out as a Machinist Mate 1/c. Like 13 of his 18 colleagues on the Western Turbine leadership team, he opted for a shoreside-power career after serving in the armed forces.

Boyd's years of unselfish service to the Western Turbine Users were celebrated at the Las Vegas meeting. He served on the Board of Directors from 2008 to 2013, and was elected secretary and managing chairman of the exhibit hall upon Casey's elevation to president. Board Member Jermain Woodall replaced him as secretary, and also as co-chair of the exhibit hall with Bill Lewis, when Boyd was piped ashore Wednesday noon.

Casey saluted Secretary Boyd as one of the hardest-working of the WTUI volunteers. Organization of the exhibit hall, involving about 160 vendors from around the world, the president said, takes five months of serious effort to accommodate the needs of individual exhibitors and to design a floor plan that optimizes traffic flow—among other things. One of Boyd's many accomplishments was the development of the sponsorship program to fund the group's first-rate Sunday evening reception celebrating the opening of the exhibit hall.

Casey's data: Rooftop solar can dramatically reduce residential consumption of utility power—at least in Riverside, Calif, and other areas bathed in sunlight.

Next, the weekend car buff will put an electric vehicle through its paces to quantify its expected benefits. That research project will begin as soon as the Tesla Model 3 on order arrives. The unknown only seems to heighten Casey's interest as evidenced by the slide he showed with a quote from engineer/author R R Whyte: "Progress is the art of getting out of trouble you wouldn't have been in if it was not for progress."

He then wondered out loud about the future of gas turbines given the aggressive nature of some proposed Renewable Portfolio Standards (RPS), such as the following:

- California's proposed 50% RPS by 2025.
- Nevada's consideration of an 80% renewables mandate by 2040.
- New Mexico's SB-312 with an RPS goal of 80% by 2040.
- Hawaii's 100% renewables goal by 2045.
- Oregon's passed 50% mandate by 2040.

Energy storage targets also are on the horizon, he said.

Casey urged the membership to be positive, stay relevant, and make progress.

The value of Western Turbine meetings to owner/operators was the president's next topic. He touted a conference atmosphere conducive to self improvement. Challenge yourself, he said, and then challenge the OEM and the suppliers in the exhibition hall. "Be the leader and innovator," Casey continued. "Turn failure into success." Low-hanging fruit grows back, he reminded.

The president continued with introductions of key staff, officers, board of directors, and breakout-session chairs. In the process, he announced the retirement of Secretary Alvin


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Boyd, also co-manager of the exhibit hall, who served the group unselfishly for years in various capacities (see box). In related news, Devin Chapin completed his three-year term as a board member and Jermaine Woodall transitioned from the board to secretary, replacing Boyd. Wayne Feragen of Noresco and Al Vanhart of PSEG Power LLC were elected to the board, filling the two vacant positions.

Casey concluded his presentation with details on several administrative matters, a cursory review of the agenda, and what he called 2017 conference fun facts—including these:

- Countries represented, 20.
- States represented, 41.
- States with the greatest representation: California, 228; Texas, 111; Florida, 64; Ohio, 46.
- Companies represented in the exhibit hall, 156.
- First-time vendors, 26.

The Axford Report

Mark Axford, the Houston-based consultant considered by many to be the leading independent expert on gas-turbine markets, packed more information than ever before into his annual one-hour presentation on the state of the energy industry's GT sector. He accomplished this by partnering at the podium with Tony Brough, PE, president of Dora Partners & Co, who shared his company's stats on more than 35,000 GTs worldwide rated from 1 to more than 300 MW (total capability, 1525 GW).

First, Axford's predictions: At last year's meeting in Palm Springs, The Turbine Guy forecasted US orders for GTs in 2016 would *decrease* by 10% (megawatt basis) compared to 2015; also that orders worldwide would *decrease* by 10%. Axford got the direction right, but the magnitude wrong: US orders were down 30% year over year and worldwide orders were down by 14%.

For 2017, he sees orders for units larger than 10 MW up by 10% in the US, in part because of improving demand in regional pockets. Plus, expected approval of new pipelines will increase orders from companies in the oil and gas industry. Worldwide, Axford predicts a 10% decrease in orders year over year for 2017.

The following bullet points reflect some of his thinking on international business:

- Europe still is in recession. Power demand is soft and orders for GTs will reflect that in 2017, as it has for the last few years. Germany is retiring nuclear generating stations and adding high-efficiency (high cost) coal-fired units and offshore wind. Electricity is very expensive, perhaps a luxury product.
- Business in South America—mainly Argentina and Bolivia—was good in 2016. Whether a robust GT order book continues in 2017 is open to question.
- In Canada, political pressure may limit growth in the oil and gas sector despite Keystone Pipeline optimism. Any spending likely will be cautious given the strength of the US dollar against Canada's.
- Mexico remains active thanks to continuing development of its energy-industry infrastructure. Energy reforms and financial help from north of the border are the most significant business drivers. However, 2017 GT orders are predicted drop back to the traditional annual order book of about 1000 MW from the 5000 MW bought last year to support six new pipelines. What happens after President Enrique Pena Nieto's term expires at the end of 2018 is anyone's guess.
- In Asia, LNG spot prices, linked to crude, are down dramatically from the $19/million Btu recorded in 2014. In 2015 the price had dropped to $11 and by May 2016 it plummeted to $4. By early spring 2017 the spot price had rebounded to about $9/million Btu. Axford believes $8 LNG is feasible long-term. This is positive news for GT owner/operators and should stimulate orders.
- Action in Africa and the Middle East does not signal an order bonanza in the near term, although business in Saudi Arabia and the Sahara region remains good. Orders in 2016 from Oman for 2900 MW of combined-cycle capacity, and from Egypt for 6500 MW, may be the last of the good times for a while.

Observations, comments

Axford closed out his portion of the state-of-the-industry report with "some thoughts and comments." He believes these are some of the things industry participants—users as well as suppliers—at least should be aware of in their planning activities. They are facts and observations, not analyses, and were delivered rapid-fire:

- GE closed its Houston gas-turbine packaging facility (formerly Stewart & Stevenson) which had delivered more than 800 LM turbines in its 30 years of operation. First out the door was an LM2500 for the city of Wellington, Kansas (1986), last was an LMS100 for the Exelon West Medway II Project in Massachusetts (2016).
- The medium-size GT genset market is shrinking, with units larger than 100 MW capturing the lion's share of available business.
- Medium-speed reciprocating-engine gensets accounted for 45,000 MW of installed capacity worldwide—the equivalent of 900 LM6000s—since the beginning of 2006. The selling points: quick start and flexible.
- Renewable-energy generating facilities installed last year in the US totaled 26,000 MW. Solar and wind each captured half of that total or 30% of the market, natural gas 33%.
- Axford spent a couple of minutes talking about subsidies and how they have favored electricity production by solar and wind resources. He reminded attendees of the "Grand Compromise" that congress jammed into the 2016 federal budget:
  - The oil export ban enacted in 1975 was canceled permanently.
  - The investment tax credit for solar facilities was extended through 2019 at 30%. In 2020 it drops to 26%, in 2021 to 22%, and in 2022 to 10%. The effect of extending solar subsidies from 2011 through 2021: The installation of 18,000 MW of solar power—the equivalent of 360 LM6000s.
  - The wind production tax credit of 2.3 cents/kWh was extended through 2016. This year it is 1.84 cents, in 2018 it drops to 1.38 cents, and in 2019 it goes to 0.92 cents. Axford noted the effect of extending wind subsidies from 2011 through 2021: The installation of 19,000 MW of wind power—the equivalent of 380 LM6000s.

  He then got a chuckle for his definition of "subsidy": "A government grant to a private party to encourage an investment that no logical person would consider." Subsidies are sold to the public as "the right thing to do" but the only thing they really do is distort free markets.
- The "duck curve" was worth a minute or two given about 40% of the attendees were from California. "Who pays?" was the speaker's question. More solar would be required to hit the state's goal of 50% renewables by 2030. But the duck's belly, already fat, is getting fatter and its head is getting bigger. The impact: Heavy ramp daily from 1500 to 1800 hours; GT load is highest from 2100 to 2200.


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When you considered the data on the screen, some questions came to mind. Example: What is the practical maximum for renewables as a percentage of total installed capacity? Do you shut down solar and wind plants in favor of big hydro in the North during the spring runoff?

- Axford frequently is asked if President Trump will try to repeal solar and wind subsidies. His typical response is "probably not," but no more extensions. His reasons:
  - Subsidy value declines until expiration in 2021.
  - The Grand Compromise was passed by bipartisan vote.
  - The largest wind installations are in the Midwest (Republican states).

  Axford said to expect more wind and solar "gold rush" in 2017 and 2018.
- Regarding oil price, Axford's outlook is for crude to remain below $60/bbl throughout 2017.
- An update on LNG exports was the subject of another slide. These are the LNG export terminals in construction or operation in the US and their production capability in millions of tons per year:
  - Cheniere 1, Sabine La, 27.
  - Dominion, Cove Point, Md, 5.
  - Cameron, Hackberry, La, 15.
  - Freeport, Freeport, Tex, 14.
  - Cheniere 2, Corpus Christi, Tex, 13.

Axford said one or more North American terminals might be added to the list, given permits pending for three sites in the US and two in Canada.

- The speaker's final 10 slides focused on electrical vehicles (primarily Tesla) and batteries. Axford closely follows the EV market for personal and business reasons. The latter: If successful, he says, Tesla will disrupt automotive, oil, and electricity markets. The Houston consultant provided details on Tesla's background, sales, goals, etc. Challenges for Tesla abound. For one, it seemed as if it would be tough to justify to an investor the financial data provided. Regarding technical issues, likely they will take years to uncover and correct.

  Using a published prediction of EV market penetration by 2030 equivalent to 7% of the US vehicle population, Axford calculates that the additional generation required to fuel this fleet would be at least 5000 MW. That translates to the equivalent of 100 LM6000s over the decade leading up to 2030.

  Finally, the speaker pointed to batteries as the next energy subsidy. As many in the room were aware, the California PUC mandated, in October 2013, 1325 MW of storage by 2020. Southern California Edison and Pacific Gas & Electric each were responsible for 44% of that total, San Diego Gas & Electric the balance.

Gas-turbine database

Dora Partners' Tony Brough answered many of the questions regularly received by the editors regarding numbers of gas turbines in service, fleet sizes, etc. By way of background, he was affiliated with GE Aeros from 1986 to 2003 and with Rolls Royce from 2003 to 2007. Brough founded Dora in 2013.

His firm has sliced and diced the worldwide installed base of gas turbines every which way:

- By OEM. GE has a 52% market share on a megawatt basis, Siemens is a distant second at 27%.
- By turbine capability. Units in the 150-300-MW range dominate the market (megawatt basis) with a 54% market share; units in the 100-150-MW range have 11% of the market; those in the 40-100-MW range, 15%.
- By sector—electric power producer (82% on a megawatt basis), oil and gas (15%), marine (3%).
- By geography—regions and countries. In round numbers, North America (25%) and Asia Pacific (24%) combine for half of the world's

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gas turbine capability. The Middle East comes in third at 17%; Europe is fourth at 14%.

- By type of cycle—simple, combined, cogeneration.
- By topography—onshore, offshore.
- By application—power generation, mechanical drive.
- By technology—heavy duty (82% on a megawatt basis), aero (12%), light industrial (5%).

Brough dissected the aero market for attendees. Here are the number of *engines* in the respective fleets:

GE. LM6000, 1103; LM2500, 1073; LM2500+, 948; LM5000, 87; LM1600, 119; LMS100, 83.

Siemens. RR501, 678; RB211, 640; Avon, 763; Trent 60, 111.

PWPS. FT4000, 3; FT8, 561.

A snapshot of the US aero market for 2016 provided these facts:

- Aero *unit* orders were down 46% in 2016 compared to 2015.
- Aero *megawatt* orders were down 65% in 2016 year over year.
- GE's share of market was more than 90%.

Globally, the picture was not much different:

- Aero *unit* orders outside the US were down 42% in 2016 compared to 2015.
- Aero *megawatt* orders outside the US were down 35% in 2016 year over year.
- GE's share of market outside the US was just under 50%.
- There were no FT4000 or RB211 orders in 2016.

The aftermarket. Finally, annual spending to maintain the global aero fleet is about $2.2 billion, according to Dora. And this doesn't include BOP equipment, controls, and accessories.

The SPS report

It is important that SPS continue to provide industry benchmarks leading up to, and during the annual WTUI conference, Salvatore A DellaVilla Jr, CEO of Strategic Power Systems® (SPS), told the editors at his company's booth on the exhibition floor. "Participation by owner/operators of LM engines in the ORAP® program allows us to aggregate data and provide meaningful analytics to the group," he said.

"Our effort to provide the high-quality information required for decision-making demands automated collection of data from the control system," DellaVilla continued.

"We bring this to your attention because our engineers and analytics team are seeing more and more issues related to the manual submittal of data. For example, you may have

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noticed that we do not provide any metrics for starting reliability. Our experts are concerned that the information submitted to SPS regarding starts is increasingly inaccurate and we are not confident in the starting reliability data to provide it as an industry benchmark."

As stated in IEEE Standard 762, the document SPS uses to guide the processing of ORAP data, "a starting failure is an unsuccessful attempt to bring a unit from shutdown to the in-service state within a specified period (which may be different for individual units). Repeated initiations of the starting sequence without accomplishing corrective repairs are counted as a single attempt."


DellaVilla

Simply, if the unit does not reach breaker closure in a specified period of time, it is considered a failure to start.

Additionally, SPS is questioning much of the information reported to it from NERC GADS. The company says it continually sees issues in the fidelity of the data as that information relates to causes of downtime and duration.

"Our engineers have conducted a data-quality comparison referencing one of our long-time customers that recently moved from submitting data directly to us versus submitting NERC GADS data," DellaVilla said.

"We found NERC GADS data are inherently high-level and do not have the same granularity of detail that ORAP requires. Plus, NERC GADS does not require users to identify component-level root causes to forced-outage events, a detail that creates issues when trying to compare this customer to the rest of the fleet.

"These data also raise concerns with the manufacturer. Periodically, we conduct quality reviews with the OEMs. During these reviews we often are questioned on the accuracy of events that have been submitted from NERC GADS reports. All the issues identified above make it difficult to use NERC GADS data to allow meaningful and accurate comparison with the rest of the fleet in ORAP."

The easiest way to remedy these issues Team SPS says is by use of automated data collection from the control system, as DellaVilla had mentioned earlier in the conversation. By automating the data, the system records each mission, from startup to shutdown—including all major states from signal to start, through the permissives, to ignition, flame established, acceleration, breaker closure, through each change in load state, to shutdown,

Table 1: Key performance indicators developed from ORAP® simple-cycle RAM metrics

Parameter	2016 Aero	2011-2015 Aero
Peaking units:		
Annual service hours	390	379
Annual starts	102	91
Service hours/start	3.8	4.2
Service factor, %	4.4	4.3
Capacity factor, %	4.0	4.0
Availability, %	90.6	91.7
Reliability, %	96.0	96.2
Cycling units:		
Annual service hours	1989	2152
Annual starts	183	162
Service hours/start	10.8	13.3
Service factor, %	22.7	24.6
Capacity factor, %	14.4	17.0
Availability, %	92.2	92.2
Reliability, %	96.7	96.8
Baseload units:		
Annual service hours	6845	7021
Annual starts	45	53
Service hours/start	152.9	132.6
Service factor, %	78.1	80.1
Capacity factor, %	64.8	67.6
Availability, %	92.2	92.6
Reliability, %	96.5	97.4

and then the cool-down period. This is the only way to eliminate human error and ambiguity and ensure data accuracy.

However, SPS still does need input from plant maintenance staffs regarding the symptoms, corrective actions, and eventually the root causes of outages to ensure that the full scope of the event is captured correctly. There always will be a human element to this reporting.

That said, SPS has prepared the latest RAM KPIs from ORAP (Table 1). The data have been reviewed thoroughly and analyzed for accuracy. The information compiled in the table comes from 607 aero units for 2016 and 1,092 units for the 2011-2015 period. The aeroderivative gas turbines in the sample include engines from GE, P&W, and Siemens AGT (formerly Rolls-Royce) and represent units operating worldwide.

Table 2: Comparing capacity (CF) and reserve standby (RSF) factors regionally

Parameter	2016 Aero	2011-2015 Aero
West		
CF, %	13.6	20.5
RSF, %	72.9	67.8
Midwest:		
CF, %	21.3	10.8
RSF, %	67.9	75.4
Northeast:		
CF, %	25.8	15.5
RSF, %	65.4	71.2
South:		
CF, %	15.4	13.9
RSF, %	72.7	76.4

Note: West includes Alaska and Hawaii

There was a minimal increase in annual operating (service) hours for peaking units from the 2011-2015 period to 2016; availability decreased by about 1.1% for 2016 and reliability was pretty consistent within the two time periods. Cycling units operated 163 hours less in 2016 than they averaged in 2011-2015; availability stayed exactly the same, while reliability decreased slightly (0.1%). Baseload units operated 176 less hours in 2016 versus 2011-2015 and annual starts decreased.

The regional analysis in Table 2 revealed capacity factor was down by 6.9% in the West, but showed an increase of 10.5% and 10.3% in the Midwest and Northeast, respectively. Another interesting thing to note is that all regions with the exception of the West, had a reduction in reserve standby factor.

Special technical presentations

Last year (2016), at the 26th Annual Meeting, the WTUI leadership increased by 50% the number of speakers participating in the group's popular special technical presentations session to expose attendees to more subject of interest beyond the basic engine. The new agenda was well received by attendees and nine presentations were arranged for the Las Vegas meeting.

The Tuesday afternoon program at the South Point Hotel & Spa began at 2:30. Three one-hour sessions were conducted in series, each offering three concurrent presentations. The lineup:

Session 1, 2:30.

- "Aeroderivative Gas-Turbine Control Systems 102 'Lab,'" Eric Freitag and John Stulp, *Woodward Inc.*
- "Online PD testing: An Essential PM Tool for Motors and Generators," Sunny Gaidhu, *Qualitrol (IRIS Power).*
- "Eliminate Vent Flow Switches" and "Better Diagnostics with Current Transducers," Ed Jackson, *Missouri River Energy Services.*

Session 2, 3:30.

- "Borescope Findings and Critical Service Bulletins," Dale Reed, *Reed Services Inc.*
- "HRSG Evaporators," Ned Congdon, *HRST Inc.*
- "LM Turbine Controls: Troubleshooting 101," Andrew Gundershaug, *Calpine Corp.*

Session 3, 4:30.

- "Orientation and Maintenance Overview of Aero-driven Generators," Derek King, *Mega-Watt Consulting LLC.*
- "NFPA 12 Life Safety Upgrades and Water Mist Suppression for Turbines," Chuck Hatfield, *Orr Fire Protection Systems.*
- "Battery Maintenance," Sam Ayoubi, *Borri Power US Inc.*

For the most part, the presentations were thorough, covering the subject matter advertised in meaningful depth, as evidenced by the number of slides and the amount of information packed into many of them. Only two presentations had fewer than 37 slides; two had more than 70 and another two more than 60. One presentation in the last session ran over by half an hour.

Some points can be tough to grasp when an attendee is unfamiliar with the subject matter and the speaker is intent in getting through his or her too-long slide deck before time runs out. The clock can be a significant factor because the "effective" presentation time is not the one hour shown on the program but more like 50 minutes because of the movement among the meeting rooms between sessions. What about the all-important Q&A and open discussion? Not much time for that, if any.

However, for users wanting to fill in gaps in their notes, and for those who wanted to attend more than one presentation in a given session, having access to detailed slides is valuable. The Western Turbine leadership has made the PowerPoints available to registered users at www.wtui.com.

What follows are editorial notes on a few presentations to give you the flavor of their content and the motivation to dig deeper by accessing the proceedings on the Western Turbine website.

Controls troubleshooting

There were two user presentations among the nine selected for the special technical program—one by LM6000 Breakout Chair Andrew Gundershaug, the other by Western Turbine VP Ed Jackson. The latter dug into the details of two best practices Jackson and his team at Exira Station submitted for consideration in the WTUI/CCJ awards program; they are summarized later in this report.

Gundershaug spoke to the value of checklists in troubleshooting. He introduced the subject by stressing the need to make plant processes systematic to keep things from falling "through the cracks." Without systematic processes, he said, "we are vulnerable to:

- Processes left to *chance;*
- Processes left to *human error;*
- Sometimes we do it, *sometimes we don't."*

The Calpine plant manager admitted to being "obsessive about the use of checklists," because he believes nearly all processes can be improved by using them. "I feel that often we get bogged down developing robust and complex procedures to establish the 'why' and 'how' of processes, yet often missing in the implementation is the tool to make it happen and the process for determining that it is being done correctly."

Have a plan. Just as it is important to use a procedure when you start a powerplant, Gundershaug said, it is important to have a structure for troubleshooting complex issues. It will ensure consistent positive results and improve the outcome. A friend, Nick Voorhis, was credited for the following troubleshooting methodology that Gundershaug embraces:

- *Determine the problem.* Site personnel can get caught up in working on the symptom of an issue and not the problem itself. Important to discuss the problem with all stakeholders, to weed out opinions, and to concentrate on the facts.
- *Gather information.* The more information you have available for reference, the speaker said, the more likely the issue will be resolved. He suggested reviewing the documentation, witnessing the problem personally, and determining if the problem is intermittent. Also, if software logic is involved, be sure you have access to understand the process.
- *Form a hypothesis.* It is important, Gundershaug continued, for plant personnel to use the information gathered to derive a hypothesis; it supports a learning culture. Tools at your disposal include OEM flow charts, test data, measurements, etc.
- *Test the hypothesis.* After deriving the hypothesis, develop a way to test the theory. This is fundamental to the process because it requires those involved to become experts on the issue.
- *Implement the repair.* Focus on repairing the component determined to be the root cause of the problem. Afterward, determine if the repair was successful. Also verify that the repair has not created a new issue.
- *Analyze the results.* You may find test results challenge investigators' assumptions and hypothesis. If this is so, ask these questions: Was the hypothesis correct? Is more testing required? Is a new hypothesis needed? If need be, continue or return to previous steps in the process.
- *Document the results.* According to Gundershaug, this may be the most important step in the process. Documentation helps to form and reinforce long-term memory, he said, and becomes a tool for analyzing future events. The value of documentation extends to the following:
  - It is a repository of information that can be shared among plant personnel to increase knowledge and awareness of the issue.
  - Enables the sharing of information outside the immediate work group to promote knowledge across the fleet.
  - An RCA will expose other issues and aspects of the problem that were unknown in the early phases of troubleshooting.

Gundershaug stressed that "you cannot fix something that you do not understand" and went on to illustrate use of the troubleshooting checklist for diagnosing and correcting an LP turbine overspeed issue and an engine trip caused by what plant instrumentation said was a vibration problem.

Fire protection

Fire protection is a topic in safety discussions at virtually every user group meeting, one that seems to be generating more interest as plants age. For example, systems installed 20 or more years ago have been cited for unwanted release of the extinguishing agent because of unreliable sensors. In some cases, the extinguishing agent is no longer in favor and should be replaced.

It's important to keep safety systems current and well maintained. With the many retirements and staff changes of late, perhaps the person with most knowledge of your plant's fire protection system is gone. That knowledge gap must be filled. The presentation by Chuck Hatfield of Orr Fire Protection Systems is a good first step in the learning process.

Orr promotes itself as a one-stop shop for things having to do with fire protection—including alarm, detection, notification, and suppression. It provides testing, inspection, and

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maintenance services for all types of fire protection systems offered by the major manufacturers of that equipment. The company also offers design/build, system modification, and decommissioning services, focusing on businesses with mission-critical operations—like powerplants.

Hatfield's presentation addressed CO_2 and water-mist systems. Given the number of slides and the amount of material covered, this could have been divided into two presentations. No matter, registered users can access the slides at www.wtui.com; they are easy to follow.

The basis for Hatfield's CO_2 system coverage was NFPA 12, "Standard on Carbon Dioxide Extinguishing Systems." He referenced the 2005 standard but be aware that the latest version was published in 2015. CO_2 is an effective suppression agent, but there are safety concerns for personnel.

Hatfield discussed normally occupied, normally unoccupied (but occupiable), and unoccupiable areas, and things of general importance regarding CO_2 systems—such as safety-sign specs (type size, color, etc) and where they should be placed, supervision of automatic systems and manual lockout valves, rules for discharge pressure switches and pneumatic time delays, provisions for prohibiting entry into given spaces, etc.

Locations where new CO_2 systems should not be installed was another topic. The standard says, "Carbon dioxide total flood systems shall not be used in normally occupied enclosures if other fire extinguishing agents can be used to provide an equivalent level of fire protection to CO_2."

You hear more about high-pressure water mist systems today than only a few years ago because of concerns about the accidental release of CO_2 when personnel are in normally unoccupied spaces—such as the gas-turbine compartment. In fact, at least one OEM prohibits package entry when the GT is in operation.

Hatfield went on to describe high-pressure water mist systems, importance of droplet size, etc. Most of this should have been familiar to LM owner/operators because virtually the same technology is used in GT inlet systems to restore power lost on hot days.

What appeared helpful to many in the room was the speaker's rundown on the offerings of four major suppliers: Marioff Co's Hi-Fog®, Fike Corp's DuraQuench™, Securiplex, and Victaulic Co's Vortex™. He covered design details for each.

For some attendees, the last was the most interesting system given its use of a supersonic emitter to create a multi-layer shock wave of nitrogen which atomizes the water to a sub10-micron mist. It creates a homogeneous suspension of nitrogen gas and water.

Aero GT controls

Woodward's Eric Freitag and John Stulp picked up in Las Vegas where colleague Mike Toll left off last year in Palm Springs. They began "Aero GT Controls 102" with a review of Toll's "Aero GT Controls 101," hitting the highlights of control-system architecture, presenting an overview of the engine system and critical sensors for speed, pressure, temperature, etc, and reviewing basic control theory.

Then they conducted a series of what they referred to as "lab exercises":

- Turbine startup (light-off and acceleration to synch idle).
- Ramping to maximum power.
- Sprint™ operation.

There was a quiz after each exercise and a final exam.

Certainly was an interesting presentation approach, one conducive to learning. It held audience interest and encouraged questions and discussion.

The Western Turbine value proposition

If your job responsibilities involve the operation and/or maintenance of one or more GE land and marine (LM) aeroderivative gas turbines at a simple-cycle, cogeneration, or combined-cycle generating plant and you're not familiar with the Western Turbine Users Inc, please read on.

WTUI's annual meeting in March (next year at the Renaissance Hotel/Convention Center in Palm Springs, Calif, March 18-21) is the place to learn what you need to know about your engine—from both colleagues and industry experts—to grow in your job. Knowledge, of course, is the pathway to more responsibility and a bigger paycheck.

A history of the Western Turbine Users, the world's largest independent organization for gas-turbine owner/operators was published by CCJ and distributed at the organization's 25th anniversary meeting in 2015. Learn more about this user organization and how it can benefit you and your company by scanning the QR codes below with your smartphone or tablet.

Major contributors to the commemorative publication included Wayne Kawamoto, WTUI treasurer and plant manager of Corona Cogen; Mike Raaker, WTUI's historian and ambassador, and president of Raaker Services LLC; Sal DellaVilla, CEO of Strategic Power Systems Inc; Mark Axford, president of Axford Turbine Consultants LLC; Jason Makansi, president of Pearl Street Inc, and Steve Johnson, president of SJ Turbine Inc.

QR 1: Before incorporation, *contributed by Mike Raaker*
QR 2: After incorporation, *contributed by Sal DellaVilla*
QR 3: Legislative drivers of GT technology, *contributed by Jason Makansi*
QR 4: The LM engines, *contributed by Team GE*
QR 5: A turbine salesman remembers, *contributed by Mark Axford*
QR 6: WTUI's place in gas-turbine, power-industry history, *contributed by Wayne Kawamoto and Mike Raaker*
QR 7: Aero engine portfolio, *contributed by Team GE*
QR 8: Profiles of ANZGT, TCT, IHI, MTU, *contributed by the depots*
QR 9: User remembrances, *compiled by the CCJ editorial team*
QR 10: Vendor remembrances, *compiled by the CCJ editorial team*

QR 1 QR 2 QR 3 QR 4 QR 5 QR 6 QR 7 QR 8 QR 9 QR 10

Borescope findings, critical service bulletins

Reed Services Inc's Dale Reed was on the Tuesday afternoon program for the third year running. He's popular among LM6000 owner/operators judging from the full meeting room year after year. Reed's primary reference for this year's presentation was the same one he introduced to the group in 2015: GEK 105059, Volume 1/Chapter 12 (in particular Table 12-1).

The speaker's focus was on borescope inspections, which are recommended as part of the maintenance overhaul for the LM6000PC every 4000 hours, 450 starts, or annually (whichever comes first).

Reed focused on Service Bulletin (SB) 310 first (later SB 283), showing and explaining what users should be looking for during borescope examinations and the results they don't want to see. He then explained to attendees how to extract information from the document to determine if a particular service bulletin is critical to their operation.

The cover page provides the following information:

- Subject—the system or part that is affected.
- Category—optional, routine, campaign, alert.

Planning information is included in paragraph "I." It drills down into the product, model, serial numbers affected, the reason for the service bulletin, general description of the action required, tooling and parts requirements, man-hours it should take to complete the tasks recommended, etc.

Reed said the most important information for determining if a particular service bulletin is critical to your operation is found in paragraph "I," sub-paragraph D—compliance. It tells you if compliance is optional (financial or operational benefits), routine (will improve operating characteristics, reduce lifecycle cost, etc), campaign (enhance product reliability), or alert (immediate action required).

Sub-paragraph D also describes the level of expertise required to complete the recommended actions—that is, can the work be done in the field by trained maintenance personnel or must it be conducted offsite at a service or repair center? The timing of remedial action is also found in this section. Examples: Prior to restart of the engine, at first opportunity, at next depot visit, etc.

Paragraph II provides detailed instructions and diagrams to complete the work recommended, paragraph III where to register your compliance record (GE portal, e-mail, fax, etc).

Battery maintenance

Sam Ayoubi of Borri Power US Inc had a PowerPoint with far too much information for a 50-min presentation; the company's history and extensive product line alone took a dozen slides.

However, this is a presentation owner/operators might want a copy of because it might be suitable for use as a core component of an in-house training program. Here's a sample of the content:

- IEEE and NERC standards that apply to battery maintenance.
- Maintenance/inspection schedules (monthly through five years) recommended for all types of batteries—including when to (1) conduct visual inspections, (2) check float voltage, specific-gravity, and connection resistance, (3) take temperature readings, conduct tests, and check safety equipment.

A separate section of the presentation focused on chargers and included a comparison of the various charger technologies (ferroresonant, mag amp, switch mode, and SCR), digital displays, standard features, alarms, and options, etc.

Partial-discharge testing

A primer on partial discharge—small electrical sparks that occur at voids (air pockets) within, or on the surface of, insulation and degrade it—was conducted by Iris Power's Sunny Gaidhu. His objective was to help users monitor the condition of their stator-winding insulation via regular online PD testing. If identified early enough, insulation damage might possibly be repaired. If ignored, there's a high risk of stator-winding failure, the speaker said.

Gaidhu's slides, like Ayoubi's (immediately above) might complement other material selected for an in-house training program. To dig deeper on this subject, conduct a keyword search on the CCJ website at www.ccj-online.com. There are several articles posted that can add to your staff's collective knowledge—including one by the highly regarded generator troubleshooter, Clyde V Maughan, president of Maughan Generator Consultants.

Aero generator O&M

Derek King, who recently founded Mega-Watt Consulting LLC, is well known to many LM owner/operators, having served as the head of the Brush aftermarket services unit in the US for many years. Brush generators are widely used in GE aero packages.

King is challenged as a speaker with a time limit because he literally knows too much and wants to share everything he's learned over the years (decades). His 66 slides were the foundation for a productive half-day (or longer) workshop.

King began at the beginning: His third slide discussed an 1880 lighting dynamo and distribution system in New York City. This is not a criticism; CCJ also has material going back that far in its offices. We're both information junkies.

King then dived right into generator basics—how electricity is produced, how losses are minimized, etc. Next topics were rotor and stator construction. He then transitioned to maintenance, spare-parts you should have on the shelf, upgrades, generator monitoring, rotor ground-fault detection, bearing examination and replacement, how to remove and ship the rotor, stator inspection and what to look for, rewind, damage mechanisms, etc.

This seems like an excellent presentation to review before performing maintenance on a generator that requires removal of the field. You can learn a lot about what to look for, and where to look, from the photos.

HRSGs

Ned Congdon, PE, of HRST Inc's West Coast team, has been a "regular" Tuesday afternoon presenter for several years. At each meeting he addresses a different element of heat-recovery steam generators; put them together you have an aero HRSG handbook. Congdon's focus in 2017 was evaporators—for natural-circulation boilers and once-through steam generators.

In case you're unaware, HRST does not manufacture boilers but its staff inspects, audits operations, supervises maintenance, re-engineers components not meeting expectations, and troubleshoots HRSGs worldwide made by virtually all manufacturers.

Congdon's was another of the 2017 meeting's "keeper" presentations—an editorial opinion. He offered a good mixture of engineering (beginning with what's the function of an evaporator and how it works) and practical O&M. Congdon shared a wealth of meaningful photos from HRST's extensive files to illustrate problems (like flow-accelerated corrosion, under-deposit corrosion, etc) and explain why they occurred and how to avoid them.

The boiler expert touched on chemistry and gave cycling effects on evaporators and drum downcomer nozzles their due. Common errors related to installation of steam separators and drum gaskets offered valuable lessons. **CCJ**

WTUI, CCJ collaborate on best practices

The Western Turbine Users and CCJ are working together to expand the sharing of best practices among owner/operators of GE aero engines. WTUI VP Ed Jackson, Missouri River Energy Services, plant manager of Exira Generating Station in Brayton, Iowa, said the organization's mission is to help members better operate and maintain their plants, and a proactive best practices program supports this objective.

Jackson announced the joint program at the user organization's 26th Annual Meeting (2016) in Palm Springs where he encouraged attendees to support the initiative and explained how they would benefit from the experience. The fruits of that effort are the eight best practices profiled on the next several pages.

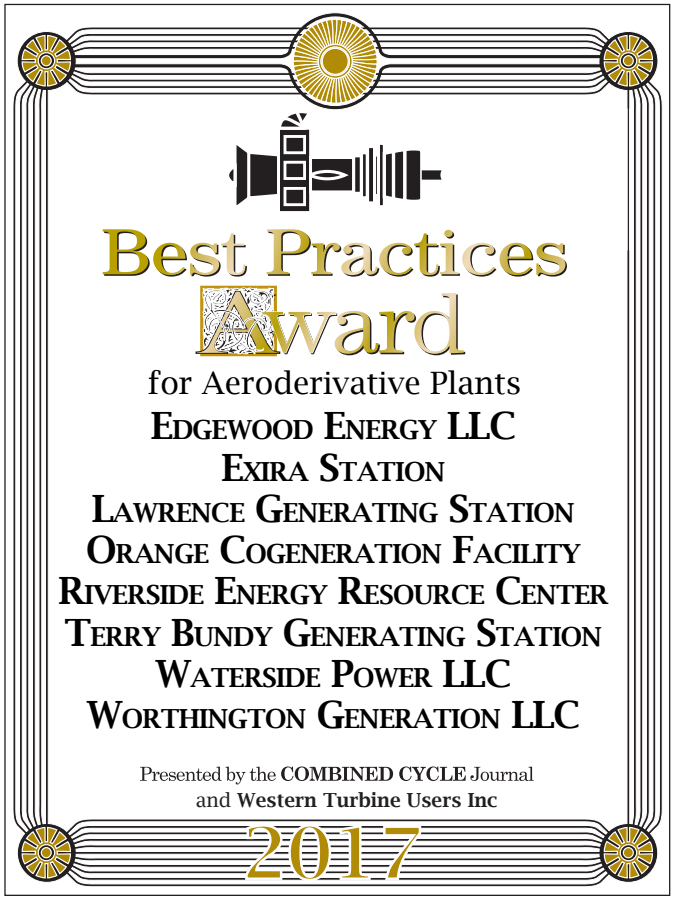
Recall that CCJ launched its industry-wide Best Practices Awards program in late 2004. Its primary objective, says Senior Editor Scott Schwieger, is recognition of the valuable contributions made by owner/operator personnel to improve the safety and performance of generating facilities powered by gas turbines. Schwieger and Jackson are collaborating to grow participation by aero users.

The partnership between WTUI and CCJ has added a new dimension to the Best Practices Awards program: live discussion. With seven of the eight aero plants sharing best practices this year equipped with LM6000s, Breakout Chair Andrew Gundershaug, made time available in his track at the 27th Annual Meeting in Las Vegas (March 2017) to present thumbnails of each entry, dive into the details to the degree attendees requested them, discuss possible alternative solutions, etc. More than an hour of productive questions/answers and discussion ensued.

Chuck Casey, *Riverside*

Cody Mothershead, *Exira*

John Lawton, *Edgewood*



Tyson Chambers, *Terry Bundy*

Matt O'Hara, *Lawrence and Worthington*

Joe Shaffer and Bryan Malbry, *Orange Cogen*

Riverside

Plant staff fine-tunes operations, implements mods, upgrades to reduce startup NO_x

These are difficult times for owner/operators of conventional assets. They get no relief from regulatory bodies regarding emissions, grid operators aren't bashful about making still more demands on them, profit margins and O&M budgets have been squeezed dry in many cases, OEM solutions can be too costly, etc.

What to do? One thing is to "improvise, adapt, and overcome" the challenges facing your plant with in-house talent. Take a page from the lesson book of Riverside Public Utilities, the only aero facility recognized in 2017 with a Best of the Best award in the CCJ Best Practices Program.

The Riverside Energy Resource Center consists of four LM6000 simple-cycle peakers used to supply 200

MW of reliable fast-start power to the 105,000 electric customers served by the municipal utility. Each gas turbine satisfies its NO_x emissions permit with water injection and a selective catalytic reduction system using 19% aqueous ammonia.

In addition to Riverside's commitment to its city customers, the California Independent System Operator (CAISO) demands the four gas turbines be available for state-required dispatch when not used for self-generation. The CAISO frequent calls for the engines to start up, sometimes multiple times daily. The problem faced by the asset owner: Each start produces three times the amount of NO_x as does a normal production hour.

The Riverside facility is located in the most environmentally challenged air district in the nation—the South Coast Air Quality Management District. It restricts monthly and annual operations based on pounds of NO_x discharged. Given the frequent starts mandated by the CAISO, the South Coast AQMD in effect reduces the number of hours the Riverside units can run monthly and annually. But the CAISO and the city of Riverside need the power "on demand" 24/7/365.

The utility found itself between the proverbial "rock and a hard place." It could re-permit and purchase emissions offsets at prohibitive cost in both time and money, or find a way to reduce startup NO_x emissions. The latter was the path chosen and it proved a career test for the solutions team headed by Generation Manager Chuck Casey, Plant Manager Bryan Atkisson, and technicians James Mysliwiec, Will Patton, and Ron Herrero.

One of the first steps was to see what the OEM could offer. The team re-learned that the turbine manufacturer would not deviate from tried and true historical methods of equipment operation and was more interested in selling new systems than in upgrading old ones.

The team moved forward by creating a wish list of possible changes to reduce NO_x mass emissions. They termed this effort "black box" considerations because many of the proposed solutions were visionary—not yet available—but seemed achievable. Equipment suppliers were dared to go beyond their safety nets—to loosen limits without damaging equipment or causing emissions upsets. Staff worked closely with equipment and operations partners to seek feasible results.

Success! After two years of researching, teaching, challenging, experimenting, brainstorming, and implementation, a 30% reduction in startup NO_x was achieved, allowing a commensurate increase in operating hours while still holding emissions within the South Coast limits. Specifically, the number of starts was increased from 40 to 62 per month.

The path chosen to achieve a 30% reduction in startup NO_x involved the following:

- Use of a megawatt feed-forward signal to control ammonia flow rather than fuel flow, which is a lagging indicator.
- Tune/improve the water injection curve. Keep in mind that water does not harm the SCR catalyst.
- Lower the NH_3 control valve/SCR temperature interlock set point.
- Reprogram the ammonia vaporization heater. The SCR/NH_3 injection temperature was reduced to 350F from about 540F to start the SCR earlier.
- Improved maintenance.

The NO_x mass emissions reduction program achieves the equivalent of investing $2 million in emissions offsets while increasing operational flexibility without exceeding local, state, and federal limits. The Riverside team believes it has learned enough to aim for a higher target by year-end—a 40% reduction in startup NO_x mass emissions.CCJ

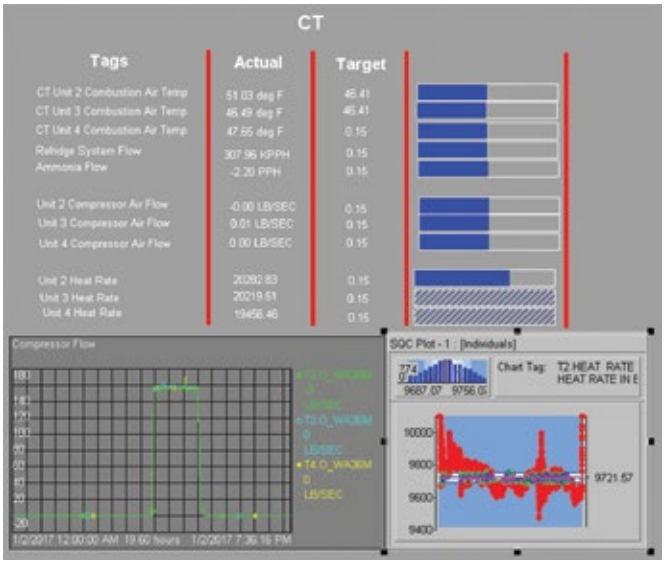
Small improvements add up to significant savings

Challenge. Identify opportunities to reduce station heat rate by 1%.

Methodology:

- Identify and classify plant subsystems critical for efficient and reliable operation.
- Identify and inventory key components of each subsystem that contribute to reliable and efficient operation.
- Identify/develop system and equipment metrics that accurately represent equipment performance.
- Confirm all required equipment operating variables are being recorded in the plant historian.
- Complete cost/benefit process for additional monitoring points.
- Develop baseline operating factors.
- Become familiar with O&M processes for major plant systems (include both operators and techs in the discussion).
- Develop dashboards for each system to facilitate access to data by plant operators, managers, and engineers (include operator input on system interface layout to insure effective use).
- Identify the best approach for distributing plant performance information outside the control room to plant and engineering staff (and possibly others in the future), while insuring NERC CIP issues are properly addressed.
- Develop procedures for periodic review of performance metrics and trends, and of the performance management system.

Results. While quantifying the actual heat-rate improvement is difficult, and additional operating hours are required to identify performance-improvement trends over time, plant owner/operator Lincoln Electric System (LES) believes activities associated with the performance-improvement program have increased efficiency. One result of the program was a coordinated review of, and when appropriate, implementation of BOP energy-saving equipment or processes (increasing net plant output and lowering net heat rate).



HMI screens showing operating metrics have contributed to the plant performance-improvement effort

Efficiency projects completed in 2016 included the following:

- Upgraded the plant air system with a new station air compressor equipped with a variable- frequency motor drive. Energy saving: 214 MWh/yr. Peak demand reduction: 24 kW. Cost: $45,000.

Terry Bundy Generating Station

Lincoln Electric System

170-MW, natural-gas-fired, 2 × 1 combined cycle and a simple-cycle gas turbine, plus three landfill-gas-fired internal combustion engines, located in Lincoln, Neb

Plant manager: Jim Dutton

- Replaced most station lighting with LED lights. Energy saving: 46 MWh/yr. Peak demand reduction: 3.9 kW. Cost: $8200.
- Replaced the Wonderware-based data historian with OSIsoft's PI, and transferred 12 years of operating data from the old platform to the new one, to improve plant reporting and monitoring capabilities. PI training for plant support engineers and operating staff was planned for early spring 2017. Cost: $216,000.

HMI screens showing operating metrics in real time also were developed. These screens, and associated data-trending capabilities, are used to compare actual plant performance to modeled/theoretical performance and identify any anomalies.

- Add a pre-circulation system to the gas-turbine chiller to reduce spikes in chiller loading on startup. Its function is to circulate chilled water in the system before the chillers are started. Cost: $34,000.

Other program investigations/evaluations included these:

- Use the existing 3-million-gal effluent storage tank for inlet-cooling chilled-water storage (not economically feasible).
- Use of waste heat from three 1.6-MW landfill-gas-fired internal combustion engines for building heating, gas-turbine inlet heating, and/or a bottoming cycle. The building and GT inlet heating options were not economically justifiable. LES continues to investigate an organic Rankine bottoming cycle and to evaluate the use of waste heat in a greenhouse operation.
- Upgrade the control system for the six 1200-ton chillers used to cool gas-turbine inlet air. An economic analysis is forthcoming.

Project participants:

Jim Dutton, plant manager

Chris Hodges, engineer, Projects Engineering Dept

Orange Cogen

Rethinking yesterday's safety solution to better protect personnel

Orange Cogeneration

Owned by Northern Star Generation

Operated by Consolidated Asset Management Services LLC

104 MW, gas-fired 2 × 1 combined-cycle cogeneration plant powered by DLN-equipped LM6000 engines, located in Bartow, Fla. Condensing, extraction steam turbine is rated 25 MW. Steam is sold to producers of orange juice and ethanol

Plant manager: Allen Czerkiewicz

Challenge. Integrating modern safety practices into a 20-yr-old plant, sometimes a challenge, usually can be accomplished with a little creativity and teamwork. At Orange Cogen, an operator submitted a safety suggestion recommending two improvements to existing infrastructure and procedures:

1. Make the oily water separators (OWS) more accessible. Plant personnel remove OWS chevron elements for preventive maintenance and cleaning during the annual outage each fall. There are two sumps, north and south, of the exact same design.

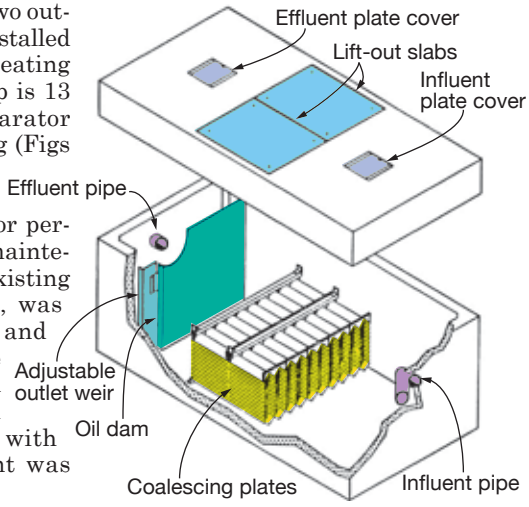
   The original sump cover was a 1-ft- thick concrete lid reinforced with channel and rebar. Its access hatch measured 32 × 40 in.—barely large enough to remove the separator sections, especially the two outboard ones. They had to be installed and removed diagonally, creating alignment issues. The sump is 13 ft deep and the three separator elements each are 10 ft long (Figs 2 and 3).
2. The second suggestion was to improve fall protection for personnel assigned to sump maintenance and cleaning. The existing tripod, although adequate, was clumsy in this application and hard to use effectively. The operator's suggestion pointed out that it restricted lateral movement; fall protection with more freedom of movement was added as a design goal.

Solution. The Orange Cogen management team, which takes safety suggestions seriously and promotes employee driven improvements, questioned the originator about all aspects of his suggestions and he provided the initial design ideas. The team decided to replace the lid with a carbon-steel channel framework. A local contractor provided the final design and fabrication.

The framework was galvanized locally for corrosion prevention and anchored to the sump after the original lid was removed. This allowed full access across the width of the sump and enabled separator sections to be lifted out vertically. A 1-in. grating covered the top of the sump, giving operators the ability to look inside the vault as part of their daily rounds—thereby improving the chances of identifying problems in the sump early.

Lastly, removable hand rails were incorporated into the design to protect personnel from a fall hazard when the grating is removed for maintenance.

1. Original hatch in the concrete lid for the oily water sump was small, inhibiting maintenance access



2. Oily water separator at Orange Cogen did not have the double door shown in this exploded view from the OEM's manual

3. Filter elements for the oily water separator are 10 ft long and rest at the bottom of a 13-ft-deep sump

The fall-protection suggestion was addressed by bringing in a local safety-products company to provide an engineered fall-protection system. The team endorsed a davit mount design and a permanently fastened mount was provided at each location. The davit arm can be moved to either location as needed, minimizing cost. The davit arm can rotate 360 deg and the length and angle of the arm are adjustable, allowing it to be set up as the maintenance personnel need to perform their job.

Results. Maintenance of the oily water separator performed during the last fall outage took 50% less time to complete than previously; the engineered fall-protection system worked perfectly.

Project participants:

Allen Czerkiewicz, plant manager
Joe Shaffer, maintenance manager
Brian Mallory, operations manager
Kristen Albritton, EHS manager
Ben Costine, originator/auxiliary operator

4. Removable hand rails and davit-arm fall-protection device offer personnel greater protection than was available previously

Assuring personnel safety during periods when a single operator is onsite

Challenge. Worthington and Lawrence each were staffed by two operators who worked overlapping 8-hr shifts to provide 14 hours of coverage (0600 to 2000) on weekdays, as well as weekend on-call coverage. This meant that single-person operation occurred for several hours each day and on weekends—a safety issue that management had to address.

Solution. The safety committee serving both plants met to come up with ideas. Collectively, the members worked out a new procedure (bullet points immediately below) that would require a few schedule modifications but greatly reduce safety concerns when an operator was onsite alone:

- Each operator verifies he/she has access to a smart phone.
- Each operator downloads the ManDown™ app to his/her phone.
- Each operator verifies he/she has an "In Case of Emergency" ID.

Job-hazard and site-hazard analyses were conducted to determine high-risk tasks that should not be performed during single-person operation. Plus, work schedules were modified to minimize the amount of single-person operating time.

Once these few changes were made, the following new procedure was implemented:

- Operator activates the ManDown app whenever he/she is onsite alone.
- Operator obeys standing orders regarding unauthorized single-person tasks.
- Each operator attaches "In Case of Emergency" sticker to hardhat (a waterproof, reflective worker ID that ensures first-responders can access vital info and emergency contact numbers).

Working hours were modified to reduce single-person operation from six to four hours per shift. Site manning hours shifted from 0600-2000 to 0700-1900. The individual operator's hours went from 0600-1400 to 0700-1500 for first shift and from 1200-2000 to 1100-1900 for second shift.

Results. When an operator is onsite alone, the ManDown one-minute safety

Worthington Generating Station

Owned by Hoosier Energy Rural Electric Co-op Inc

Operated by NAES Corp

174 MW, four simple-cycle LM6000 natural-gas-fired peaking units, located in Greene County, Ind, and connected to Hoosier's 138-kV transmission line

Plant manager: Robert VanDenburgh

Lawrence Generating Station

Owned by Hoosier Energy (four units) and Wabash Valley Power Assn (two units)

Operated by NAES Corp

258 MW, six simple-cycle LM6000 natural-gas-fired peaking units, located in Lawrence County, Ind, and connected to Hoosier's 161-kV transmission line

Plant manager: Robert VanDenburgh

1. ManDown mobile app

2. Hardhat sticker with emergency info

timer is activated. The phone will activate an audible warning 30 seconds into the one-minute timer if the phone remains still. This audible alarm alerts the operator to move the phone, which will deactivate the alarm. If the operator is unable to move the phone at any point during the one-minute safety timer, ManDown will send a text message/email to the plant manager and lead O&M technician, who will initiate emergency procedures.

While the ManDown app does not in itself increase safety, it does improve emergency response time substantially should an incident occur. However, the job-hazard and site-hazard assessments for operator tasks directly improve safety by restricting high-risk tasks during single-operator operations. In addition, reducing the overall hours of single-person operation contributes to an overall safety improvement by reducing exposure to potentially hazardous situations.

The change in working hours had the added benefit of a slight reduction in maintenance overtime hours previously incurred during maintenance evolutions that required two persons onsite; the new procedures double the regular time each day that two operators are together at the plant. The required modifications were made at negligible cost, and the new procedure has not increased operator overtime.

Project participants:

Brian Bauman, Lawrence O&M/IC&E technician
Matthew O'Hara, lead O&M technician
Bruce Button, Worthington generation O&M technician
Jason Robertson, Worthington generation O&M/IC&E technician
Jared Thomas, Lawrence O&M technician

Waterside

Demin-system automation reduces operator time outside the control room

Waterside Power LLC

Owned by Western Generation Partners

Operated by Consolidated Asset Management Services LLC

72-MW, oil-fired, three-unit (TM2500s) simple-cycle peaking facility located in Stamford, Conn

Plant manager: William Jolly

Waterside recently reduced staff from five employees to three, including the plant manager. The rif requires that operators reduce the amount of time away from the control room during dispatches. Personnel cutbacks aside, the fast-start emergency peaking station still must provide the requested peak power within 30 minutes of dispatch and satisfy all other grid requirements as well.

Prior to automation of the demin system, the on-shift operator manually started the demineralizers, checked conductivity levels were within spec by walking out to the mixed-bed trailer, ensured the inlet valve to the mixed beds was open, and monitored tank levels during a dispatch by calculating gallons per hour consumed.

With the manual approach, water sometimes was wasted because the tanks were overfilled. The operator had to leave the control room periodically to check tank level, conductivity, and valve position. Keeping the operator in the control room during all dispatches increases availability and reduces downtime.

Solution. Team Waterside installed an Ethernet cable from the control room to the demin trailer and water tanks. Staff then put level transmitters on the tanks and tied the system into the HMI via a programmable logic controller. They also tied the demin system into the HMI via an Ethernet cable. These enhancements allowed the on-shift operator to start the system, view tank level, monitor the demin water conductivity, and verify valve position without leaving the control room.

Results. The upgrades described above allowed Waterside to reduce the time an operator is out of the control room during a dispatch. In addition, they eliminated the waste of treated water and assure high-quality water is distributed to the gas turbines. Waterside continues to excel in meeting all dispatch requirements with a performance factor of 99.86%.

Project participant:

William Jolly, plant manager

Operator now gets plant's vitals by screen

Edgewood

Edgewood Energy LLC

Owned by J-Power USA

Operated by NAES Corp

Peaking facility equipped with two LM6000 engines, located in Brentwood, NY

Plant manager:
Kenneth Ford

Sprint upgrade with premium valve improves unit availability

Background. The Sprint™ system for the GE LM6000 is a power-augmentation solution that injects atomized demineralized water into the engine to reduce HP-compressor inlet temperature, thereby allowing the compressor to accept more air and increase GT output—by as much as 17% in warm ambient temperatures.

Challenge. The regulators installed at Edgewood to control and maintain pressure in the Sprint systems serving the site's two LM6000s were prone to failure caused by internal diaphragm rupture. When this occurred, the Sprint system automatically disabled when water pressure dropped below the permissible minimum. Unexpected Sprint trips such as these led to unplanned turbine shutdowns caused by loss of emissions control or excursions in exhaust-gas temperature.

Solution. Following review of the pressure regulator's design, both internally and with outside valve professionals, staff determined that the close proximity of the high-pressure regulator's discharge to the suction of the low-pressure valve significantly reduced the life expectancy of valve seats and diaphragms. Rather than redesign skid piping to increase the distance between these two points, plant personnel looked for a less radical solution.

Based on previous experience with a valve designed by another manufacturer, Straval Machine Co, plant personnel contacted Straval to discuss the feasibility of replacing the existing regulators with a different style of valve that could withstand existing site conditions. The new valve would need to meet the following requirements:

- Accommodate pressure drops of 1400 to 550 psi and 550 to 225 psi.
- Have a field-adjustable, working regulator setup.
- Operate in close proximity to discharge/suction with 90-deg pipe bends.

After identifying a Straval valve that met these requirements, the plant purchased two and installed them on the Unit 1 gas turbine to test their durability before committing to replace the valves on the other unit (photo).

Results. Following many months of reliable service from the new valves on Unit 1, the two valves on Unit 2 were replaced during spring 2016. Since the valves were replaced, there has been no downtime on either Sprint system caused by regulator failure. This has saved Edgewood approximately $10,000 in annual repairs to the original valves, and has eliminated the availability losses associated with the failure of them.

Project participants:
Anthony Angieri, chief engineer (NAES Corp)
John Lawton, O&M manager
Kenneth Ford, plant manager

New pressure-regulating valves for the Sprint system reduced annual maintenance cost and increased unit availability

Use fan motor current for accuracy in air flow measurement

Challenge. Ventilation-fan flow switches are not reliable indicators of flow. The starter could fail and little flow from other fans could set the switch and show false flow. Since they are unreliable, operators could dismiss a true low-flow condition as a faulty switch. The switch itself doesn't give much information.

Solution. Install an inexpensive current transmitter with analog output to provide real-time display of the fan driver's current draw. Then set a soft switch based on a window that current should be in. If motor current usually is 100 amps, for example, consider a window of 80 to 120 amps. Now you can set a true low-flow alarm.

This gives much more diagnostic information than a flow switch or feedback from the MCC starter. If amps trend up the indication could be tight belts, failing bearing, or other problems that can be addressed prior to failure. If current trends down, belts might be loose, etc. If current is in the window, then it is a safe assumption that fan is on and doing work. Then flow will be good.

Result. Success!

Project participants:
Ed Jackson, plant manager
Allen Scarf
Cody Mothershead

Exira Station

Owned by Western Minnesota Municipal Power Agency

Operated by Missouri River Energy Services

140 MW, three simple-cycle LM6000 dual-fuel peaking units, located in Audubon County, Iowa, and connected to a 161-kV transmission line owned by the Western Area Power Administration

Plant manager: Ed Jackson

Prevent package heater operation when ventilation fans are running

Challenge. Package heaters at Exira had a high failure rate. Staff explained to a supplier representative that the heaters were not designed to operate when ventilation fans run, do not need to operate when fans run, and it doesn't do any good to operate the heaters when the fans run.

The vendor engineer agreed the heaters should be shut off when the fans run and said his company did not know, at the design stage of the project, that the heaters would be on while the fans were running. He added: If the plant runs the heaters with the fans on, the heaters cannot keep up and will short cycle and fail—exactly what the plant was experiencing.

Solution. Package heaters usually are fed from a disconnect, not a starter, and cycle based on a thermostat. At Exira, the packages had disconnects on the unit MCCs.

Plant staff decided that instead of feeding heaters straight from a disconnect they would supply them from a starter. And then run the auto circuit of the starter through the normally closed aux contacts of the fan starters. This way, whenever a fan starts, the heaters turn off. Very simple and only costs a little wire.

Result. Success!

Project participants:
Allen Scarf
Cody Mothershead

Register for STUG2017 today: Too valuable to miss

Most subscribers are familiar with steam turbines; some believe they "know" steamers and some of those readers really do. But until you attend a meeting of the Steam Turbine Users Group (STUG) you can't appreciate how much there is to learn. The first and last articles in this issue (pages 4 and 78) cover only a small fraction of the material presented and discussed at last year's meeting. They should help you decide in favor of attending the 2017 Conference and Vendor Fair at the Sheraton Grand at Wild Horse Pass, Chandler (Phoenix), Ariz, August 28-31.

STUG was founded in 2014, making the upcoming annual meeting the group's fourth. What began as a conference focusing on GE A10 and D11 steam turbines for combined-cycle plants is now a meeting covering steamers used in the production of electricity from every major OEM.

The group operates under the PowerUsers umbrella (p 91), an organization run by users for owner/operators to enable the sharing of experiences, best practices, and lessons learned via attendee-driven discussions focusing primarily on design, installation, O&M, overhaul, and safety. A quick look at the names and affiliations of steering-committee members below tells you if there's one meeting that can get you "up to speed" on steam turbines, this is the one:

- Eddie Argo, Southern Company (2017 chair).
- Jess Bills, Salt River Project.
- Gary Crisp, NV Energy.
- Jake English, Duke Energy.
- Jay Hoffman, Tenaska Inc.
- John McQuerry, Calpine Corp.
- Bert Norfleet, Dominion (2017 vice chair).
- Lonny Simon, OxyChem.

While you may think you're already "up to speed," don't be so sure. There have been many design changes/enhancements in the last couple of years. At the 2016 meeting, a GE engineer compared designs of his company's steam turbines (STs) both before and after the Alstom acquisition. One change noted: Before Alstom, the D11 had high- (HP) and intermediate-pressure (IP) turbines of the impulse type. Today's enhanced steam path features a reaction HP cylinder (IP turbine is still impulse).

The new HP rotor is made of 10Cr steel and is retrofittable. The upgraded material was said to add more stiffness to the rotor. Plus, the new rotor won't grow as much at high temperature as the original did. J seals dissipate heat if a rub occurs; heat does not flow into the rotor.

Attendees were told that for an HP/IP shell (single casing, not the current two-casing design) in good condition, a steam-path upgrade can increase steamer output by up to 1.5% through the recovery of ageing losses and better technology—such as advanced Singlet™ high-efficiency diaphragms, abradable coatings and brush seals, modern N2 packing head, integral covered buckets, etc. A decrease in overhaul time is another benefit of the upgrade, the speaker said. In the illustration given, the outage was reduced from 60 to 37 days.

The HP/IP enhancements presented were said to solve the rotor bowing issue that had affected the fleet and to mitigate shell and packing-head cracking and diaphragm dishing. OpFlex steam-turbine agility was mentioned as a comprehensive system solution configured to improve ST starts through revised control settings. And a shell warming system described promised faster starts (sidebar).

So, you say, most if not all of this information is available on the OEM's website. It is, but you don't get to ask questions interfacing with a website and you don't have the opportunity to poll your peers regarding their experiences with the enhancements promoted. Personal contact with the experts: That's the value of attending user-group meetings. Register today at www.stusers.org.

GE's day-long 2017 agenda includes presentations on valves and actuators, "digital valve" packages, diaphragms and N2 packing head, structures, rotating components, electrohydraulic control oil fluids, repair technologies, outage strategies, etc.

Alternative vendors for turbine upgrades and major outage work presenting this year include Siemens, EthosEnergy, and MD&A. This gives you the opportunity to compare offerings in a dynamic environment. MD&A's planned podium time in Phoenix is a solid two hours. Last year the company provided critical thinking on valve issues and maintenance, diaphragm dishing, casing re-rounding, and rotor straightening—all hot topics.

Follow the "living" conference program posted at www.stusers.org to get the details as they become available. What follows are summaries of some presentations delivered last year. Registered users can access the PowerPoints at www.stusers.org.

User presentations

Repairing a steam leak at the horizontal joint

Repairs of leaks at casing joints in gas and steam turbines are a frequent discussion topic at user-group meetings. At STUG2016, an owner/operator shared his experience with a steam leak at the horizontal joint of a D11. The leak, on one side of the HP/IP machine in the vicinity of the first two HP stages, was noticed a couple of months after completion of a major inspection. Leaking steam tore holes in the insulation.

The speaker said the single-casing HP/IP is prone to distortion at the horizontal joint because of stresses associated with frequent starts and external piping loads. He added, "After an outage, the casing horizontal joint is cleaned of blue blush which opens path for steam to escape. Sometimes the leak will stop itself when blue blush builds up again in the joint." Other causes of a casing flange leak include contaminants on the joint, broken casing stud, and insufficient torqueing of one or more studs.

If the leak persists, the owner/operator has two primary options: opening the machine, identifying the issue, and taking corrective action, or installing an external patch. The decision should reflect the results of a close examination of the leakage area by an experienced engineer after insulation

has been cut out and the joint cleaned. Feeler gauges are among the tools used to characterize the leak path.

Opening the machine has its risks and financial downside, of course. However, if this is the path taken, attendees were told it's important to be sure nothing is hanging up the shell and there are no bolting issues. Then the focus should be on correcting distortion of the horizontal joint—the likely cause of the leak.

This is a significant task. First, the upper shell, rotor, and diaphragms must be removed, and the joint mapped with a laser or optical equipment. Next, a special self-leveling milling machine must be brought onsite to cut the horizontal flange. The cut complete, all diaphragms, packing glands, and the casing must be realigned. A boring bar also may be needed to establish casing fits for diaphragms and packing glands.

An external joint patch was the favored option for the case described by the speaker. The half-pipe patch for this machine was designed by an industry consultant who said D11 horizontal joint leaks have become more common because of the single shell design and the age of the fleet. He noted that the half pipe was developed two decades ago and has been used successfully on many steamers, including D11s. It allows for sealing uneven casing-joint flange sidewalls and for the injection of Furmanite later if the patch does not hold.

Steam turbine issues since the millennium

A user with deep knowledge of steam turbines (STs) in combined-cycle service reviewed his company's O&M experience with nearly two dozen units installed from 2000 to 2014. There are roughly equal numbers of GE, Alstom, and Toshiba machines.

The speaker began with a backgrounder on duty cycle and typical inspection intervals. The steamers, he said, originally were used as peaking units but now typically operate baseload with turndown at night. Inspection intervals: STs in combined cycles with AGP-equipped gas turbines, minor at about 32,000 hours and major at no more than 64k; no advanced gas path, minor at about 24k hours, major 48k.

The owner's D11 steam turbines, all installed between 2000 and 2002, are managed by a long-term service agreement (LTSA) with the OEM. Historical issues mentioned: N2 packing head cracking, shell cracking/distortion, rotor bowing, stellite liberation from the seats of combined stop/control valves, and diaphragm dishing. The first three remain as current concerns.

Regarding N2 packing head cracking, all eight of the owner/operator's D11 steamers were affected. The worst casing crack, approximately an inch and a half deep, was found on the lower side wall of one unit. Possible causes considered were water induction, overtemperature operation, and material defects. Some casing cracks on other units were found in the heat-affected zones associated with casting weld repairs made at the foundry.

Rotor straightening was done when necessary. One rotor had a total indicated runout of 18 mils. Cracked stellite was found in valve seats of multiple units, one experienced a failure during operation. Attendees were referred to TIL 1629-R1, "Combined Stop and Control Valve Seat Stellite Liberation." HP and reheat diaphragm dishing addressed by TIL 1589 is handled by replacing dished diaphragms during the second major (15 years).

Going forward, some plants with D11s are evaluating retrofit options—such as the OEM's enhanced steam path (single shell) and double-shell replacement.

For the company's seven Alstom steamers commissioned between 2003

and 2008, the current concerns are air in-leakage and hydraulic turning gear. Historical issues also included IP rotor and vertical-guide-key shim migration, shrink-ring seat cracking, and HP-inlet thermal cracking.

The rotor shim-migration solution selected was to replace the first two IP stages using TurboCare's shimless design with notch entry, redesigned blade root, and new blade material. The vertical-guide-key solution is described in Alstom's Customer Information Bulletin 2DESER00089B01b.

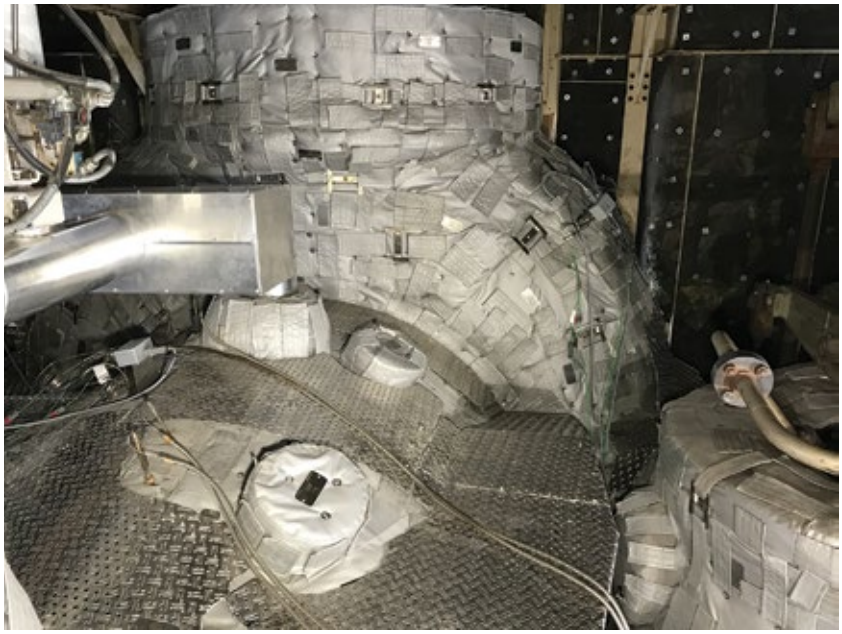
For cracking at the shrink seats of HP inner casings, attendees were referred to CIB 2DESER00090B01. Cracking of shrink-ring seats and inlet-scroll blades can be mitigated, the group was told, with enhanced radii. For HP inlet cracks, the recommendation was drill-stop.

The speaker offered the following lessons learned for Alstom steam turbines:

- Replace J-seals in the HP and IP sections at each major; replace LP seals as needed.
- Monitor solid particle erosion at the inlet and inlet-scroll blades and replace all inlet-scroll Radex blades at the second major.
- Suggestion to users with hydraulic

Heating-blanket technology advances

A cold steam turbine sometimes can compromise a combined-cycle plant's ability to start up fast enough to profit from market opportunities. Several generating facilities have reported success in eliminating cold starts by installing heating blankets capable of maintaining their steam turbines in a warm condition (nominally 500F to 600F), thereby boosting revenue with faster starts while reducing fuel consumption and emissions.

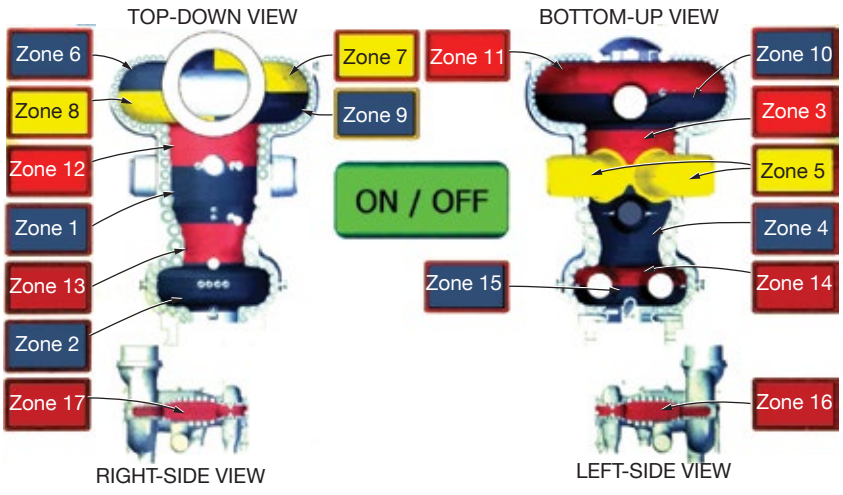


1. Warming system for the D11 can bring the turbine from a cold state to hot-start condition within 2 to 2.5 hours

But it turns out that eliminating cold starts was just a first step. A new warming system, installed a few months ago on a D11 steam turbine for an F-class combined cycle by Arnold Group, is said to maintain the unit in hot-start condition, providing the owner maximum operating flexibility.

The warming system and insulation typically can be installed in 10 days or less when the casing is properly prepared before Arnold arrives onsite. This means the old insulation must be removed by a local contractor and all pins ground down to the casing. All insulation fiber and debris must be removed from both the casing and enclosure.

Arnold's Pierre Ansmann told the editors the company's goal was to design an easily removable and highly efficient warming system using its proven single-layer insulation technology to minimize heat loss and maintain sections of the turbine shell at 700F to 900F, depending on location (Fig 1). The new system can take a cold turbine to hot-start condition in 2 to 2.5 hours.



2, 3. D11 has 17 heating zones, all controlled with one on/off switch, to maintain the various sections of the casing at the proper temperature. Operation can be local, via the touch screen (photo), or remotely from the control room. Not shown in the simplified drawing are the temperatures recorded by the two thermocouples installed in each zone

turning-gear issues: Consider an electric turning-gear retrofit.

- Sources of air in-leakage can be the LP gland piston ring and the exhaust-hood horizontal joint.

The speaker's Toshiba fleet consists of one unit commissioned in 2003 and four in the 2011-2013 period. The latter are of a slightly different design. Current concerns were said to be valve sticking, likely corrected with refurbishment and upgrade.

Interestingly, the performance of units with abradable bucket tip seals was not as good as the unit without them. Curves shown to the group showed HP cylinder efficiency flat-lined at about 90% without abradable seals; with them it decreased over time (about five years) from perhaps 89% to 85%. IP efficiency with abradable bucket tip seals held steady about 93% over time, without them it was about 97% for the same three-year period.

HP casing repair

A 71-MW non-reheat steam turbine went into commercial operation in 1992 with inlet steam conditions of 1500 psig/950F. The first inspection/overhaul of this unit was in 2015. Two indications were found in the HP upper casing in the nozzle fit area. The crack on the right side of the casing was 18 in. long, running from the inner surface to a bolt hole, the one on the left side was 12 in. long and also ran from the inner surface to a bolt hole. Photos shown by the speaker were of high quality and can be seen by registered users by accessing the presentation at www.stusers.org.

First step after discovery was a root-cause analysis. Turbine operating data were evaluated for thermal excursions and excessive temperature ramp rates at the casing inner surface. Engineers found casing thermal ramp rates were excessive (as high as 424 deg F per hour) during six cold starts in 2012.

Repairs were conducted by the OEM at its manufacturing facility. Upper casing cracks were weld-repaired, with full stress relief afterward. Total schedule for repair was 25 days, including five days for hardware removal, but the work actually took 31 days. Back in operation, plant personnel were urged to follow the manufacturer's starting and loading instructions. The steam-temperature ramp rate is limited to 100 deg F/hr during roll up to 3600 rpm, and 150 deg F/hr during loading.

D11 major

A user ran through a series of photos taken during the major inspection of a D11 that had experienced about 960 starts and operated for about 54,000 hours since going commercial in 2004. Photos were shown of valve strainer damage and foreign-object and domestic-object damage. The latter was significant, forcing the replacement of both first-, second-, and third-stage buckets.

Point of the presentation was to stimulate discussion, which it did. It also gave the speaker the opportunity to use the PowerUsers electronic polling system to get feedback from attendees. Here is some of the information shared:

- Have you performed an ST major? Yes, 86%.
- Did you replace first-stage buckets? Yes, 50%.
- Did you perform major repairs to first-stage nozzles? Yes, 73%.
- Did you have stop-valve stem damage? Yes, 55%. CCJ

The D11, equipped with 17 zones as shown in Fig 2, has been tested successfully at low temperatures to verify both proper operation of the heaters and thermocouple response. High-temperature full-capability tests will be conducted after the summer run season.

All heating zones operate simultaneously via one on/off switch and ramp to their proper temperatures at a predetermined rate. Controls for the 110-kW (477-V) warming system are designed to prevent temperature differentials that might otherwise contribute to uneven casing expansion. Specifically, if one zone is heating too rapidly, the control system turns it off until the other zones catch up and all can again work in unison.

Operation and monitoring of the warming system can be local, via the touch screen, or remote from the control room. Fig 2 is a simplified sketch of the screen. The actual screen in the Fig 3 photo provides zone temperatures and readouts for each thermocouple (two per zone).

Ansmann said Arnold spent two years developing this new product to ensure its applicability to every make and model of steam turbine. Assembly and thermal performance tests have been performed on the most recent casing materials to simulate installation and thermal conductivity both above and below, and alongside, the split line.

The number of heating zones and their design varies with the casing arrangement and steam-turbine operating temperatures at various locations on the unit. Arnold's engineers optimized the number of zones to satisfy warming requirements while simplifying to the degree possible the removal of blankets for maintenance. Heating elements and thermocouples are equipped with quick-release fasteners (Fig 4).

Ansmann noted that the performance of traditional multi-layer insulation systems can suffer when used in conjunction with warming systems if the pin substructure is not able to keep blankets and heating elements in place and assure uniform heat transfer across the casing—especially below the split line.

Keep in mind, too, that an ineffective insulation system contributes to high enclosure temperature, which can adversely impact electrical gear and wiring. Loss of efficiency and unsafe working conditions also result from poor-fitting and poorly installed insulation.

4. The warming system for a D11 can be installed within a 10-day window

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Camfil Farr Power Systems

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Contract fabricator of HRSG products—including finned tubes, pressure-part modules, headers, ducting, casing, and steam drums.

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Delivers end-to-end design solutions specializing in services that enhance performance, increase efficiency and reduce downtime. CEG delivers detailed engineering design for simple and combined cycles using aero and frame combustion turbines, with expertise in HRSG design and optimization.

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Engineers, designs, fabricates, and installs isolated phase bus, large bus duct systems, and outdoor switchgear. Specializes in rapid response needs such as IPB for GSU change-outs, quick-ship fabrication, and emergency on-site service needs.

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Our experience and innovative designs have brought best-in-class brush holders, collector rings, shaft grounding, and onsite field services for generators and exciters to some of the world's largest power companies.

DEKOMTE de Temple

Manufactures fabric and metal expansion joints which compensate for changes in length caused by changes in ductwork temperature. Axial, lateral, or angular movements can be compensated for. Company has gained a global reputation for ingenuity of design and quality of products.

Donaldson Company

Leading worldwide provider of filtration systems that improve people's lives, enhance equipment performance, and protect the environment. Donaldson is committed to satisfying customer needs for filtration solutions through innovative research and development, application expertise, and global presence.

Dry Ice Blasting of Atlanta

Offers professional dry-ice contract cleaning services performed at your facility. Company provides a full range of dry ice blasting machines and capabilities to accommodate any size job by its team of trained, certified, and experienced operators.

EagleBurgmann Expansion Joint Solutions

Leading global organization in the development of expansion-joint technology; working to meet the challenges of today's ever-changing environmental, quality, and productivity demands. Company's flexible products are installed on equipment where reliability and safety are key factors for operating success.

ECT-Engine Cleaning Technologies

Offers R-MC and PowerBack gas turbine and compressor cleaners to eliminate compressor fouling. Additionally, ECT designs specialty nozzle assemblies and custom pump skids for the proper injection of chemicals and water for cleaning, power augmentation, and fogging.

Emerson Process Management

Ovation™ control system offers fully coordinated boiler and turbine control, integrated generator exciter control, automated startup and shutdown sequencing, fault tolerance for failsafe operation, extensive cyber security features, and embedded advanced control applications that can dramatically improve plant reliability and efficiency.

EthosEnergy

This JV between Wood Group and Siemens is a leading independent service provider of rotating equipment services and solutions. Globally, these services include EPC; facility O&M; design, manufacture, and application of engineered components, upgrades, and re-rates; repair, overhaul, and optimization of gas and steam turbines, generators, pumps, compressors, and other high-speed rotating equipment.

Falcon Crest Aviation

Distributor of ZOK27 and ZOKmx gas-turbine compressor cleaning detergents. ZOK27 is a single cleaner and inhibitor in one that cleans and protects the engine—and also inhibits corrosion. ZOKmx is a power cleaner formulated to replace solvents providing exceptional cleaning without the health and environmental risks associated with solvents.

Federal Steel Supply Inc

Distributor of seamless HRSG high-energy pipe and power piping. Scheduled and heavier than scheduled walls in stock for headers, steam lines, etc. SA106 B/C and SA335 P11/P22/P91. Fittings to complement all pipe. Offering cut-to-length, custom fittings, specialty end preparation, supplemental testing, and emergency same-day shipments.

Filtration Group

Leader in manufacturing high-quality air filters from filter pads to final filters. Filtrair rigid pocket filters have high-performance properties and unique hydrophobic-treated air filters are the ideal solution for any environment with water droplet aerosol or high-humidity.

Frenzelit North America

Specializes in providing long-term expansion-joint solutions for gas-turbine exhaust applications. In addition to manufacturing superior quality expansion joints, Frenzelit also makes HRSG penetration seals, insulating materials, and acoustic pillows for silencers.

Gas Turbine Controls

World's largest stock of GE Speedtronic circuit boards and components for the OEM's gas and steam turbines. GTC stocks thousands of genuine GE-manufactured cards for the MKI, MKII, MKIII, MKIV, MKV, MKVI, and LCI controls, as well as EX2000, Alterrex and Generrex excitation.

Gas Turbine Efficiency

Provides solutions involving the application of electrical, mechanical, and process-related equipment and components for optimizing system performance. GTE's experienced team of engineers and designers has solid industrial process backgrounds with expertise in fluid systems, instrumentation, and system controls.

Gas Turbine Specialty Parts

Provides patent-pending products that are new, cutting-edge, add value, and promote a safer work environment. GTSP presently has two unique products designed for the utility industry: 1) flange leak detection and 2) open air exhaust thermowell.

GP Strategies

Provides training, engineering, and performance improvement services specifically designed for the power industry: The EtaPRO™ Performance and Condition Monitoring System and GPi-LEARN+™.

Groome Industrial Service Group

Offers a variety of SCR and CO catalyst cleaning and maintenance services nationwide and has formed strategic alliances with industry experts and catalyst manufacturers to ensure that Groome offers the most widely supported, comprehensive, turnkey service available.

GTC Services

Field engineering company offers gas-turbine owners and operators worldwide "Total Speedtronic Support." Engineers have decades of experience servicing and troubleshooting all GE Speedtronic systems.

Gulf Coast Filters & Supply

Keep your filter house and evap coolers operating at peak condition. GCF provides comprehensive, personalized filter-house products, field service, and maintenance, emphasizing safety, professionalism, efficiency, minimal job-site disruption, quality products, and thorough testing and inspections.

Haldor Topsoe

Our air pollution technology includes a series of unique catalysts for Selective Catalytic Reduction (SCR) systems for the control of nitrogen oxides (NO_x), and the reduction of carbon monoxide (CO) and volatile organic compounds (VOCs), from stationary and mobile sources.

Hilliard

The HILCO® Division cost-effectively brings fluid-contamination problems under control and engineers a full-range of filters, cartridges, vessels, vent mist eliminators, transfer valves, reclaimers, coolant recyclers and systems, and membrane filtration systems.

HRST

Specializes in technical services and product designs for HRSGs, waste heat boilers, and smaller gas or oil fired power boilers globally. Experience on over 200 boilers annually and able to provide quality inspections, analysis work, design upgrades, professional training, and more.

Hydro

Engineered solutions enable combined-cycle plants to achieve pump reliability and reduced O&M costs. As the largest independent pump rebuilder, Hydro works hand-in-hand with pump users to optimize the performance and reliability of their pumping systems.

Hy-Pro Filtration

Provides innovative products, support, and solutions to solve hydraulic, lubrication, and diesel contamination problems. Company's global distribution and technical-support networks enable customers to get the most out of their diesel, hydraulic, and lube-oil assets. ISO 9001 certified.

Janus Fire Systems

Manufacturer of special hazard fire protection solutions. Designers of engineered clean agent and high- or low-pressure carbon dioxide systems composed of hardware and software tailored to the application.

JASC

Engineers and manufactures actuators and fluid-control components for power generation, aerospace, defense, and research applications to improve operational capability and performance.

KnechtionRepair Tools

Manufactures tools designed to make thread repairs to both the female and male ends of cross-threaded compression fittings. In most cases, the repair will be accomplished without removing the tube from the system. This saves the O&M tech time and avoids additional downtime.

Kobelco Compressors America

Provides robust, high-efficiency fuel-gas compressors for use with all major types of gas turbines—including GE, Mitsubishi, Alstom, Siemens,

Rolls-Royce, and Solar. Over 300 of the company's screw-type compressors have been supplied for gas turbines.

Liburdi Turbine Services

Advanced repairs employ the latest technologies and are proven to extend the life of components for all engine types. Company specializes in high-reliability component repairs and upgrades for blades, vanes, nozzles, shrouds, combustors, and transitions.

Mechanical Dynamics & Analysis

One of the largest turbine/generator engineering and outage-services companies in the US. MD&A provides complete project management, overhaul, and reconditioning of heavy rotating equipment worldwide.

Membrana, a 3M company

Market-leading producer of microporous membranes and membrane devices used in healthcare and industrial degassing applications. The Industrial & Specialty Filtration Group manufactures Liqui-Flux® ultrafiltration and microfiltration modules as well as Liqui-Cel® membrane contactors.

Mitten Manufacturing

Leading fluid system packager for numerous OEMs, EPC firms, utilities, and plant operators all over the world offering a number of value-added designs, spare parts management, and field services.

Multifab Inc (MFI)

Over 40 years of experience in design and manufacturing of products used for high-temp equipment along with air and flue gas applications. Offers a wide variety of services for all types of expansion joints, dampers, and high-temp products including installation, removal, repair, and splicing.

NAES

One of the world's largest independent providers of operations, construction, and maintenance services, provided through a tightly integrated family of subsidiaries and operating divisions. NAES services include O&M; construction, retrofit, and maintenance under dedicated long-term maintenance or individual project contracts; and customized services designed to improve plant and personnel effectiveness.

National Electric Coil

Leading independent manufacturer of high-voltage generator stator windings with expertise in design and manufacturing of stator windings for any size, make, or type of generator. This includes diamond coils, Roebel bars—including direct cooled, inner-gas, and inner-liquid cooled bars—and wave windings.

Nor-Cal Controls ES Inc

Provides control-system consulting, engineering, and training solutions and services to the power generation sector. Cost-effective solutions are based on proven technology and open-architecture design, eliminating the need for service contracts at the end of the project.

Parker Balston

Develops and manufactures nitrogen generators for all your power generation needs including boiler layup, gas seals, purging gas lines prior to service, blanketing demin water tanks, and LNG terminals.

Parker Hannifin

Reduce costs and optimize performance with the world's leading diversified OEM of motion, flow, process control, filtration, and sealing technologies, providing precision engineered solutions for the power generation market.

PetrolinkUSA

Provides high-velocity hot-oil flushing, EHC flushing, chemical cleaning, lubricant reconditioning, and auxiliary on-line filtration. Preventive maintenance services include equipment assessments and lubricant analysis.

Praxair Surface Technologies

Leading global supplier of surface-enhancing processes and materials, as well as an innovator in thermal spray, composite electroplating, diffusion, and high-performance slurry coatings processes. Company produces and applies metallic and ceramic coatings that protect critical metal components such as in gas turbines.

Precision Iceblast

World leader in HRSG tube cleaning. PIC cleans more HRSGs than any other ice blasting company in the world. It ensures that HRSGs operate efficiently by providing the cleanest boiler tubes possible.

Proco Products

Supplies rubber expansion joints to the power industry in sizes ranging from 1 to 120 in. ID. Proco keeps joints up to 72 in. ID in stock at its Stockton (CA) warehouse and works through an agent/distributor network to supply products to combined-cycle plants.

PSM

Full-service provider to gas-turbine equipped generating plants, offering technologically advanced aftermarket turbine components and performance upgrades, parts reconditioning, field services, and flexible Long Term Agreements (LTAs) to the worldwide power generation industry.

PW Power Systems

Provides competitive, efficient, and flexible gas-turbine packages rated from 25 to 120 MW. PWPS offers a full range of maintenance, overhaul, repair and spare parts for other manufacturers' GTs with specific concentration on the high-temperature F-class industrial machines.

Real Time Power

Offers smart optimization solutions for power generation. Expertise spans machine learning, predictive modeling, diagnostics, and forecasting. Employs data scientists with unique domain knowledge of gas turbines to create realistic and practical algorithms, providing accurate predictions which improve plant operations.

Rentech Boiler Systems

International provider of high-quality, engineered industrial boiler systems. Rentech is a market leader in providing HRSGs for cogeneration and CHP plants. It is in its second decade of designing and manufacturing high-quality custom boilers—including HRSGs, waste-heat boilers, fired packaged boilers, specialty boilers, and emissions control systems.

RMS Energy

Performs all aspects of isolated phase bus duct maintenance, inspections, removal, installations, retrofitting and testing. Services also include cutting, aluminum and substation welding, transformer termination compartment removal, and provision of replacement parts.

Rotating Equipment Repair Inc

Specializing in high pressure multi-stage boiler feed pumps, RER provides its customers high quality engineering services, repairs, and parts for centrifugal pumps through the utilization of highly skilled professionals, cutting-edge technology, and proven work methodologies.

Sargent & Lundy

Provides complete engineering and design, project services, and energy business consulting for power projects and system-wide planning. The firm has been dedicated exclusively to serving electric power and energy-intensive clients for more than 120 years.

Siemens Energy

A leading global supplier for the generation, transmission, and distribution of power and for the extraction, conversion, and transport of oil and gas. Leadership in the increasingly complex energy business makes it a first-choice supplier for global customers. Known for innovation, excellence and responsibility, company has the answers to the sustainability, flexibility, reliability, and cost challenges facing customers today.

FIND A VENDOR, FIX A PLANT

SSS Clutch Company

Clutches enable operators to disconnect generators from simple-cycle turbines for synchronous-condenser service. Clutches also find application in CHP plants and in single-shaft combined-cycle facilities where operating flexibility is beneficial.

Strategic Power Systems

Provides products and services focused on capturing powerplant operational and maintenance data to develop reliability metrics and benchmarks for end users—including some of the most recognized organizations in the global energy market.

Structural Integrity Associates

Powered by talent and technology, SI is a global leader in providing innovative engineering solutions. Using a multidisciplinary approach, our experts bring a fresh perspective and proven solutions for structural evaluation and repair.

Sulzer

Provides cutting-edge maintenance and service solutions for rotating equipment dedicated to improving customers' processes and business performances. When pumps, turbines, compressors, generators, and motors are essential to operations, Sulzer offers technically advanced and innovative solutions.

SVI Dynamics

Engineers and supplies gas-path solutions for power and process applications including inlet/exhaust system upgrades, silencer repairs and retrofits, gas plant hot-gas-path inspections, and fleet-wide gas-path maintenance.

Taylor's Industrial Coatings

Highly skilled staff is trained and equipped with the latest tools and equipment necessary to complete coating projects on time and in scope with a commitment to safety, technical support, and quality workmanship.

TEC-The Energy Corp

Our skills and experience assist GT owners with front-end engineering, procurement of major equipment, and management of engineering, construction, and commissioning of new facilities. From due diligence to detailed design, TEC covers all phases of complex power projects.

TEi Services

Offers a full range of heat-transfer products and services and fully trained, certified maintenance personnel. Provides world-class emergency repair services, underpinned by a 75-yr history in the design and manufacture of condensers, feedwater heaters, and heat exchangers.

TEServices

Superior metallurgical experience in managing components, creating repair and bid specifications, selecting the repair and coating vendor, and verifying them during the refurbishment of critical IGT components when your company does not have the resources available.

TesTex Inc

World leader in electromagnetic non-destructive testing (NDT). We continually define the state-of-the-art for the testing of ferrous and non-ferrous materials and structures through applied research and development.

Texas Bearing Services

Manufactures and repairs fluid film (babbitt) bearings and seals for turbomachinery including gas and steam turbines, compressors, generators, gearboxes, and more. Works with OEMs, distributors, and end-users all over the world and offer 24/7/365 emergency services for critical outages.

Thor Precision

Value-added service center provides reverse-engineered rotor bolting for the gas-turbine aftermarket—specifically for Frame 3, 5-1, 5-2, 6B, 7E, 9E engines—including compressor, turbine, marriage, and load-coupling hardware.

Turbine Technology Services (TTS)

Wide range of expert engineering and consulting services, conversion, modification and upgrade services, GT installation and reapplication services, and design and implementation of complete turbine management systems.

Universal AET

Designs, procures, and manufactures OEM and retrofit inlet and exhaust systems including filter houses, inlet duct/silencers, enclosure doors, diffusers, plenums, expansion joints, transitions, exhaust ducts/stacks, exhaust baffle silencers, and stack dampers.

Universal Plant Services

Specializes in the maintenance, repair, and overhaul of gas and steam turbines, centrifugal and reciprocating compressors, as well as all rotating equipment, with qualified millwright and field machining specialists.

Victory Energy

Offers all types of industrial boilers: watertube, HRSG, firetube, and solar-powered units. Company provides unprecedented support with its rental boilers, spare parts, field service, and auxiliary equipment—including water-level devices, economizers, stacks, expansion joints, and ductwork.

Vogt Power International

Supplies custom-designed HRSGs for GTs from 25 to 375 MW and has extensive experience in supplementary-fired units. Scope of supply includes SCR and CO systems, stack dampers, silencers, shrouds, and exhaust bypass systems.

USA Borescopes

Global supplier and repair service provider of borescopes, videoscopes, and pipe inspection cameras for today's turbine maintenance professional, offering a full complement of remote visual inspection equipment with a wide range of features and configurations.

World of Controls

Worldwide, low-cost provider of DCS circuit boards offering an array of ancillary services which include testing/repair of circuit boards, parts, DCS troubleshooting, Dos support, HMI upgrades/backup and field-based mechanical and controls training.

Young & Franklin

Premier fuel control supplier for combustion turbines for both long-term hydraulic solutions and, more recently, innovative all-electric controls solutions. Product scope supports natural gas, liquid, syngas, and alternative fuels as well as providing air controls to provide proper fuel to air mixtures.

Zokman Products

Distributor of ZOK27 and ZOKmx gas-turbine compressor cleaning detergents. ZOK27 is a single cleaner and inhibitor in one that cleans and protects the engine—and also inhibits corrosion. ZOKmx is a power cleaner formulated to replace solvents providing exceptional cleaning without the health and environmental risks associated with solvents.

CCUG

COMBINED CYCLE USERS GROUP

Seventh Annual Meeting

Sheraton Grand at Wild Horse Pass, Chandler (Phoenix), Ariz

August 28-31, 2017

Please mark your calendar and plan to attend

Registration opens in April at www.ccusers.org

The CCUG Steering Committee invites your input for the group's Seventh Annual Meeting. Here are some of the ways you can participate and make your attendance more productive:

- Suggest a topic for inclusion in the program.
- Make a short presentation on best practices, lessons learned, HRSGs, control systems, plant outage management, diagnostics and prognostics, knowledge management, training, safety, employee retention, fuel systems, emissions control, heat rejection systems, etc. Can be 5, 10, or 15 minutes, or longer.
- Bring a thumb drive to the meeting with a couple of photos describing a problem at your plant and ask your fellow users for suggestions on a solution. Think of this clinic as free consulting by those who walk in your shoes.

The CCUG Steering Committee

Top row (l to r): Dr Robert Mayfield, *Tenaska Inc;* John Baker, *Riverside Public Utilities;* 2016 Chair Steve Royall, *PG&E*

Bottom row: Jimmy Daghlian, *NV Energy;* 2016 Vice Chair Phyllis Gassert, *Talen Energy*

Camera shy: Brian Fretwell, *Calpine Corp*

Email Vice Chair Phyllis Gassert (phyllis.gassert@talenenergy.com) with your thoughts/ideas today.

BUSINESS PARTNERS

David Brumbaugh, a positive force in all aspects of life

If you never met David Brumbaugh at your plant or office, or at a user-group vendor fair—often with wife Shelley and occasionally daughters Abigail and Hannah—that's unfortunate. The late president of DRB Industries LLC was particularly knowledgeable on gas-turbine inlet and exhaust systems, air filters, and cooling towers (Fig 1), and always willing to share best practices and lessons learned. He was positive-minded and had an engaging personality; many in the electric-power industry benefited from his caring/sharing nature.

Brumbaugh died April 16 of a heart attack—so unexpected it left even close personal friends in shock. Rick Shackelford, division director, powerplant operations, for NAES Corp, knew him well, both personally and professionally. He told CCJ, "Such a terrible loss for Oklahoma. . .the power industry. . .his family. . .and his friends. David was a true-life world-changer."

Industry people generally are aware that Brumbaugh founded DRB Industries to support powerplant owner/operators in the selection, installation (including design and construction services to the degree necessary), inspection, and maintenance of filtration and cooling products. But that was only the tip of the iceberg for this perpetual-motion machine of a man.

Family, politics, and religion were Brumbaugh's passions. At the time of his death, he was chairman of the House (of Representatives, State of Oklahoma) Majority Caucus. A representative from the Broken Arrow area since 2010, he authored numerous bills that have been signed into law. His legislative focus was streamlining of government processes, job creation, transparency of government activities, and protection of religious liberties.

1. David Brumbaugh conducts a cooling-tower performance assessment

Local news reported that House members held a moment of silence for their colleague on Easter Monday and sang "Amazing Grace" together. Fig 2, from The Washington Times, shows the folded American flag on the chairman's desk at the front of the chamber to honor his service in a rapid-deployment air assault infantry unit attached to the 101st Airborne Division, as well as the state flag draped across his empty chair. Later in the week, his body lay in repose in the state Capitol building.

Deeply religious, Brumbaugh was an ordained deacon, former chairman of the deacon board, and Sunday school teacher at Tulsa Bible Church. Reflecting on Brumbaugh's years of teaching Sunday school, Phil Martin, the Tulsa Bible Church's associate pastor of discipleship, told local news, "He was a legend there."

2. The vacant chair: American flag honors Brumbaugh's military service, the Oklahoma flag is legislative service

Brumbaugh was well known to the editors. His work was featured in several CCJ articles over the years and more were in the works. At least one of those in the latter category was to address filter testing to help guide users in product selection. He was working with EPRI on a methodology for verification of manufacturers' claims at the time of his death.

He shared his thoughts on cooling-tower performance assessments both in print and by way of webinar; the latter still is accessible to you at www.ccj-online.com/onscreen and just as pertinent today as when it was presented and recorded.

Brumbaugh achieved more in his 56 years than most would accomplish in multiple lifetimes. But no one really does everything on his, or her, own. Much of his strength derived from strong family support. He was the very visible part of Team Brumbaugh, but Shelley, with help from Abigail and Hannah, helped to make that possible by managing both the family home and daily business activities.

HRSG technology and other recent books

Safe to say, it is the rare engineer who wants to write. . .anything. Other than the required company internal reports, engineers occasionally will compile technical papers for engineering society meetings, perhaps even a magazine article, typically to gain recognition or to sell something.

It used to be that the table stakes for presenting at an industry meeting was the preparation of a technical paper for review by conference organizers. The large OEMs all had technical writers on staff to translate engineering jargon and poor grammar into acceptable English. But those positions are just memories today, superannuated by computer software, such as PowerPoint. Virtually anyone can put together a series of slides for content review that don't require complete sentences—simply sound bites—to gain podium access.

So when three engineers, each with three or four decades of experience in technologies important to the electric power industry, publish books within a three-month period, one can assume the literary equivalent of a "100-year flood" has occurred. The books:

- Heat Recovery Steam Generator Technology, edited by Vernon L Eriksen.
- Knowledge Management in the Digital Age, by Dr Robert Mayfield

The umbrella organization for managing and coordinating the technical programs for the industry's leading User groups

Conferences

- Each year in May:
  - 7F Users Group annual conference: www.7FUsers.org
- Each year in August:
  Three separate conferences… three different agendas
  Same dates, same location, shared meals and shared vendor fair
  - Combined Cycle Users Group – www.ccusers.org
  - Generator Users Group – www.genusers.org
  - Steam Turbine Users Group – www.stusers.org

Forums

- 7F Combustion Turbines
- Combined-Cycle Steam Turbines
- Combined-Cycle Users
- Heat-Recovery Steam Generators
- Generators

Power Users Group is a non-profit company managed by Users for Users. It is designed to help Users share information and get solutions to power-production problems.

www.PowerUsers.org

with Jason Makansi.

- Painting by Numbers—or How to Sharpen your BS Detector and Smoke out the "Experts," by Jason Makansi.

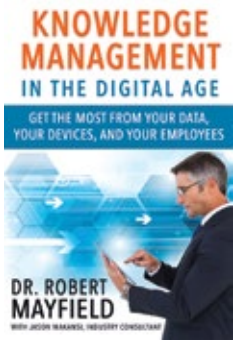
HRSGs. Perhaps the most significant work of the three for industry personnel responsible for managing, operating, and/or maintaining hard assets is Eriksen's. His name is synonymous with HRSGs: Vern is the Eriksen in Nooter Eriksen, which probably has supplied more large heat-recovery steam generators than any other manufacturer in the world. This work was needed by the industry, in the minds of the editors. The only other "boiler book" of note is B&W's *Steam,* but it is weak in this area of the technology because the manufacturer was an on-and-off supplier of HRSGs over the years.

Eriksen did not write the book, he edited it. He went out and got top talent in the industry to support the effort by writing individual chapters and then fashioned them into a well-organized reference that you want on your bookshelf. Among his contributors, beyond Nooter Eriksen engineers current and past (like Joe Schroeder), are catalyst experts from BASF Corp, duct-burner experts from John Zink Company, and well-known industry subject-matter experts Barry Dooley, Nancy Stephenson, and Joe Miller.

Key features of the work include the following:

- Presents the fundamental principles and theories behind HRSG technology, supported by practical design examples and illustrations—many in full color.
- Includes design details of HRSGs for today's largest combined-cycle plants, covering the tradeoffs important to financial decision-making.
- Provides readers the foundation for doing a better job of specifying, procuring, installing, operating, and maintaining HRSGs.

Mayfield's second book on knowledge management—KM for short—is chock full of useful information, best practices, and lessons learned to help managers extract the greatest value from data available and get the most from their electronic devices and employees. The author should know: He is a seasoned powerplant executive and educator who came up through the hawsepipe in the US Navy, retiring as a submarine commander with bachelor's and master's degrees in electrical engineering.

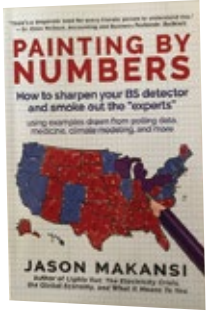


Mayfield is passionate. Knowledge doesn't just happen, he says, putting mustard on the message: It must be created and captured, shared and transferred, organized and integrated, and it must be managed. He shows readers how to turn information into actionable intelligence; manage complex powerplant systems with ease, efficiency, and effectiveness; and give your organization the competitive advantage required to succeed in the digital age.

Important to note is that all proceeds from the sale of this book go to benefit Wounded Warriors. Order on Amazon.

Makansi, president of Pearl Street, a Tucson-based consultancy, has deep experience in engineering and finance. He also may be the best technical communicator in the electric power industry today. Makansi is adept at synthesizing and simplifying complex material.

Painting by Numbers is short book



(150 pages of type you can read without glasses) that you sit down and read when you have a couple of hours. It encourages you to listen and read with understanding and to question virtually everything. We live in a post-fact world as Makansi likes to say; you just can't nod at numbers and "facts" and accept them without thinking. Examples illustrate how deceiving numbers can be.

AGTSI, Eaton team-up to distribute aero parts globally

AGTSI President Alan Mibab called to say Eaton had selected his company, Aeroderivative Gas Turbine Support Inc, as its global distributor for aeroderivative industrial and commercial marine gas-turbine components and services. The two companies signed a five-year agreement after partnering for several years to expand Eaton's worldwide distribution network of aero products—including dynamic and static seals, hoses and fittings, and specialty lube-system sensors and components.

AGTSI, established in 2004, maintains an extensive inventory of parts and assemblies for aero engines at is Boca Raton (Fla) headquarters to meet customer "just-in-time" delivery expectations. The company also facilitates overhauls and maintains rotable exchanges for many components.

Eaton provides energy-efficient solutions to help customers manage electrical, hydraulic, and mechanical power efficiently, safely, and sustainably. It has customers in more than 175 countries and had 2016 sales of nearly $20 billion.

PWPS introduces its 7FA.03+ upgrade to owner/operators

PW Power Systems Inc (PWPS), a group company of Mitsubishi Heavy Industries Ltd, announced its 7FA.03+ upgrade to owner/operators at the 7F Users Group's annual meeting in San Antonio, May 15-19. It offers a power increase of 8 MW and a 32,000-hr operating interval.

Company representatives said the second- and third-stage components previously re-engineered and improved by PWPS for the 7F frame were combined with a new first-stage design to achieve the upgrade package. Flexibility options are available to customize service interval and/or power increase to benefit the owner/operator.

Sulzer update

Groundbreaking conducted for a new pump service facility in Pasadena, Tex, adjacent to the company's existing center for electromechanical services. The new shop will become the regional headquarters for pump services in the Americas, including state-of-the-art equipment and technical support.

At-speed balancing bunker, located in the company's Houston Service Cen-

CTOTF

Combustion Turbine Operations Technical Forum

2017 FALL CONFERENCE & TRADE SHOW

Conference Theme: Responding to the New Energy Paradigm … Are You Ready?

Hyatt Regency Hill Country
Resort & Spa
San Antonio, Texas
September 17 - 21, 2017

Users CTOTF is the leading Users' Technical Conference with everything in one location … *Total Plant Concept … all OEM equipment, BOP Systems, CT Tech … AND a Leadership Development Track … Come experience it!*

Vendors Presentation & Sponsorship Opportunities

User Registration will open in May 2017
Details @ www.ctotf.org

Our 42nd Year of Serving the Power Generation Industry

ter, celebrates 20 years of service to the industry. The machine, which has balanced over 2800 rotors, is an integral part of the diagnostic and repair process for large rotating components. The service center's dedicated vacuum chamber, bunker, and advanced electronics work in concert to achieve precision balancing. Turbomachinery up to 30 ft long, 8.5 ft in diameter, and 25 tons can be tested at speeds up to 40,000 rpm.

Sulzer is selected by ABB to provide maintenance and repair services in the UK for the OEM's medium- and high-voltage motors and generators. Named an ABB Loyalty Partner after successful completion of a comprehensive audit, Sulzer will provide inspection, remedial work, modifications, repairs, and rewinds of machines rated at 6.6 kV and above. Its service centers in Birmingham and Falkirk have expanded their facilities to meet the additional demand.

Gas turbines at Associated Electric Cooperative Inc's Holden Power Plant, a 3 × 0 V84.2-powered peaking facility, recently were upgraded to extend calendar-based inspection intervals to 10 years for HGP and to 20 years for a major without affecting reliability and performance. The units each had accumulated about 10,000 EOH since first operation a dozen years ago. Here is some of the work done by Sulzer:

1. Compressor components were coated to prevent oxidation by guarding against corrosion, fouling

2. New fuel-nozzle seal design eliminates gas leakage, reduces emissions

- Compressor—rotating and stationary sections, including inlet guide vanes—was coated to prevent oxidation by protecting against corrosion and fouling (Fig 1).
- The flame tube F-ring was machined to expose fresh material, overlain with Inconel 82, and re-machined

to original dimensions. Expected result: Improved component durability.
- Combustion section was protected with a full thermal barrier coating; chromium carbide was applied to mating services in the combustion section to minimize wear during expansion/contraction.
- Additional cooling holes were drilled in the flame tube behind the A-row tiles to reduce oxidation and erosion.

Solved: Gas-fuel nozzle leak issue on Frame 6B and 7EA engines (Fig 2). Solution can be implemented during routine scheduled maintenance to effectively reduce to zero previously tolerable minor leaks at the primary-fuel nozzle tips. This enables the turbine to run at optimum parameters for power, efficiency, and component lifespan—while assisting the owner/operate meet more-strict emissions regulations.

Siemens update

Plant commissionings:
- Panda Power Funds' 778-MW, 2 × 1, F-class Stonewall Power Project recently began commercial operation. A long-term service agreement is in place for the combined cycle—including parts, inspections, scheduled service/maintenance, and Siemens Power Diagnostics®.
- The first four of twelve 1200-MW, 2 × 1 H-class combined cycles for Egypt's Beni Suef, Burullus, and New Capital power projects were connected to the grid only 18 months after contract signing. Completion of the fast-track project is expected in May 2018.
- The OEM commissions Tate & Lyle's 2 × 0 SGT-700-powered cogeneration plant in Loudon, Tenn.

New engines:
- A 44-MW mobile power unit introduced by Siemens is said to be the largest in the growing market for fast power. It can be installed in less than two weeks. The mobile system features the SGT-A45 TR engine based on Rolls-Royce aero-engine technology. The gas-turbine core uses components from the industrial Trent 60 that have been adapted to a proven free power turbine.
- SGT-A35 RB, a 38-MW aero gas turbine for the oil and gas industry recently introduced by the OEM, was designed jointly by Siemens' Dresser-Rand and Rolls-Royce businesses. It is said to have a 30% smaller footprint and be lighter in weight than its predecessor, the RB211.

Alliances:
- Siemens and Atos, a leading European digital services firm, will leverage their portfolios to help US utilities and O&G industry establish an integrated first line of defense against cyber-attacks.
- Chromalloy Gas Turbine Corp and Siemens form Advanced Airfoil Components, a joint venture. The new company's mission is the manufacture of turbine blade and vane cast components for power generation. Possible sites for the new production facility are under evaluation.

Recent orders:
- Turnkey 2 × 1 H-class combined cycle for the Electricity Generating Authority of Thailand.
- Four turnkey powerplants for IPP customers in Argentina with a combined capability of nearly 690 MW. Six SGT-A65 TR (formerly industrial Trent 60) gas turbines are at the heart of two plants in

the cities of Lujan and Matheu; six SGT-800 engines will be installed in San Pedro and Zarate.

- Five SGT6-5000F engines for the Fadhili CHP plant in Saudi Arabia, with a total capability of about 1500 MW.
- Two SGT-700-powered compressor trains and two SGT-700-powered simple-cycle generator packages for the Liwa Plastics Industries Complex in Oman.
- A 1 × 1 SGT5-4000F-powered combined cycle for the King's Lynn Power Station in Norfolk, UK.
- Compressor trains for two onshore natural-gas processing plants in Iran. Commercial operation is expected year-end 2018. Likely of greatest interest to CCJ readers is the selection of prime movers. Four compressors will be powered by DLE-equipped SGT-700 gas turbines rated 33.7 MW in mechanical-drive applications. Another four compressors will be driven by SGT-100 gas turbines rated 5.7 MW in mechanical-drive service. The SGT-100 began life as the Typhoon, designed by Ruston Gas Turbines, which spawned European Gas Turbines. EGT became part of Alstom Gas Turbines which sold this and several other gas-turbine models to Siemens. Compressors for the remaining two trains will be motor-driven. All compressors are of Siemens design (Demag/Demag-Delaval).
- Castle Peak Power Co, Hong Kong, orders a combined-cycle power block for its Black Point Power Station in Tuen Mun. The single-shaft unit, consisting of one SGT5-8000H gas turbine, one SST5-5000 steam turbine, and one water-cooled SGen5-3000W generator, will be commissioned before 2020.
- Macquarie Infrastructure Corp orders two Trent 60 wet low-emissions engines for the Bayonne Energy Center, which delivers power to Con Edison in New York City via an underwater transmission line. The units can produce full power from a standing start in less than 10 minutes.
- Vattenfall Europe Warme AG orders a combined-cycle cogeneration plant for commercial operation in 2020. The 260-MWe/230-MWt plant will connect to the heating/cooling network in the Marzahn district of Berlin.
- Kuwait's Ministry of Electricity & Water orders a steam turbine to convert the two-unit Az Zour South 3 simple-cycle plant to combined cycle. The gas turbines went commercial in 2015; the combined cycle is planned for mid-2019 operation. Plant capacity will increase by about 263 MW without using any additional gas.

Other news:

- Argentina's Pampa Energia SA selects the OEM to provide service and maintenance for its Genelba 21 simple-cycle plant (10 years) and Genelba combined cycle (eight years). The agreements cover spare parts, repairs, logistics support, field services, and Siemens Power Diagnostics®. Also included are upgraded replacement blades for the peaker and upgraded IGVs for the two gas turbines in the combined-cycle unit.
- The first industrial gas turbines for the expansion of three Bolivian powerplants are on their way from Siemens Industrial Turbomachinery's Finspong (Sweden) manufacturing plant. After ocean transport to Chile, the engines will be trucked more than 1100 miles to the plant site. The second leg includes crossing the Andes at more than 14,000 ft.
- Dubai Electricity & Water Authority and Siemens agree to collaborate on an advanced data-driven project designed to help DEWA achieve its vision of becoming a sustainable, innovative world-class utility, and to ensure the highest levels of performance, efficiency, and reliability of its power generation assets.

Company news reports

MHPS Americas President Paul Browning opened Mitsubishi Hitachi Power Systems' technical conference in Buenos Aires in mid-April making mention of the following:

- Alexandre Aoki is appointed president/CEO of MHPS South America.
- Record order year in the Americas for advanced-class gas turbines and other equipment.
- Air-cooled J-series gas turbine introduced for the South American market.
- M701JAC was said to have a world-record rating of 717 MW and a combined-cycle efficiency of 63%.
- Continued support from the Japan Bank for International Cooperation to provide funding options for project developers across the region.

Maxim Power Corp announces its intent to sell the following US assets:

- Basin Creek Equity Partners LLC.
- Capitol District Energy Center Cogeneration Associates.
- Pawtucket Power Associates LP.
- Forked River Power LLC.
- Pittsfield Generating Co LP.

Ansaldo Energia is awarded a service contract for the Taweelah Initial B (IB) and Initial B Extension (IBE) powerplants, both located in Abu Dhabi's Taweelah Power & Water Complex. The facility supplies 2000 MW of power and 190 million gal/day of water. Contract includes a permanent AE maintenance staff onsite and covers all scheduled overhauls, plus preventive and corrective maintenance activities, for IB's and IBE's principal rotating equipment.

Structural Integrity Associates Inc acquires Tobolski Watkins Engineering and TRU Compliance, its product certification company.

Turbine Technics Inc, a global distributor of parts and components for industrial and marine gas turbines, earns ISO 9001:2015 certification. President David Simon also announced the launch of a new website at www.turbinetechnics.com.

Mee Industries Inc announces the ready availability of high-purity water systems. The dual-pass RO skids with EDI polishing produce 50 gpm of product water with a conductivity of 0.5 µS/cm. Listed benefits of the system include the following: compact footprint, consolidated controls, single pump.

In other news, the company uses a case history to describe the success of its inlet cooling technology during the challenging summer experienced at an Italian refinery in Venice. Output of a 25-MW gas turbine was increased by 1 MW and emissions were reduced. Details at www.meefog.com.

Powerphase signs a memorandum of understanding with Indonesia's state-owned power company, PT Perusahaan Listrik Negara, for the phased implementation of Turbophase® dry air injection, beginning with a feasibility study for two 50-MW projects.

Day-Ray Products Inc acquires the assets of CEC Vibration Products Inc. The manufacture of CEC sensors, electronics, and transducers will continue as CEC Vibration Products.

ep³ LLC describes its new process improvement tool in a short video "Lessons Learned," which explains how to inject new life into your plant's continuous improvement efforts. Write info@ep3llc.com for a demonstration.

M&M Engineering Associates, a provider of field and lab engineering

services, is acquired by Acuren Inc, a provider of non-destructive testing, inspection, and related services. A goal of the merged company is to help plants optimize the lifecycles of their critical assets.

Babcock & Wilcox Enterprises Inc acquires Universal Acoustic & Emission Technologies Inc. UniversalAET is a bolt-on acquisition for B&W MEGTEC, a supplier of environmental control technologies and engineered products, operating under the trade name B&W Universal.

Camseal® zero-leakage ball valves are designed for long life and inline access to internal components for ease of maintenance and repair. Brochure provides plant personnel the information required to make a purchasing decision—including Cv values, operating torques, working-pressure charts, dimensions, materials, fire-safe test data, quality certifications, etc. A short video brings key points in the brochure to life. Access both the brochure and video at www.conval.com.

People in the news

Mike Hartsig, until recently the plant manager of Griffith Energy, a 2 × 1 F-class combined cycle in Kingman, Ariz, has put his work boots in the closet. He was replaced by Scott Henry, who had been O&M manager at that facility.

Frank Mead replaces Jeff Zelik as plant manager at Eagle Point Power Generation, Westville, NJ, commissioned in 1991 as a 7EA-equipped refinery cogeneration facility and recently upgraded by new owner Rockland Capital. Zelik is now at WorleyParsons.

Conval Inc appoints Michael Glavin VP of engineering with responsibility for new product development and technology. He has more than 25 years of experience in fluid handling, including engineering leadership positions at Cameron, Tyco Valves and Controls, and Worcester Controls.

US Water Services Inc, a subsidiary of Allete Inc—an energy company that owns Minnesota Power and Superior Water, Light & Power—names LaMarr Barnes CEO. Most recently, he was the company's senior VP of marketing and strategy.

Allied Power Group appoints David Theis president/COO. He was the founder of Leading Edge Turbine Technologies, which was acquired by Dresser-Rand in 2010.

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