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COMBINED CYCLE Journal

30th Anniversary

WTUI

World's largest aero user group

March 29-April 1

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29th Annual Meeting

7F USERS GROUP

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INDEPENDENT VOICE OF THE GAS-TURBINE-BASED GENERATION SECTOR

GUEST COMMENTARY

'Future Shock' Where are we, where are we heading?

Salvatore A DellaVilla Jr, managing director, Gas Turbine Association

"Too much change in too short a period of time," the definition of *'Future Shock,'* was conceptualized, defined, and shared in a book by Alvin and Heidi Toffler, published with the same name in the 1970s. If we look at today's energy market, and we consider the messages that we hear almost every day, change has been too slow. But the global message is pretty strong: Change has to come fast and furious to mitigate the social and global impacts of using fossil fuels in power generating plants—no fossil fuels by 2040 or 2050.

Not many people would disagree that there is a need to reduce greenhouse gas (GHG) emissions to attenuate the rate of climate change. The goal of implementing a carbon-neutral economy demands will, policy, and technology; all three are required over a sustained period to effect positive change. Promoting clean energy solutions that include renewables, battery storage, and carbon sequestration cannot overlook the value and real benefit of natural-gas-driven gas-turbine technologies that already result in environmental improvement by transitioning the market to a cleaner energy future.

One has to wonder if where we are now is a result of not enough change over too long a period of our past, or simply a reflection of social confusion with the breakdown of normal decision-making that the Tofflers suggest is a consequence of "accelerated change."

No fossil fuels by 2040 or 2050? That's 20 to 30 years from now. That is fast! Is anybody worried about where baseload generation will come from? What about reserve margins? What will provide the base and load-following requirements, how will it be delivered? Who will provide the needed ancillary services, or black-start capability when power has been interrupted and must be restored quickly? Has anyone considered what will happen to energy costs in a 100% fossil-fuel-free energy economy? Balancing the grid, power and voltage, demands energy stability and resilience—a necessity.

The *"Future Shock"* is that heavy-duty and aeroderivative gas turbines will have a continued role with considerable sustainable investment value; they are part of the *"Clean Energy Solution."* Replacing retirement-ready older coal-fired stations with more efficient gas-turbine-driven combined-cycle technologies has had a sustainable impact on reducing GHG emissions. Research from the Electric Power Research Institute (EPRI) indicates that *"The US is responsible for 44% of global CO_2 emission reductions since 2005, and 80% of that was from the electricity sector. Energy efficiency and cleaner generation have been the reason for these gains. Fuel blending can also help lower CO_2 further."*

The US has met the terms of the Paris Climate Change accord, at least in spirit and execution.

Gas-turbine combined-cycle systems integrate cost effectively with wind, solar, and existing battery storage applications. These hybrid systems can fill the cyclic, load-following, or peaking-power requirements that intermittent generators are not designed to fill alone. With new realistic "cleaner fuel" opportunity and availability, such as an appropriate hydrogen mix or blend, gas turbines will continue to meet the needs of baseload generation.

New-cycles development and associated R&D investment will ensure that gas turbines evolve in performance and capability to meet changing market demands. Gas turbines will add value as a clean energy technology that supports the needs of other market segments, like transportation charging stations. A vital component to the nation's generating mix and the global installed base, gas turbines represent an investment-grade opportunity with a real return on investment that includes cost-effectiveness, reliability, efficiency, and resiliency.

The Tofflers were concerned with taking control over what they called "the accelerative thrust." The "accelerated thrust" is always triggered by man, and it's where we are right now. The Tofflers' message: Control the waves of change or be overtaken by them. We need to heed this message. Climate change is real. Addressing this major global challenge means embracing the best mix of energy technologies. Gas-turbine technology, now and in our future, is a major part of the "Clean Energy Solution."

Salvatore A DellaVilla Jr, *managing director of the Gas Turbine Association (www.gasturbine.org), is the CEO and founder of Strategic Power Systems Inc. GTA is a membership organization established in 1995 with a goal of communicating the message that gas turbines are, and will continue to be, a vital component of power generation in the US.*

Gas turbines now produce approximately one-third of our nation's electricity. They are a cornerstone energy-conversion technology, providing electricity and heat for industries and communities. Today's dynamic, innovative, and competitive energy market depends on clean and efficient gas-turbine products coupled with growing renewable generation capabilities.

Progress with centerline issues; non-drive-train topics dominate discussion

Now in its second year, the 7HA Users Group Conference fosters an open and transparent dialogue among users and the OEM on all aspects of the turbine, so that technical issues can be resolved and best practices shared. Because the 7HA fleet is relatively young, the user group's steering committee has structured the event to drive strong collaboration with the OEM. For example, this year's meeting, held in Greenville, SC, August 26 – 28, included tours of GE's facilities and a social event for informal user/OEM interaction.

The first day is an open, user-only forum among the fleet leaders and others operating units, as well as users in the installation and commissioning phases. Newer users learn from more-experienced HA site representatives.

The agenda for the second day, GE Day, is developed by the steering committee and GE, and covers technical issues, root-cause investigations, solutions for resolving open issues, updates on HA fleet statistics, operating modes, and field performance.

The 7HA community also hosts quarterly webinars to share updates throughout the year.

The steering committee was especially gratified by the overall growth in attendance and greater international participation as new 7HA user sites are added throughout the world. Present at the conference were representatives from five 1 × 1 combined cycles (CC), six 2 × 1 CCs, two 3 × 1 CCs (both outside the US), and one simple-cycle installation representing the first facility with hot selective catalytic reduction. The simple-cycle unit is currently the only one of its type worldwide.

The 60-Hz fleet leader had 17,217 total fired hours at the time of the conference, the 50-Hz leader 20,000+, as well as 340 factored starts. Although the latter site reported numerous trips, it was not possible to distinguish between customer-driven trips and machine-related ones.

GE reported the second day that it had secured orders for 96 HA units, 59 had been shipped, 40+ commissioned, and 39 had achieved commercial operation. By the time of this writing, the order number had grown to 100.

Although forums such as this focus on resolving issues, it is important to remember that the HA machine is breaking records for performance in terms of start times, turndown, output, efficiency, ramp rates, and emissions.

Progress abounds. For reference and context, a review of last year's report on the inaugural 7HA Users Group conference (CCJ, 3Q/2018, p 24) is necessary, especially around four issues: first-stage bucket (S1B), axial fuel staging (AFS), train vibration, and control hardware and software—especially thermocouples.

Users at this year's conference added only one significant failure event involving the generator (and a lengthy outage), although it should be noted this is not drive-train related.

Fortunately, based on the 2019 presentations, the AFS failure event appears to be specific to "cold-fuel/high-starts" CC units and simple-cycle machines (which likely would be in peaking service with high starts), of which there are only a few; the S1B issue appears to be under control, at the time of this writing; and a new thermocouple design, being validated at one user site, seems to be working out, based on initial reports.

As shown below, hardware and control issues persist but these are hardly of the same pedigree because it's the drive-train components which represent the most advanced technology.

Given historical patterns in commercializing advanced gas-turbine technology, this is, actually, good news. Fleet leaders have a year's worth of additional factored fired hours (FFH) and starts (FFS) and more machines have been commissioned.

But there's no resting on laurels yet. One nagging conclusion from the "GE Day" portion of the conference (see companion article): The excessive start-to-start vibration issue, which clearly contributes to other O&M issues, is still proceeding towards a thorough root-cause analysis (RCA).

GE experts have identified a primary factor and corrective action for excessive and inconsistent start-to-start vibration, but are still investigating secondary factors. The good news is that when the vibration issue is resolved, other issues may be correspondingly eliminated or reduced in severity.

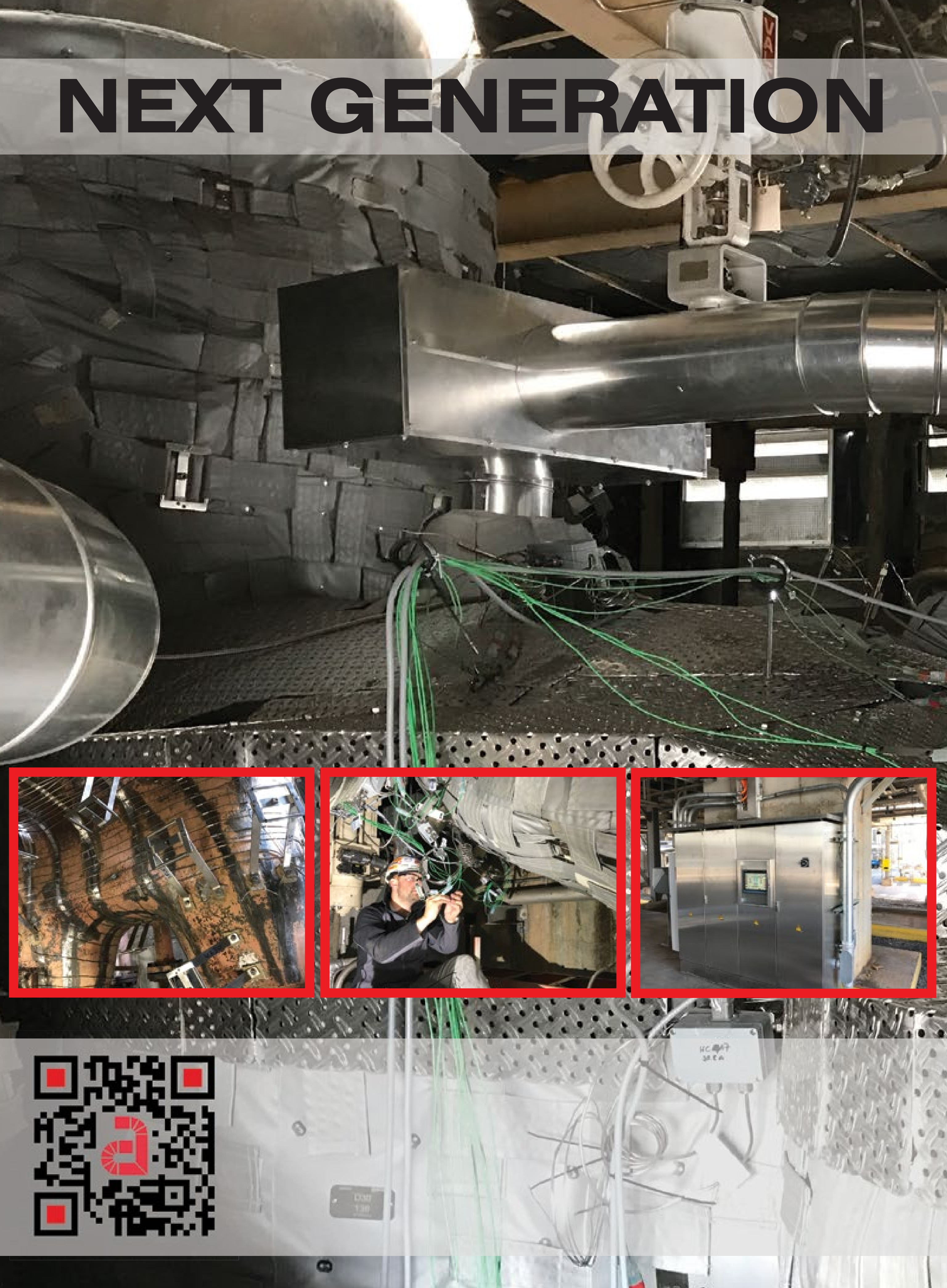
Users also have observed "distress" at the trailing edge of the first-stage nozzle (S1N), although no "events" have been associated with it.

Several issues with non-drive-train components appear rooted in process/organizational gaps among GE, its sub-vendors, and the EPC, though that gives users little comfort. They just want the responsible party to get them back online as quickly as possible. Another broad theme from the presented material: Many other technical issues are lacking satisfactory RCA-based explanations.

Other sub-systems, most notably exhaust assemblies and critical valves, are exhibiting technical issues common to multiple users. Keep in mind that non-drive-type issues are common to, and consistent with, most other advanced gas-turbine facilities since the beginning of the "boom period" in the 1990s.

S1B status. Only one site represented at the conference was still operating with the original S1Bs, which the OEM restricted to 6500 FFH; all others have the Gen II S1B replacing the original buckets, or units shipped with the new ones. By contrast, in

NEXT GENERATION



7HA, insulated by ARNOLD Group, is ready to ship from the shop to the owner/operator

one 7HA unit, the new buckets have exhibited "no issues during operation," and will be thoroughly inspected this month after around 6700 FFH. These airfoils will be removed from service and tested; the user community is watching this development closely.

Explanations from GE for the active cracks resulting from the internal oxidation at the shank level "are varied," according to users.

Start-to-start vibrations. S1B failures aside, the start-to-start train vibration issues may be more insidious. First, they contribute, even if not directly correlated, to less dramatic but still nagging problems which cause unit trips. Second, the OEM has not offered a full RCA explanation. A new load coupling is being tested and validated at a user site to help correct the vibration issue, but no word yet on results. Third, users report there is little consistency in the vibration measurement variations from start to start.

Counter-balancing this reporting, some users noted privately that units experiencing relatively normal vibration levels still exhibit many of the associated issues.

One 9HA user said "the explanation is not yet satisfactory" and the first fix, replacing an inlet plenum cone with a stiffer one, showed a net improvement but still "isn't good enough." Vibration is below the alarm point but still significantly higher than expected. The OEM is now "acting on the rotor mass balance to modify rotor excitations at this site."

Several 7HA users listed some of the secondary consequences of machine vibration: loose wiring in electrical and control cabinets, structural cracks, cut wiring where wiring makes sharp turns against aluminum housing, trips on compressor bypass valves, failures with exhaust thermocouples, fire-protection water-mist nozzles detaching, and generator fixator torque issues.

One user reported that the OEM would soon be coming out with a GEK document addressing vibration through modifications to foundations.

Generator failure. The 2 × 1 CC site that experienced the generator failure on one unit after 8500+ FFH and 105 starts reported that an arc flash occurred at the collector prior to the failure, and endwinding dusting and loose ties observed at this time were addressed. A MAGIC (miniature air gap inspection crawler) inspection had been conducted before the failure. The unit that failed exhibited the least amount of endwinding dust.

There were no leading indicators or alarms prior to the failure, and other users noted privately that the failure may be specific to this model number and/or site.

The site rep asked rhetorically, was it mis-operation, improper reassembly, the fact that the OEM does not do a "bump" test" (frequency response testing on the stator endwindings), out-of-synch phase, or the significantly reduced number of collector brushes recommended by the OEM? The site is still proceeding through the RCA with the OEM, which reportedly had validated the auto-sync process during commissioning.

The generator in question is a 2016-vintage "leads up" with the three phases coming off the top of the unit.

AFS, combustor hardware. GE issued a Technical Information Letter (TIL) on the AFS indicating that cold-fuel/high-start machines are most affected. Cold fuel in this case refers to 80F-120F, although the term can refer to temperatures less than 300F. Two machines at the same site experienced forced outages caused by failure of the AFS fuel delivery pipes.

Modifications for the one site experiencing the most severe AFS failure included a change to a welded design for attaching fuel tubes to the "unibody." The TIL recommends fuel-gas leak detection and haz-gas detectors to indicate an imminent failure situation. One plant is validating the TIL recommendations.

A 9HA site reported issues with fuel nozzles, effusion plate, combustor liner, and the transition piece. The effusion plate cap parts "have been modified because of cracks and liberated pins" and the new design has shown "pretty satisfactory experience" after one year of operation. Cracks have been observed on liners but this was thought to be less of a forced-outage risk.

More than one site has observed spallation on the combustor unibody component. A user reported observing cracks in the transition pieces on the cold side, and a crack at the frame weld on the cold side, of the compressor outlet. This was labeled by the user as "a design flaw, aggravated by abnormal vibration and combustion dynamics." The user commented about now suspecting the durability of the combustor generally.

Initial, final control elements.

GE Day: Some permanent solutions in pl

During the 7HA Users Group Conference second day, "GE Day," high-level managers kicked off the event by proclaiming "significant progress in [corporate] restructuring," HA technology investment is up in 2019, and "we are moving from financial metrics to operating metrics, and users should feel this going forward."

GE officials shared progress on several issues discussed in the first HA User Conference last year to an attendee group that has swelled by 50%.

As the fleet matures into its fifth year, $2-billion has been invested in the HA technology to date, 96 units had been ordered at the time of the conference (total now stands at 100), 59 have been shipped, 40+ have been commissioned, and 39 are in service—10 more than at the time of last year's conference—with more than 415,000 hours of commercial operation.

All but one or two HA plants are

Many users are experiencing nagging issues with digital valve positioners (DVP), especially on fuel-gas valves, but also on other critical valves and inlet guide vanes. One user attributed six unit trips to the DVP issue. Several attendees clearly noted that high start-to-start vibrations contribute to the problem. They also noted that each valve has its own configuration.

What appears to be occurring at some sites is that the vibration causes problems with signals and connections, the unit trips, and then site personnel have difficulty performing the online diagnostics. OEM responses to site inquiries involve long lead times, mostly because this is sub-supplied equipment. For one thing, hardware and software reportedly can't be obtained directly from the hardware supplier, which is responsible for programming of the software while GE is responsible for the valve and its performance, which is proprietary (though a common practice among turbine OEMs).

Another issue across several sites involves temperature control of the fuel-gas DVPs, which are sensitive to extraneous sources of heat. One 9HA site provided details of a forced outage caused by multiple electric gas-control-valve (eGCV) failures. Subsequent analysis upon disassembly showed a powdered metal deposit at the gap between the valve spring seat and shaft resolver link (which provides valve position feedback to the actuator drive), heavy wear of the anti-rotating bearing slot, and coupling-shaft damage (a shaft screw loosened and dropped out).

Oddly, similar symptoms have been observed with other eGCVs at the site, but no symptoms have been observed at this owner/operator's other sites with similar valves. After the presentation, a user noted from the audience that they had replaced a GCV because motor amps had spiked up to 30-40 amps and the motor was overheating. Operators noted a gas-valve position deviation alarm, which was supposed to fail the valve closed, but instead was observed to be 29% open at shutdown.

An RCA on the matter continues but the cause of the wear is still not known. DVP failures were noted in last year's conference report.

The story with GT exhaust thermocouples (TC), also a source of copious discussion last year, is a bit cheerier. One user reported that exhaust TCs broke 11 times in 16 months. Two other sites are now testing the OEM's upgraded TCs; one noted it has 12 of the new ones installed and they "have been successful so far."

Exhaust sub-systems. Several users reported "excessive leakage" at the hot-gas expansion joint between the exhaust diffuser and the casing. One site implemented the OEM's new design in October 2018, which was then "corrected" in May 2019. "Long-term reliability needs to be confirmed," he said.

Another user reported on exhaust-casing insulation defects observed after a full-speed/no-load (FSNL) test. Multiple insulation panel cover plates and washers detached, damaging several of the plates.

Gas leakage in this area also is causing the malfunction of nearby equipment—such as fieldbus cables, cooling-fan cables, and haz-gas detectors.

Myriad other issues. Users brought up a laundry list of control-system issues—including the integrity of flame detectors and combustion dynamics monitoring probes; problems with fieldbus connectors, device ID tags, and communications; and having to add and troubleshoot software logic. Likewise, a punch list of issues were raised with ancillary components like cranes, seals, DC system ratings, igniters and cables, fuel-gas heater, static-starter controllers, a variety of valves, complex insulation arrangements, and several more.

However, while there were detailed discussions around some of these topics, they tend to be one-offs and/or common to installation and commissioning experiences generally.

People and process issues. One reason users groups are invaluable is the collective leverage they provide for users to work more knowledgeably with their suppliers. They also are good reminders that not all root causes are technical in nature.

A user nearing the commissioning of new HA machines reviewed what was discovered during their oversight activities. This owner/operator hired third-party quality inspectors to review things onsite.

One overarching concern was that the OEM has what's known as "free release" with its sub-vendors. As an example of a consequence, "we won't have a true history of where our compressor blades come from." There was general agreement that the OEM needs to improve sub-supplier quality assurance/quality control.

At least one user present intimated that the OEM's quality processes may not be good enough, and that others should distinguish between parts for which GE does receive complete quality support documentation and those for which the OEM does not.

Seams issues between EPC and OEM also need attention and require diligence and a high level of owner/operator engagement.

One example involves critical valves; a user insisted that "you have to force GE to deliver quality." Another user outside the US mentioned "many issues with other auxiliaries," and that working with GE was "difficult." A third mentioned that "GE does a terrible job with report writing." A fourth noted that "communications between the OEM and EPC are lacking." Finally, a fifth exclaimed that, when it comes to work under warranty, "the GE people for the non-GT part of the plant are inadequate."

Get engaged—early and often. A variant of the old slogan about voting in Chicago applies here. Prospective users and those with units coming online or on order are urged to participate in the user-group activities as early as possible and begin developing your own comprehensive checklists for repeated review among owner/operator staff, OEM, EPC, and subsystem suppliers. As one user said, "it's good to learn from experience, but better to learn from others' experiences." CCJ

ace, other root-cause analyses on-going

operating baseload. For seasoned power-industry veterans whose notion of "baseload" may be different, here it is defined as a higher than 40 ratio of factored fired hours (FFH) to factored fired starts (FFS). In a hint of performance to come, GE believes it can push maximum ramp rates from 60 MW/min to 90.

Approximately 80% of the first-stage-bucket (S1B) retrofit outages have been completed. FieldCore, GE's field service organization, is now 12,000 strong—including 6000 craft, 3000 gas/steam engineers, and 2000 with other skills.

Users questioned executives about the internal measurements GE uses to ensure how well FieldCore team members are performing, and quality of final reports—a topic of discussion during the user-day sessions.

After the intro talks, specialists got down to the business of addressing specific technical issues, covered here largely in the order which they were presented. Keep in mind that, in some cases, the issues mentioned are specific to a certain site or a small group of users, and not fleet-level issues. Users are encouraged to check relevant technical information letters (TILs) and contact their GE reps concerning their units.

Rotors. A TIL was released on rotor-life calculation. Main points on rotor life were that maintenance factors provide a process to account for operational variation and are critical for optimized unit operations. Compressor discharge temperature and high ambient temperatures are the important parameters for FFH, while forced cooling during shutdown impacts FFS. Inlet air chilling has significant benefits in rotor life, the presenter noted.

Owner/operators were urged to "consider what it costs on the rotor side to deliver on ISO grid contractual obligations." A full rotor inspection is required at published rotor life limits to "address accumulated damage." TILs describe more than one life-limiting factor.

Referencing the release of the rotor life TIL, one user asked if any defects have been found on the rotors and the response was "none associated with the rotors." The latest units feature "better materials in the middle of the rotor and different cooling strategies," although the presenter stressed these improvements have nothing to do with the start-to-start vibration issues (see below). GE clarified this exchange, noting that this TIL was a convenient way to publish rotor maintenance factors, and does not suggest an issue.

Hexavalent chrome. The OEM issued Product Service Safety Bulletin (PSSB) 20180709A to inform users of potential contamination (yellow residue) that has been discovered on some parts during outages. This issue was not brought up in the user sessions, but owner/operators should "expect to find this material." It originates in anti-seize compounds and forms as a reaction between calcium and chromium compounds at elevated temperature. The PSSB provides guidelines for EHS practices, including respiratory protocols and the handling and removal of this material.

Combustors. TILs have been issued for combustor hardware. GE reported that two units experienced outages because of failures in fuel delivery pipes. To address fuel-line leaks, users are encouraged to implement the axial fuel staging (AFS) leak-detection algorithm outlined in TIL 2194, and install the new bellows and flow-sleeve modifications. Hot fuel units, defined as 300F or higher, are not affected by this issue.

The outer fuel nozzle pre-orifice leak is considered a low-risk event—that is, it presents no downstream effects. No immediate action is required but users should build in time during a planned outage for weld repairs and plan to ship spare end covers to the GE shop for the weld repair. There is a NO_x level impact of less than 1 ppm from this issue, noted the specialist

The RCA was described as "data shifts in combustion signals," and "loose outer fuel-nozzle pre-orifice plugs allowing more fuel flow than anticipated." Fuel switching may have caused this problem originally.

One user asked if there was a check to determine whether spare end covers had to be shipped back, and the response was to have the site's GE rep evaluate them.

The center fuel-nozzle leak in 9HA.01 units can potentially lead to "base burning and damage to combustor and hot-gas-path hardware." The risk is elevated in early operation. Smaller-diameter Omega seals combined with non-conforming end covers is the source of the issue, and seal changes are the recommended solution.

In 7HAs, minor cracks were discovered at the tips of center fuel nozzles at several sites. GE believes the cracks are benign and will continue to monitor them.

Hot gas path. Oxidation distress at the inner and outer sidewalls of the first-stage nozzle (S1N) seals is considered an unplanned outage risk, and a TIL has been issued to address it. The solution is to install new slotted seals at earliest opportunity and retune the unit to minimize the impact on NO_x emissions, which can be as high as 3-6 ppm.

Missing material from S1N trailing-edge distress is caused by flaking in the compressor discharge casing and the cold side of the combustion components. Debris flows downstream and blocks impingement cooling to the trailing edge of the S1N. The RCA is still being worked through but GE recommends increasing borescope inspection scope during outages to include the cold side of combustion components.

Rubbing between the S1B and first-stage shroud (S1S) observed on some shroud segments, the subject of TIL 2141, can be addressed by changing 10 non-step shrouds to step shrouds. Concerns with fourth-stage shrouds for a small subset of specific units can be addressed through a configuration evaluation and validation tests.

Accessories. TILs 2149, 2125, 2144, 2110, and 2077 address accessories and controls.

The width of the exhaust aeroplate spans too far over the exhaust joint, specialists said, allowing excitation to force the leading edge to lift upwards and liberate. Recommendations are included in TIL 2149.

Exhaust leakage, a hot topic in the user portion of the conference, is caused by improper installation of the rope seal and the clamping bar inadequately compressing the rope seal. Fixing it requires two to three days per unit. If elevated temperatures are observed, users can also record axial and radial alignment of the diffuser, and install an insulation barrier to protect the hazardous gas panel and exhaust blower motor. For the 9HA exhaust expansion joint, improvements have been made to the flex-seal design.

Regarding exhaust thermocouples (TC), the hybrid TCs, considered an interim step, mitigate connector head and cable failures (but not other types of failures). The Gen II design, constructed of stainless steel instead of Inconel, includes a radiation shield. Units shipped in the last six months still have the original TCs, GE noted.

Oxidation from the 28 in. point to the tip of the wheel space TC is caused by misapplication of over-sheath material, and the TC is unable to withstand the temperatures to which they are exposed. A new design, based on Inconel 625 material for the over-sheath, is being made available "with significantly less lead time than the exhaust TCs." Field validation is in progress and a TIL will be released soon.

A final presenter under auxiliaries stressed the importance of inlet air filtration as well as meeting the inlet-filter-house leak-detection specification, GEK 111330.

Control systems. To address reported loss-of-HMI events, GE noted that users were often unaware of redundancy loss when one of three servers becomes "unhealthy." However, the Mark VIe is still protecting the plant. Users are urged to check vSAN disk space consumption, storage drivers version, and the Dell storage controller; review newly added suggested maintenance schedule and troubleshooting documented in GEH6851 rev B; and perform periodic manual system health checks.

GE indicated it was moving to Dell Wyse 5070 for Windows and away from Dell Wyse 7020 for Linux.

Issues with fieldbus and the digital valve positioners (DVP) were raised by one attendee. GE said it was difficult to troubleshoot fieldbus and recommended a site's IT techs undergo training in Houston. In the meantime, GE is working with Woodward to improve troubleshooting.

Train vibrations. Start-to-start vibrations continue to be a focus for GE and its user community. GE specialists have identified a root cause described by the "mass shift/system resonance" effect. Excessive and variable movement may be associated with changing circumferential position of the compressor blades on Stages 4-14, with system level resonances amplifying the effect.

The current "Phase I" corrective action is a redesigned, solid, heavier load coupling, around 10% heavier than the original. One has been installed and is currently being validated, with "positive response noted on bearing vibration," according to GE.

With this primary root cause completed and corrective action identified, GE specialists are turning their attention to secondary factors driving the vibration issues. Unique thermal transients are induced during cold, warm, and hot starts, turndown, and part-load operation. Turbine exhaust casing and supports "exhibit visible contribution to movement." Analysis is in process to determine if future corrective action could be necessary.

Transient vibration limits have been instituted: alarm at 0.65 in./sec, runback at 1.0 in./sec, and trip at 1.25 in./sec.

GEK 63383 Rev G addresses potential modifications to the foundation to address vibration. This is considered an EPC issue. GE is working with customers on timing for when new couplings will be available for each site. In the meantime, GE continues to address the vibration issue with balance shots. This issue is not preventing customers from operating their units, stressed the OEM.

Punch list items. This year, based on requests from several participants with units currently being installed or commissioned, a GE commissioning expert covered best practices, lessons learned, and a punch list of topics that users should focus on. As most of these are site-specific; fall within the gray area of shared responsibility among user, OEM, and EPC; represent standard "no brainer" items for a successful commissioning; and/or are complaints common to most if not all facilities, they are not listed here.

Capping off the day was a comprehensive tour of GE's Greenville facility, when users got a first-hand look at a good portion of that $2-billion investment in the HA technology, and take-home bottle openers manufactured with GE's latest additive (3-D printing) production processes. CCJ

WESTERN TURBINE Users

LONG BEACH
March 2020

30th Annual Conference and Expo

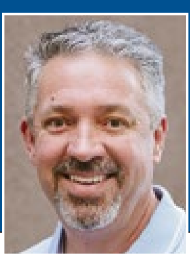
President's welcome

On behalf of the board of directors, officers, breakout-session chairs, and support staff, welcome to the 30th anniversary of the Western Turbine Users conference.

In the late 1980s, a handful of brave investors purchased some early model LM2500 and LM5000 gas turbines for service in California. Their operations and maintenance personnel quickly realized the common issues and advantages of the LM engine, gathering in small groups to compare experiences and provide solutions to present to the OEM.

Western Turbine Users was born. Incorporating in 1990, the small group of plant representatives grew to 50, doubled to 100, then 500, and now is over 1000 members strong. Be proud to associate with our organization's legacy, rich history, and worldwide influence as you collaborate with other industry professionals. Little did our predecessors imagine their forethought would result in something as meaningful, relevant, and influential as WTUI.

Join me in celebrating 30 years of the evolving General Electric aeroderivative gas turbine industry. Users like you have challenged equipment suppliers to improve their products, as we demand new uses and extend the lives of our gas turbines and all support equipment. As a WTUI member, your conference contribution is the root to our success. You are a vital element of the volunteer organization as we move forward.



Chuck Casey
President, WTUI
Utility Generation Manager
Riverside Public Utilities

Highlights

Sunday, March 29

7:30	Golf tournament
10:00	Bowling tournament
2:00	Conference registration opens
3:30	Conference familiarization session
5:30	Welcome reception, exhibit hall opens

Axford

Monday, March 30

8:00	President Chuck Casey's welcome, program updates, introductions, treasurer's report
9:30	Presentations by the ASPs: ANZGT, IHI, MTU, TCT
10:45	Mark Axford's worldwide gas-turbine business update
12:00	Lunch/exhibits
2:30	Technical meetings for LM2500, LM5000, LM6000, LMS100
6:30	Monday night reception

Tuesday, March 31

8:00	Technical meetings (users only) for LM2500, LM5000, LM6000, LMS100
12:00	Lunch/exhibits
2:30	Special technical presentations on best practices, HRSGs, controls, water technology, varnish, vibration, NDE, air filtration, and insurance

Wednesday, April 1

8:00	Technical meetings for LM2500, LM5000, LM6000, LMS100
10:45	GE new products update
12:00	Adjourn

Details, session locations at www.wtui.com

What's inside:

Western Turbine Users Inc, the world's largest independent organization of gas-turbine owner/operators, celebrates 30 years of service to the industry at its 2020 Conference and Expo, March 29 – April 1, in Long Beach, Calif (visit www.wtui.com). If you're involved in the specification, installation, management, operation, and/or maintenance of one or more aeroderivative gas turbines manufactured by General Electric Co (LM2500, LM5000, LM6000, and LMS100) plan to attend.

You will not be disappointed; this meeting has it all, including the following:

- Presentations by the OEM and its authorized service providers (ASPs) on shop findings and solutions.
- Experience with upgrades to boost output, availability, and/or reliability, and to reduce emissions.
- Technical presentations by consultants and third-party parts and services providers invited by the organization's leadership team.
- Open discussions in user-only sessions that provide insights you'll find valuable for improving the performance of your engines.
- Access to the industry's top technical talent on the exhibit-hall floor for one-on-one aero-engine problem-solving—free consulting!

As you read through this report, keep in mind that it has a three-fold purpose:

- Present the agenda for the 2020 meeting to pique your interest.
- Update the organization's 25-year historical profile published in 2015.
- Review the highlights of the 2019 conference, which speak to WTUI's value to owner/operators.

WTUI

2020 Conference & Expo

March 29 – April 1
Long Beach (Calif) Convention Center

www.wtui.com

2020 program

The format for Western Turbine meetings has been the same for at least a couple of decades, save a few tweaks over the years. One reason: It works! The proof: Attendance has grown from 130 in 1991, the first meeting following incorporation of the organization, to more than 1000 today. In fact, registration at the last five meetings (2015-2019) has averaged more than 1050 attendees. With relatively few exceptions, anyone who is anyone in the LM (for land and marine) aero community participates.

Another reason for the loyal following: The organization has never strayed from its original mission—to provide members a forum for the exchange of technical O&M information and experience to improve the reliability and economic viability of LM series powerplants. Thus, there is a logical transition of knowledge gained from one meeting to the next.

There have been suggestions over the years to expand conference coverage to aeros made by others—Siemens and Mitsubishi (Pratt & Whitney), for example. But the prevailing view has been that would dilute the content valued by the attendee base. Likewise, there have been suggestions to expand the program from its 2.5-day format (plus Sunday), but that was not considered productive.

Sunday, March 29

Two social events start the day, allowing early arrivers to catch up with vet-

Special Events

Sunday

Golf. The Skylinks at Long Beach is the premier course in the area, with a demanding slope rating of 130. Designed by award-winning architect Cal Olson in 2004, it is said to challenge all levels of golfers. The championship links-style course extends 6909 yards and features narrow, rolling Bermuda fairways, over 70 bunkers, and well-guarded bentgrass and poa annua greens.

Format for the tournament will be a four-person (sometimes three or two persons), 18-hole shotgun scramble. You must pre-register for golf at www.wtui.com; fee is $100 per player.

Buses depart the Hyatt Regency Long Beach lobby entrance at 6:00 a.m. and the Renaissance Long Beach at 6:15.

Bowling. The WTUI tournament for the first 50 pre-registered bowlers takes place at Cal Bowl, located about 20 minutes from the Long Beach Convention Center. The facility is equipped with 68 state-of-the-art lanes. Registration is at www.wtui.com; fee is $30, including shoes and refreshments.

Welcome reception. Doors to the Convention Center Exhibit Hall open at 5:30, allowing all registered conference attendees and spouses/guests their first look at products and services offered by the more than 150 sponsoring exhibitors. Refreshment stations are located throughout the exhibit hall. Doors close at 8:30.

Monday

Spouse tour of the legendary cruise ship *Queen Mary* runs from 10:00 a.m. to 3:00, and includes lunch. Exhibits throughout the vessel chart the ship's history from its launch as the most luxurious and technologically advanced ocean liner of its time, to her duty as a troop ship during WWII, and through the golden years of the 1950s.

Participation is limited to the first 55 pre-registered spouses/guests (sign up at www.wtui.com). Fee of $75 includes the tour and luncheon and bus transportation from the Hyatt Regency Long Beach lobby entrance at 9:30.

Women in power, a special session from 1:30 p.m. to 2:30 in Promenade 102A, will be chaired by JoAnn Haynes of CleanAir Engineering.

Monday night reception, from 6:30 p.m. to 9:30, in the Pacific Ballroom (adjacent to the Convention Center), features entertainment by the Spazmatics, a well-known chain band that plays cover songs from the 1980s. Sure to be a fun evening. Admission is restricted to conference attendees and registered guest/spouses 21 years and older; name badges or wristbands are required.

Tuesday

Recognition awards for service to WTUI and the industry will be presented at the luncheon, between 1:00 p.m. and 2:00.


We are your
engine experts
MTU
Power

Technical Program

As of Dec 31, 2019

Registration: Convention Center Promenade Lobby
Exhibition: Convention Center Exhibit Hall
Luncheons: Convention Center Exhibit Hall

LM2500 Breakout Meetings: Promenade 101
Chair: Garry Grimwade, Riverside Public Utilities

LM5000 Breakout Meetings: Promenade 102A
Chair: Perry Leslie, Yuba City Cogeneration Plant

LM6000 Breakout Meetings: Promenade 103
Chair: Dave Fink, Southwest Generation

LMS100 Breakout Meetings: Promenade 102B/C
Chair: Steve Worthington, Arizona Public Service Co

Sunday, March 29

AFTERNOON

2:00 to 7:30 Registration
3:30 to 5:30 Welcome to WTUI/Conference Familiarization, *Promenade 102A*
All new registered attendees

EVENING

5:30 to 8:30 Exhibitor-Sponsored Welcome Reception, *Convention Center Exhibit Hall*
All registered attendees, spouses/guests

Monday, March 30

MORNING

7:00 to 4:00 Registration
7:00 to 8:00 Breakfast, *Convention Center Exhibit Hall*
All registered attendees
7:00 to 5:30 Exhibit Hall open
Must have name badge to enter
8:00 to 9:30 General Session, *Promenade 104*
All registered attendees
9:30 to 10:30 ASP Presentations, *Promenade 104*
All registered attendees
10:30 to 10:45 Break, *Convention Center Exhibit Hall*
10:45 to 11:45 Worldwide Gas-Turbine Business Update, *Promenade 104*
Mark Axford, Axford Turbine Consultants LLC
All registered attendees
11:45 to noon GE Services Presentation, *Promenade 104*
All registered attendees

AFTERNOON

Noon to 2:30 Lunch/Exhibits
Must have name badge to enter
2:30 to 5:30 Breakout Meetings: LM2500, LM5000, LM6000, LMS100
Users, ASPs, and GE only

EVENING

6:30 to 9:30 Monday Night Reception, *Pacific Ballroom (adjacent to Convention Center)*
All conference attendees and registered spouses/guests. Must have name badge/wristband and be 21 years old for entry.

Tuesday, March 31

MORNING

7:00 to 4:00 Registration
7:00 to 8:00 Breakfast, *Convention Center Exhibit Hall*
All registered attendees
7:00 to 2:30 Exhibit Hall open
Must have name badge to enter
8:00 to 9:30 Breakout Meetings: LM2500, LM5000, LM6000, LMS100
Users only
9:30 to 10:00 Break, *Convention Center Exhibit Hall*
10:00 to noon Breakout Meetings: LM2500, LM5000, LM6000, LMS100
Users, ASPs, and GE only

AFTERNOON

Noon to 2:30 Lunch/Exhibits
Must have name badge to enter
2:30 to 5:30 Special Technical Presentations
All registered attendees

2:30 to 3:30
1. Combined Cycle Journal's Best Practices, *Promenade 101*
2. Ageing HRSG Inspection and Maintenance Priorities (HRST Inc), *Promenade 103*
3. What's Going on in My Turbine Controls (Woodward Inc), *Promenade 102B/C*

3:30 to 4:30
1. Best Practices Around Equip/Chemistry (Suez Water Technologies & Solutions), *Promenade 103*
2. Varnish and Clean Oil Practices (Hy-Pro Filtration), *Promenade 102B/C*
3. Vibration 101 (Baker Hughes Co), *Promenade 101*

4:30 to 5:30
1. Using Eddy Current to Identify Defects in GT Internals (Olympus Corp), *Promenade 101*
2. Air Filtration (Nederman Co), *Promenade 102B/C*
3. How to Use Your Insurance (Zurich Insurance Group), *Promenade 103*

Wednesday, April 1

MORNING

7:00 to 8:00 Breakfast, *Convention Center Promenade Lobby*
All registered attendees
8:00 to 10:30 Breakout Meetings: LM2500, LM5000, LM6000, LMS100
Users, ASPs, and GE only
10:30 to 10:45 Break, *Convention Center Promenade Lobby*
10:45 to 11:45 GE New Products Update, *Promenade 104*
All registered attendees
11:45 to noon Wrap-up/Adjourn, *Promenade 104*
All registered attendees

Chronicling WTUI´s first 25 years of service to the industry

A history of the Western Turbine Users Inc, the world's largest independent organization for gas-turbine owner/operators was published by CCJ and distributed at the organization's 25th anniversary meeting at the Long Beach Convention Center, March 15-18, 2015. You can access this special publication by scanning the QR codes below with your smartphone or tablet.

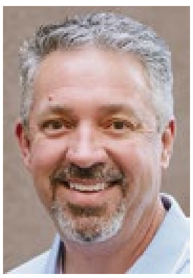
Major contributors to the commemorative publication included Wayne Kawamoto, then WTUI treasurer and plant manager of Corona Cogen; Mike Raaker, WTUI's historian and ambassador, and president of Raaker Services LLC; Sal DellaVilla, CEO of Strategic Power Systems Inc; Mark Axford, president of Axford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

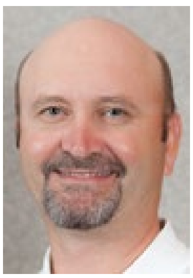
QR1 QR2 QR3 QR4 QR5

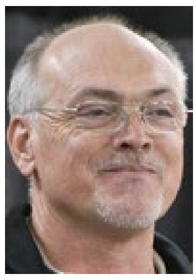
QR6 QR7 QR8 QR9 QR10

QR1: Before incorporation, *contributed by Mike Raaker*
QR2: After incorporation, *contributed by Sal DellaVilla*
QR3: Legislative drivers of GT technology, *contributed by Jason Makansi*
QR4: The LM engines, *contributed by Team GE*
QR5: A turbine salesman remembers, *contributed by Mark Axford*
QR6: WTUI's place in gas-turbine, power-industry history, *contributed by Wayne Kawamoto and Mike Raaker*
QR7: 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*

Western Turbine has had only four presidents in its history


Chuck Casey
2013 -


Jon Kimble
2008 - 2013


Jim Hinrichs
1992 - 2008


John Tunks
1990 - 1992

eran colleagues and meet first-timers. WTUI's annual golf tournament will be conducted at the Skylinks at Long Beach Golf Course beginning at 7:30 a.m., the bowling tournament at Cal Bowl starting at 10:00 (details in the Special Events sidebar). Both are fun and a good way to relax before the gavel launches the official start of the meeting on Monday morning.

Conference registration opens at 2 p.m. in the Convention Center Promenade Lobby. If this is your first Western Turbine meeting, think seriously about attending the conference familiarization session in Promenade 102A at 3:30. Participation will enable you to extract maximum value from the meeting.

Highlights of information typically shared by the session leader are presented below. In 2020 that person will be Andrew Gundershaug of Calpine Corp, who served as the LM6000 track chair for the last five years.

- WTUI history, organization, members of the leadership team, and how the conference is conducted. You'll find some of this information on pages 18, 30, and 31 of this report.
- A short course on meeting etiquette.
- Knowledge you can expect to gain from the Monday, Tuesday, and Wednesday sessions.
- Thumbnail histories of the LM2500, LM5000, LM6000, and LMS engines and their applications.
- How LM engines work.
- Key components of LM engines and their purpose.
- Engine terminology and acronyms. This is particularly important because presentations and floor discussions rely on "code"—such as HPTN for high-pressure turbine nozzle. You can find a listing of the most common acronyms on page 32. The same list will be in the pocket guide prepared for WTUI attendees by CCJ editors and available at the registration desk.

The last event on Sunday's program, and the most important, is the opening of the exhibit hall in the Convention Center at 5:30 p.m. The exhibitor-sponsored welcome reception, open to all registered attendees and spouses/guests, provides an opportunity to visit with consultants and suppliers of products and services critical to your plant's performance. The exhibit hall remains open until 8:30; it will reopen at 7 a.m. Monday and Tuesday. In sum, the exhibit hall will be open 21 hours during the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Fulfilling your LM6000 Maintenance Needs
Are you satisfied with the services available to you for your LM6000 engines? At IHI, we are all ears, listening to respond to your specific requirements flexibly and quickly with its long-time experience and proven technology developed through many years in the jet engine maintenance business. Authorized by GE since 1995 as a Level 4 Depot for LM6000, we are ready to serve your engines with the professionalism and sincerity expected of a 'takumi' and 'omotenashi.'
Takumi: a person who has vast experience and knowledge in a specific field.
Omotenashi: customer-specific hospitality catering to each customer's unique needs.
IHI doubled maintenance shop area
M40
KAIZEN
IHI Corporation
http://www.ihiincus.com/index.html
Cheyenne Service Center
3909 West 5th Street, Cheyenne WY 82007 TEL 307-638-8983 Email: atsunori_ikejiri@ihi.co.jp

conference—more than enough time to visit with any company of interest.

Find special sessions and events scheduled for Monday and Tuesday in the sidebar on page 14.

Monday, March 30

The first morning of the formal meeting is important for the perspective it provides on the world of LM engines. Presentation times and locations are in the Technical Program summary on page 16.

Mike Raaker, WTUI's ambassador and historian, will be the first to the podium with a review of the organization's accomplishments and contributions to the success of LM engines over the last three decades— this being a major anniversary year. There will be no "fake facts," to be sure, with LM pioneers Conference Executive Director Wayne Kawamoto, Consultant Brian Hulse, SPS CEO Sal DellaVilla, SJ Turbine President Steve Johnson, Consultant Mark Axford, and WTUI VP Jim Bloomquist in the audience and listening to Raaker's presentation.

WTUI President Chuck Casey will follow Raaker with housekeeping items, safety message, introduction of the leadership team, Treasurer Wayne Feragen's financial report to the membership, nominations for new directors, and his vision of the future for gas turbines.

Presentations by representatives of the Authorized Service Providers (ASPs formerly known as depots) are next. Understanding what Air New Zealand Gas Turbines, IHI, MTU, and TransCanada Turbines have in the way of experience and shop capabilities will help you make the optimal overhaul decisions going forward.

ANZGT last year discussed its maintenance and overhaul capabilities as a GE-approved Level I to IV shop for LM2500 and LM5000 engines, working out of the company's facilities at Auckland International Airport—accessible from anywhere in the world. A full range of support services—including plasma spray, welding, machining, and NDT—are available onsite. The company has two 24/7 teams of field-service technicians—one in Auckland, the other in Bakersfield, Calif—equipped to perform engine inspections, hot-section change-outs, top-case removals, and trim balancing.

IHI's GM of gas-turbine business, Yasuhiro Inoue, discussed the company's aftermarket services, powerplant engineering capabilities, and SCRs for gas-turbine applications. The SCR portion of Inoue's presentation talked about IHI's vertical reactor design based on its successful product for conventional boilers, which was said to be advantageous for sites with space restrictions. An SCR improvement example outlined the process IHI uses to boost NO_x removal efficiency, beginning with gas sampling and inspections and a work plan for customer evaluation.

Inoue closed with several slide showcasing IHI's integrated solutions, including solar power systems and battery storage and a controls package.

MTU Power's presentation focused on its shop expansion and the addition of liquid-fuel test capabilities. The company's marketing theme, "We are global and close to you," introduced attendees to MTU's various service centers in Europe, North America, South America, Africa, Asia, and Australia.

Most active of the facilities in 2018 were the Level IV shop in Berlin with 864 employees, which recorded 346 visits, and the Level II shop in Dallas with 18 employees, which recorded 182 visits. An LM2500+G4 DLE overhaul for a Texas university was one of the company's 2018 highlights.

TransCanada Turbines traditionally focuses its presentation on the company's safety record. Last year was no different. Its safety management system, anchored by OHSAS 18001 certification and more than two-score internal safety-related policies, earned TCT the silver badge in Canada's Safest Employers program in the oil and gas category. In sum, 31 companies from across Canada were honored in 13 categories.

TCT has the only shops authorized by both GE and Siemens to work on LM6000, LM2500 and LM2500+, RB211, and Avon engines. It has facilities in nine locations: Canada, US (Bakersfield, Calif, and Houston), Scotland, Khazakstan, Abu Dhabi, Singapore, and Australia. Field-service training and capabilities were also described.

GE also had some facetime with attendees during the morning session. Presenter Martin O'Neill, GM of the aero product line in the company's power services group, provided some feel-good highlights on the OEM's Gas Power segment while providing an overview of its network of global service centers.

Perhaps surprising to some attendees was the depth of GE's repowering experience, which goes beyond the LM fleets and includes the company's Frames 5 and 6, Siemens SGT600 and SGT700 engines, and Rolls-Royce Avon, Olympus, and RB211 engines

Authorized users have access to more detail on ASP and GE capabilities at www.wtui.com. Sign up today.

Enter Axford. A highlight of every Western Turbine meeting is Houston-based Consultant Mark Axford's "Worldwide Gas Turbine Business Update," including his predictions of future orders. Axford's connection with gas turbines spans more than four decades and his affiliation with WTUI goes back to well before the organization's incorporation.

As the sun set on the 1970s, Axford was selling Allison gas turbine/generator sets and compressor sets for Stewart & Stevenson, which also was a GE-authorized "packager" of nominal 20-MW LM2500-powered gensets. The company sold its first LM2500 packages in 1981 for an offshore platform and won its first US order in November 1982.

The latter package was installed in 1983 at the Hawaiian Independent Refinery Inc, where WTUI's Kawamoto, then in his 20s, had general responsibility for the multi-fuel unit. After GE bought S&S's turbine business in early 1998, Axford launched the consulting firm that bears his name. He likely is the most recognizable non-user at Western Turbine meetings.

The focus of Axford's presentations has shifted since the 25th anniversary meeting from order stats and projections to industry changes and their potential impacts on electric supply business and gas turbine O&M. Time-challenged attendees have found this format particularly valuable for keeping them current on subjects outside their normal purview. At the last two meetings, Axford provided valuable perspective on the following industry headlines, among others:

- Big layoffs in the power-generation ranks of both Siemens and GE.
- Emergence of battery storage.
- US shift to larger combined cycles and away from medium-size gensets.
- Focus of OEMs on high efficiency.
- Impact of oil prices on gas-turbine operations.
- Success of medium-speed recip-engine gensets in the 5-MW-and-above market.
- Impact on solar and wind subsidies—specifically investment tax and production tax credits—on gas-turbine sales.
- LNG exports and their positive impact on the gas-turbine market.
- Electric vehicles and their potential disruptive impacts on the automotive, oil, and electricity markets.
- Possible GE restructuring impacts on gas-turbine operations.
- Mitsubishi Hitachi's challenge to GE in the business of very large gas turbines.
- Integration of gas turbines and batteries.

- Pockets of opportunity for gas turbines in the US and worldwide.

Future business. The impacts of must-take renewables, wholesale closing of coal-fired stations, evolving nature of grid operations, etc, have made it very difficult, perhaps impossible, to predict with a high degree of confidence orders for new gas turbines. Before the 25th anniversary meeting you could pretty much "bet the farm" on Axford's predictions of new business.

Since then it has been challenging. Examples: He predicted 2016 orders for gas turbines larger than 10 MW would be down 10% (capacity basis) both in the US and worldwide compared to 2015. The actuals: US down 30%; worldwide down 14%. For 2017, Axford thought US orders would be up by 10% and worldwide down 10%. The actuals: US orders off 36%, worldwide down 28%. For 2018, he figured both the US and the world would be down by 10%. US orders were off 27%, the world off 13%.

Thus, gas-turbine orders have now dropped year over year in both the US and worldwide for three consecutive years. At last year's Western Turbine meeting Axford predicted 2019 orders would be down by 10% in both the US and worldwide. He will announce the actual figures during the general session shortly after taking the podium at about 10:45 Monday.

Axford's current format of analyzing industry events doesn't mean you don't get the stats craved by some attendees, it just means the baton for this information has been passed to his colleague Tony Brough, PE, president of Dora Partners & Company LLC, who maintains a database of the nearly 38,000 gas turbines rated 1 MW and above installed worldwide (as of Jan 1, 2018). Brough held responsible positions at GE Aeros and Rolls Royce for more than 20 years before starting Dora Partners in 2007. His insights, like Axford's, are illuminating.

At 2:30 Monday afternoon, after lunch and free time in the exhibit hall, the technical program begins in earnest with three-hour sessions dedicated to the LM6000, LM5000, LM2500, and LMS100 conducted in parallel. Discussion leaders for these sessions, respectively, are Dave Fink of Southwest Generation, Perry Leslie of Yuba City Cogeneration, Garry Grimwade of Riverside Public Utilities, and Steve Worthington of Arizona Public Service.

The meeting's premier social event, Monday Night Reception, follows at 6:30, with three hours set aside for dinner, entertainment, and time for casual networking.

Tuesday, March 31

The Breakout Sessions for each engine continue after breakfast the following morning at 8:00. For the first 90 minutes, only users are allowed into the meeting rooms. Representatives of GE and the ASPs can participate in the sessions after the break, from 10:00 to noon.

Following lunch and presentation of WTUI's recognition awards, plus the Turbine Inlet Cooling Assn's annual excellence awards for implementing inlet cooling solutions, you have time for a last spin around the exhibit hall, which closes at 2:30. Nine special hour-long technical presentations close out the afternoon with three topics presented in parallel at 2:30, 3:30, and 4:30. Details are on page 16.

Wednesday, April 1

Breakout Sessions for each engine continue, as they did Tuesday, at 8:00 after breakfast. The sessions run until the break at 10:30. GE's traditional hour-long new products update follows at 10:45. Fifteen minutes are allowed for final comments from the WTUI leadership. The meeting ends promptly at noon.

WTUI: the last five years

If you've attended Western Turbine meetings since the 25th anniversary celebration you might think there haven't been many changes since 2015. In outward appearance that's true, as noted earlier in this report: The conference remains two and a half days and the lineup of sessions and events is the same. However, what's behind the curtain is different in several respects; in sum, the changes have increased the organization's value to owner/operators.

Leadership changes are a given as officers, directors, breakout chairs, and staff complete their terms of voluntary service, retire, leave the industry, change positions in their companies, etc. The injection of new blood generally is a positive: New people bring new ideas, have experiences to share on the latest engines in the fleets served, etc.

In the last five years, Bryan Atkisson, Jermaine Woodall, Devin Chapin, Howard Hoffmann, Rick McPherson, Andrew Robertson, John Hutson, and Charles Lawless completed their terms on the board of directors, with Wayne Feragen, Al VanHart, Andrew Gundershaug, Rob Nave, Todd Kutz, Dennis Johnson, and Paul Park elected to fill those positions.

The officer corps has changed as well with Ed Jackson and John Hutson elected VPs, Jermaine Woodall replaced retiree Alvin Boyd as secretary, and Wayne Feragen took over for Wayne Kawamoto as treasurer.

Kawamoto resigned the volunteer officer position he had held since the organization's incorporation and transitioned to a new WTUI staff position, conference executive director, Jan 1, 2018. You may recall that Kawamoto retired from his day job as plant manager of Corona Cogen when that facility's power-purchase agreement expired and the plant was closed at the end of 2017.

Among the breakout chairs, John Baker resigned his chairmanship of the LM2500 group after serving in that capacity for nine years. He was replaced by the incumbent Garry Grimwade. Andrew Gundershaug, who served the LM6000 group with distinction for five years (and the LM5000 group prior to that), was replaced by Dave Fink. Steve Worthington took over the LMS100 chairman's duties from Jason King.

WTUI's first office was opened two years ago at 25201 Paseo de Alicia (Ste 215) in Laguna Hills, Calif (92653). All of the organization's records since incorporation are now resident at that location.

Best practices. At the 26th annual meeting, VP Ed Jackson announced that WTUI and CCJ would be pooling resources beginning in 2017 to expand the sharing of best practices and lessons learned among owner/operators of GE aero engines. The plant manager of Missouri River Energy Services' Exira Generating Station in Brayton, Iowa, said the organization's mission is to help members better operate and maintain their plants, and that a proactive best practices program supports this objective.

Award recipients in the first three years of the program included Equus Power, the J-Power Long Island fleet, Orange Cogen, Orange Grove Energy, Pinelawn Power, Reo Town Cogen, Shoreham Energy, Terry Bundy Generating Station, West Valley Power, Worthington Generation, Edgewood Energy, Exira, Energia del Valle de Mexico (a/k/a EVM), Channel Island Cogen, Greater Toronto Airport Cogen, Lawrence Generating, and PSEG Kearney. Most of these facilities are powered by LM6000s.

WTUI's efforts in sharing best practices and lessons learned have encouraged others in the aero community to contribute their experiences. Brian Hulse, who has been involved with aero engines for more than four decades

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and was elected to the organization's board of directors for a three-year term in 1993, has been a major contributor in this regard.

Hulse, today a consultant who has attended most Western Turbine meetings since incorporation, shared the following observation with the editors during a recent conference: Many of the problems identified by plant O&M personnel during the open discussion periods were solved years back. He thought we must still be asking some of the same questions and sharing the same experiences as our predecessors because no one took the time to write them down for posterity.

So Hulse volunteered to write a few articles for CCJ to help those in the industry with less experience avoid some of the mistakes they might otherwise make. His insights were published in 2018. You can access the following articles using the keyword search function at www.ccj-online.com:

- "Lube-oil cleanliness critical to long bearing life" (CCJ No. 56, p 16).
- "Proper O-ring storage promotes leak-tight sealing" (CCJ No. 56, p 18).
- "Building the better mouse trap" (CCJ No. 57, p 54) speaks to the importance of serving aero engines clean air at the proper temperature and with minimum directional disturbances at the compressor inlet to achieve optimal performance.
- "The importance of cleanliness" (CCJ No. 57, p 52) focuses on the need to review Material Safety Data Sheets before working with any chemicals, oils, foreign substances, etc, and the importance of good personal hygiene.

The leadership team recognized the importance of capturing the technical information disseminated at the annual meetings long ago—of course. Example: The breakout-session chairs work closely with representatives of the ASPs and OEM throughout the year to develop session notebooks identifying shop findings and presenting recommendations for damage mitigation and repair solutions. These invaluable resources, typically numbering more than 100 pages for LM2500 and LM6000 engines, are distributed to session participants.

In addition, CEO Sal DellaVilla and his team of engineers at Charlotte-based Strategic Power Systems Inc (SPS®) have actively participated in Western Turbine meetings since incorporation by taking notes during the discussion sessions for posting on the user group's website. These notes go beyond the workbooks described in the previous paragraph in that they summarize key aspects of the floor discussion.

And don't forget the ongoing coverage of WTUI presentations and discussions in the CCJ.

The bottom line: There's plenty of meaningful guidance for O&M teams at plants equipped with GE aeros in the WTUI and CCJ archives. You might want to riffle through these resources before tackling your next challenge. Follow-on steps might be calling one or more colleagues that you met at annual meetings (phone numbers were provided with your registration materials) for advice, or, in the case of LM6000s, posting a question online.

Online forum. Perhaps the most significant of the WTUI services added in the last five years is the LM6000 Forum launched by Webmaster Wayne Feragen and supported by the entire leadership team. When you don't know whom to call about a current problem and have searched through related materials posted on the organization's website to no avail, posting your question online likely will provide the guidance to get you moving in the direction of a solution.

The diversity of topics discussed online in the last year or so (bullets below) illustrates the value of an online communications "channel" for identifying colleagues with the particular expertise you can benefit from:

- Dry-ice cleaning of an HP compressor.
- Coupling replacement.
- Clutch oil-system starting reliability.
- Compressor washing.
- Exhaust stack noise mitigation.
- Crane and rigging for HSE work on LM6000PF.
- Hydraulic starter pump and motor issues.
- Rad-Rad combustor experience.
- Sub-synchronous resonance.
- Leading-edge cracking on second-stage nozzle for LM6000PD.

You can gauge the value of the information communicated over the LM6000 Forum by following the discussion below on the likely reason for a high T48 spread on an LM6000PC SAC engine.

Help requested from User 1: We experienced a high temperature spread when our engine returned from the shop following a major overhaul, which included replacement of the combustor and first-stage nozzles. The test-cell temperature spread was fine, but without steam injection and while running on borrowed fuel nozzles.

After the engine was reinstalled and run with our fuel nozzles, the spread went to 363 deg F. Changing fuel nozzles reduced the spread to 290 to 300 deg F. Thermocouples and harnesses were changed with minimal impact. A borescope inspection revealed nothing significant. We plan to pull the engine and return to the shop to inspect combustor seals and look for swirler damage. Any other items we should check closely?

Consultant (former user): Several dimensions in the combustor are in play during a repair that can affect both spreads and the emissions profile. If the combustor is pulled, check *everything* not just one or two callouts. The other assembly that could be suspect is the HP-turbine nozzle assembly. Check the nozzle throats for both correctness and balance; look at the fishmouth seals as well.

User 2: I had the same issue a few years ago. New hot section with combustors. Spread was 270 deg F and we could not keep the simple-cycle engine in emissions compliance on CO (no SCR, so tight permit). Ran well in our ASP's test cell with their nozzles—like yours. Shop also did not test on liquid fuel or with water injection, which is how our plant operates.

The G42 combustor was found out of spec; liners and cowls were clocked by a few thousandths when it was built. Might not be your issue, but it looks like you covered all the bases with the nozzles and T48 system. Unfortunately, the only way to find out would be to swap out the combustor and put the same nozzles back in.

User 3: Same issues as well on our unit; had to go back to the shop for a combustor swap.

Shop expert: What has been experienced by User 1 is rare but certainly plausible; I am aware of at least two other occurrences where the scenario described has occurred. My recommendation is to start by ensuring fuel and steam lines are clear from obstruction—a relatively low-cost procedure.

Next, I would at least do the paper exercise on that first-stage nozzle throat area. It should cost the shop nothing but a few minutes to verify the as-built records against requirements specified in the owner's manual.

If you elect to go after the combustor, I would have the shop go one step further at the same time and physically measure the A4 throat area to be sure what is stamped on the part is actually what it is. I have seen incorrectly stamped parts. Recall that A4 is the measurement of the exit throat area—essentially the gap between the trailing edges. The top shops should have that tool, which would provide a good estimate of accuracy and identify gross errors.

Finally, I would ensure all nozzles are within the expected individual range and not just the total average within limits.

Consultant (former user): Over the years I've found at least four overhauled combustors with dimensional issues. The jigging process used at repair facilities to hold the pieces together for welding is pretty complex. One little mistake is all it takes.

How the shop expert described measuring A4 is correct. But it's not uncommon to see a difference between the "calculated" A4 (adding up all the stamps) and the "actual" A4, as measured by the tool, because the stamp measurement is made with the vane assembly in a slave rig. Once it's measured with other vanes, the numbers will vary. Sometimes the aggregate variances will make a discernable difference.

Finally, keep in mind that the A4 measurement tool is supplied with a calibration block and should be calibrated frequently (every two or three uses). Reason: the inner workings of the tool are very delicate and can be disturbed easily.

Fleet population. The LM2500, LM6000, and LMS100 fleets have grown since the 25th anniversary meeting; the LM5000 fleet has fewer engines in service. Calculation of fleet size is not an exacting science, to be sure. OEMs tend to base their engine stats on shipments and consider the machines "operational." However, they may be in storage or installed but not operating. The bigger the number the better an OEM typically would feel.

By contrast, SPS, the industry's leading analytics consultancy specializing in the collection, analysis, and dissemination of O&M data for owners and operators of generating plants, focuses on engines actually in service. Note that SPS has been the industry's go-to source for O&M data on gas turbines for more than three decades. It has served WTUI members since incorporation, enabling the benchmarking of specific units against like engines as well as the fleet.

The size of the LM2500 fleet reported by GE at WTUI25 (data compiled in late 2014) was 2031 engines. Last year, SPS reported the fleet size at 2413 machines—certainly robust growth. However, keep in mind that this model serves in many markets–including power generation, gas compression, and ship propulsion–so don't get giddy about the increase.

The number of engines in the

LM6000 fleet, used primarily for electric generation, increased from 1185 (GE data) at the beginning of the five-year period to the 1229 units reported as "in service" by SPS last year. In the same period, the number of LMS100 machines increased from 51 (GE data) to 69 (SPS data).

Meanwhile, the LM5000 fleet continues to fade, primarily because engine performance lags behind that achieved by more modern machines of about the same size. The fate of Kawamoto's LM5000 at Corona Cogen likely will be suffered by others no longer serving steam hosts.

Industry records put the number of LM5000s manufactured at 102. Five years ago GE said there were 55 operating engines. By the end of 2019 that number had dropped to 30 among 19 owners worldwide, according to ANZGT, which was assigned global responsibility for the machine by the OEM.

A few weeks prior to WTUI25, GE selected Sulzer to become the exclusive licensed repair provider for the LM5000 power turbine. Repairs are done at Sulzer's Houston Service Center.

Operating metrics. One could not expect a rosy sales picture for gas turbines in the last five years given the influx and growth of renewables and the technical and policy changes influencing investments in conventional generating assets. But as DellaVilla points out in his commentary on page 3, gas turbines are a major part of the nation's "Clean Energy Future."

SPS data from its Operational Reliability Analysis Program (ORAP™) for aero peakers supplied by GE, Siemens, and Mitsubishi Hitachi Power Systems show annual service hours were off about 25% over the last five years; annual starts were down by about 20%. Reliability and availability of peaking units remained essentially constant during the period.

For baseload units, the key performance indicators—service hours, service factor, capacity factor, availability, and reliability—have been relatively constant since WTUI25, with annual starts down but service hours per start up.

Exhibit hall characterized by subtle changes. While the number of companies represented at each vendor fair since the 25th anniversary meeting has been relatively constant, hovering between about 150 to 160, a couple of dozen exhibitors in any given year had not participated in the previous show. Plus, many "regular" exhibitors revealed new products and services and/or were represented by different personnel. All good reasons to spend quality time on the carpet.

Some of the things the editors recall from their time at recent vendor fairs include the following:

- GE's launch of the LM6000PF, designed for increased performance and flexibility. MTU Aero Engines took a 13% work share as a risk- and revenue-sharing partner in the development and production of the engine.
- The emergence of Baker Hughes as an important provider of services to the LM community. Baker Hughes Co, which merged with GE Oil and Gas in 2017 to become Baker Hughes, a GE company, divested from GE in late 2019 and re-established itself as Baker Hughes Co. GE owns 38% of the new company.
- Southern California Edison, GE, and Wellhead Power Solutions partner to demonstrate the world's first hybrid battery/gas turbine at SCE's Center Peaker Facility. Retrofit of a lithium-ion battery to the existing LM6000 transforms the non-spin peaker into spinning reserve.
- ProEnergy's success as an independent aero depot—performing scheduled maintenance, emergency outages, and everything in between for owner/operators of LM6000 and LM2500 gas turbines. Its Level IV

service facility is centrally located in Sedalia, Mo.

- The launch of Victory Turbine LLC by industry veteran Rodney W Kohler (GE, Whitton Technology, Gas Turbine Efficiency, Caldwell Energy, and Danfoss Pumps) currently offering ZOK compressor cleaning products online, plus stationary and mobile water wash skids, and a wide array of auxiliary parts—including pumps, valves, actuators, flanges, adapters, and connectors.

Total booth space has increased over the years as some companies looked to enhance their visibility. Among the exhibitors occupying the equivalent of three or more standard booths last year were the following CCJ business partners: AGTSI (ad inside back cover), EthosEnergy Group (back cover), TransCanada Turbines (page 23), IHI (page 19), MTU Power (page 15), SPS (page 26), Maximum Turbine Support (page 17), and Turbine Technics (page 12).

Sponsors. A constant, and a good one, has been the continuity of support by platinum sponsors GE, IHI, ANZGT, Maximum Turbine Support, TransCanada Turbines, Umicore (Haldor Topsoe), and MTU Power. All have taken the highest level of sponsorship in each of the last five years.

Attendance also has remained relatively constant—a significant accomplishment given the business challenges facing fuel-burning generators, reductions in plant staffing, etc. Average over the last five years has been 1051, with a range of 996 to 1148.

WTUI sponsors, 2015-2019

PLATINUM

Air New Zealand Gas Turbines
GE
IHI
Maximum Turbine Support Inc
MTU Power
TransCanada Turbines
Umicore USA LLC

GOLD

AFC—Advanced Filtration Concepts
AGTSI—Aeroderivative Gas Turbine Support Inc
Airgas Specialty Products
AP+M
Caldwell Energy
Cemtek Environmental
GasTOPS Ltd
HPI LLC
Innova Global
Interlink Power Systems
Jet Aviation Specialists Inc
Kellstrom Defense Aerospace Inc
Meggitt
NAES Corp
OEM Parts Network
Puretec Industrial Water
StandardAero
STS Aviation Group
Turbine Technics Inc
Woodward Inc
Zokman Products Inc

SILVER

Advanced Turbine Support
Atco Group
Bradly Griffin LLC
Caltrol Inc
Chromalloy
Compression Source Inc
W L Gore & Associates Inc
Montrose Environmental Group
MT R&O LLC
Munters Corp
National Electric Coil
Parker Hannifin Corp
PowerPHASE LLC
Randall Environmental
Rochem Technical Services USA Ltd
SISU Energy & Environmental
Suez Water Technologies & Solutions
Turbine Inlet Cooling Assn
TVS Filters
VAW Systems
Xona Systems

Leadership Team

Western Turbine's leadership team consists of the officers, directors, breakout-session chairs, and support personnel who plan and execute the world's largest and most comprehensive technical meeting on GE aeroderivative engines for electric power production, gas compression, and ship propulsion. The thumbnail bios below glimpse the careers and accomplishments of the people in this army of volunteers who dedicate hundreds of hours of personal time annually to keep you informed on engine technology, operation, and maintenance.

A quick read will give you confidence that the material presented by owner/operators, the OEM and its authorized service providers, and independent third-party providers of products and services is important and conducive to your success. Participation in WTUI meetings will help you manage your plant in a manner that maximizes revenue, efficiency, and availability/reliability, and minimizes pollutant emissions—all while maintaining the highest degree of safety.

The entire leadership team is expected to participate in the 30th anniversary meeting in Long Beach and be available to provide guidance and direction on any technical issues that you might have. Access to this knowledge warehouse alone is worth the price of admission.

Officers

Chuck Casey, president, is utility generation manager for Riverside (Calif) Public Utilities, which serves 280 MW over 110,000 electric residents and business customers with an LM2500-powered combined cycle, four LM6000 peakers, and four GE10B1 peakers. He has 33 years of generation experience—specializing in plant construction and commissioning, and regulatory compliance.

Before joining Riverside in 2004, Chuck was a plant operator, I&E technician, plant manager, and consultant for Stewart & Stevenson, GE, and PurEnergy. He began his career as a nuclear technician on US Navy fast attack submarines.

Chuck was elected president of WTUI in 2013. During his 19 years with Western Turbine, he has been LM6000 session chair, secretary, exhibit hall manager, and a member of the board of directors.

Jim Bloomquist, VP, served as a WTUI board member before being elected one of the organization's vice presidents. He has more than 40 years of experience with Chevron and is a subject-matter expert specializing in major electrical power systems and process and gas-turbine cogeneration facilities. Jim currently leads the electrical engineering team for Chevron's California San Joaquin Valley Business Unit, an upstream oil producing company.

Bill Lewis, VP, is operations manager at a 1000-MW combined-cycle facility in western Pennsylvania. Previously, he was plant manager for a 700-MW combined cycle in the same region, and plant manager of PPL Generation LLC's Lower Mount Bethel Energy LLC. Earlier, he was responsible for PPL Generation's simple-cycle peaking gas turbines in Connecticut, Pennsylvania, and Illinois. Lewis served six years in the US Navy as a gas-turbine specialist, rising to the rank of petty officer first class before taking a shore-side job.

David Merritt, VP, is COO for Kings River Conservation District (KRCD), a California Public Agency. David directs power resources and development, Kings River flood operations and maintenance, environmental/fisheries, and grant programs. Prior to KRDC, he worked for GWF Power Systems/GWF Energy LLC, a California independent power producer, for 19 years as part of the management team overseeing nine assets. David was honorably discharged from the US Navy, having served in the aviation field. He holds a BA and Organization Leadership certification from UC Irvine.

Ed Jackson, VP, is plant manager of Missouri River Energy Services' Exira Generating Station in Brayton, Iowa. His gas-turbine experience includes Allison 501s, Solar Centaurs, LM2500s, and LM6000s. Previously he was a combined-cycle plant supervisor at Maui Electric Co and a field-service and commissioning engineer for Stewart & Stevenson. Jackson spent eight years in the US Navy as a GT systems technician (electrical).

John Hutson, VP, is plant manager of the Orange Grove Energy Center in San Diego County, operated by NAES Corp for J-Power USA. He has 26 years of power-generation experience: six in the US Navy, four in large frame units, 12 in GE aero engines, and four years in landfill-gas generation. John has managed O&M for both LM2500 and LM6000 engines. He has a BS in Nuclear Engineering Technology from Thomas Edison State College and an MBA from the University of Connecticut.

Wayne Feragen, treasurer (and board member and webmaster), is senior West Coast plant manager for Noresco, currently responsible for powerplants in Colton, Calif, and San Diego. Wayne has over 31 years of powerplant experience: six in the US Navy as a gas-turbine electronics technician first class, nine running LM2500 combined-cycle plants for Newark Pacific Paperboard and Sunlaw Energy Partners, and 16 years managing an LM6000 plant and a Fairbanks Morse reciprocating-engine combined cycle for Noresco. Wayne holds a BS in Information Systems and an Associate Degree in International Business from American Intercontinental University Los Angeles. Wayne has served as WTUI's treasurer for one year, as a board member for the last two years, and as webmaster for the last 13 years.

Jermaine Woodall, secretary, is a manager of utilities and fleet services for the Port of Long Beach. He has worked in various powerplant settings comprised of peaking units, combined cycles, and renewables (solar and bio-gas). Jermaine brings 19 years of industry experience to WTUI, gained in positions such as IC&E technician, generation supervisor at area peaker plants in Southern California, and plant manager at a major utility. He also served in the US Navy for 10 years as an aviation electrician's mate. He is an alumnus of the University of Phoenix; academic achievements include Master's Degree in Business Administration and BS in Management with a minor in electronics.

Mike Raaker, historian/ambassador. What do diapers, toilet paper, jet engines, and WTUI have in common? Mike Raaker. He started his career at Procter & Gamble assigned to install a cogeneration plant at the company's towel and tissue plant in Oxnard, Calif. The LM2500-powered facility would keep Mike busy for the next 30 years and lead to his, and wife Charlene's, participation in WTUI.

Board of Directors

Andrew Gundershaug, board member, is the general manager for Calpine Corp's plants in northern California. Previously, he held various other positions at those generating assets—including operations manager, maintenance manager, DCS technician, and IC&E tech. Andrew has been with Calpine since entering the industry in 1998 as IC&E tech at the Watsonville Cogeneration Plant, following graduation from UC Santa Cruz. He currently serves on the WTUI board and as the discussion leader for the Sunday afternoon "Welcome to WTUI/Conference Familiarization" session. Earlier he chaired the


Casey

Feragen

Bloomquist

Merritt

Jackson

Lewis

Woodall

Hutson

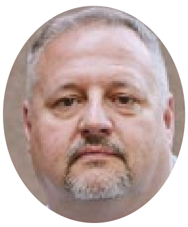
Raaker

Kutz

Johnson

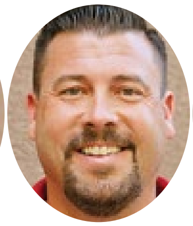
Park

Nave

Gundershaug

VanHart

Worthington

Fink

Leslie

Grimwade

Kawamoto

Raaker

LM6000 breakout session for five years and the LM5000 breakout session for three years.

Rob Nave, PE, board member, is the plant engineer for Procter & Gamble's largest manufacturing plant, located in Mehoopany, Pa. He has been responsible for major maintenance on P&G's Oxnard LM2500 and LM6000. Nave also has been involved in the maintenance, cost forecasting, and technology transfer and training on Mehoopany's W251B12, as well as the front-end engineering, funding justification, and procurement and installation of the Rolls Royce Trent 64 at that location. He has been the cogeneration leader for P&G since 2002. Following graduation from West Point, Nave spent six years in the US Army. He is a licensed professional engineer in Pennsylvania.

Alfred VanHart Jr, board member, is maintenance manager for PSEG Power LLC's peaking generating stations. He joined the company as a jet engine technician in 2004 after retiring from the USAF with 20 years of service as an aerospace propulsion master craftsman.

Al's propulsion background includes the PWTF-33, GETF-39, GECF6-50c, GEF-110, 7EA, and LM6000 PC. Starting at PSEG he was assigned to the turbine shop, rebuilding and maintaining the peaking fleet which consisted at that time of 96 FT4s, five 7EAs, and eight LM6000s.

Al was promoted to generation supervisor in 2007, plant engineer in 2010, and work control/CTE manager in 2012. In 2016 he became engineering/technical manager/PSA contract manager for the peaking division, now equipped with five 7EAs and 17 LM6000s. Promotion to maintenance manager followed.

Dennis Johnson, board member, works for DGC Operations LLC as the plant manager at Sentinel Energy Center. Previously, he was the I&C program manager overseeing all DGC-operated assets on the West Coast—nine LM6000s and Sentinel's eight LMS100s.

Earlier, Johnson worked as an IC&E technician at EG&G Defense and as a licensed industrial journeyman electrician at TOCDF—a specialized de-militarization facility. His 10 years of experience with GE aeros is the latest chapter in Johnson's 29 years of professional experience in the power industry.

Paul Park, board member, is maintenance manager at Chugach Electric Assn's Southcentral Power Plant—a 3 × 1, LM6000PF-powered combined cycle (COD 2013) in Anchorage, Alaska. Paul has managed the small projects, modifications, spare-parts inventory, craft training, and PM planning to assure SPP a long service life. Earlier, he spent nine years at Golden Valley Electric Assn in Fairbanks where he was project engineer for construction, startup, and operation of an LM6000PC-powered 1 × 1 combined cycle and of a remote 24-MW wind farm.

Todd Kutz, board member, is plant manager for Southwest Generation at the Pio Pico Energy Center in San Diego. He has more than 30 years of generation experience. Before starting and commissioning Pio Pico, Todd was a plant operator, O&M manager, and plant manager for Cogentrix and NAES Corp. He began his career as a nuclear mechanical operator on US Navy fast attack submarines, serving for over 11 years. Todd has a BA in Management and Communications from Concordia University (Wisconsin).

Wayne Feragen, board member, serves WTUI in three capacities—as treasurer, board member, and webmaster. Find his biog in the officers section immediately above.

Breakout Session Chairs

Andrew Gundershaug, conducts WTUI's conference familiarization session on Sunday afternoon. Find his biog in the board of directors section immediately above.

Garry Grimwade, LM2500, is responsible for operating and maintaining four LM6000s, four GE10s, and an LM2500-powered combined cycle for Riverside (Calif) Public Utilities. Before his involvement with land-based aero engines, Garry spent a decade working with "big iron," including a 700-MW merchant facility and two GE "H" frames.

He immigrated to the US in 1994 from the UK and joined the US Navy as an aviation machinist's mate, serving as a special-missions crewman. After leaving the service, Garry spent five years at the Pacific Gas Turbine Center (FAA Repair Station) as the lead in the rotor-balance department overhauling JT-8 and JT-8D engines.

Perry Leslie, LM5000, was plant manager of Wellhead Electric Co's Binghamton Cogeneration Plant from August 2017 until its closure in February 2018. He also has been a technician for the Yuba City Cogen-

ACRONYMS TO REMEMBER

AGB—Accessory gearbox (also called the transfer gearbox)

AVR—Automatic voltage regulator

CCM—Condition maintenance manual

CCR—Customized customer repair

CFF—Compressor front frame

COD—Commercial operating date

CPLM—Critical-parts life management

CRF—Compressor rear frame

CWC—Customer web center (GE)

DEL—Deleted part

DLE—Dry, low emissions combustor

DOD—Domestic object damage

EM—Engine manual

FFA—Front frame assembly

FOD—Foreign object damage

FPI—Fluorescent penetrant inspection

FSNL—Full speed, no load

GG—Gas generator (consists of the compressor and hot sections only)

GT—Gas turbine (consists of the gas generator pieces with the power turbine attached)

HCF—High-cycle fatigue

HGP—Hot gas path

HPC—High-pressure compressor

HPCR—High-pressure compressor rotor

HPCS—High-pressure compressor stator

HPT—High-pressure turbine

HPTN—High-pressure turbine nozzle

HPTR—High-pressure turbine rotor

IGB—Inlet gearbox

IGV—Inlet guide vane

IPT—Intermediate-pressure turbine (LMS100)

IRM—Industrial repair manual

LM—Land and marine

LCF—Low-cycle fatigue

LO—Lube oil

LPC—Low-pressure compressor (not on LM2500; just LM5000 and LM6000)

LPCR—Low-pressure compressor rotor

LPT—Low-pressure turbine

LPTR—Low-pressure turbine rotor

LPTS—Low-pressure turbine stator

NGV—Nozzle guide vane

OEM—Original equipment manufacturer

PN—Part number

PT—Power turbine (turns a generator, pump, compressor, propeller, etc)

PtAl—Platinum aluminide

RCA—Root cause analysis

RFQ—Request for quote

RPL—Replaced part

SAC—Single annular combustor

SB—Service bulletin

SL—Service letter

SUP—Superseded part

STIG—Steam-injected gas turbine

TA—Technical advisor

TAT—Turnaround time

TAN—Total acid number (lube oil)

TBC—Thermal barrier coating

TGB—Transfer gearbox (also called the accessory gearbox)

TMF—Turbine mid frame and thermal mechanical fatigue

VBV—Variable bleed valve (not on LM2500; just LM5000 and LM6000)

VIGV—Variable inlet guide vanes

VSV—Variable stator vane

eration Plant since 2004, with responsibilities including I&C, mechanical maintenance, and operations. Previously, Perry spent six years as a field service technician for GE in the Bakersfield area working on LM1600, LM2500, LM5000, and LM6000 engines. He started his gas-turbine experience with the US Navy, serving six years as a GT systems technician-electrical (GSE).

Dave Fink, LM6000, is an I&C technician and operator at Southwest Generation's Fountain Valley (Colo) facility. He is responsible for maintaining the six-unit LM6000 peaking plant, along with CEMS maintenance and reporting. Dave's power-generation career includes six years as an electrician's mate in the US Navy on a nuclear fast attack submarine. Plus, operations at Fuel Cell Energy's first utility-size fuel-cell test project in Santa Clara, Calif, and 10 years as I&C technician at Calpine Corp's Gilroy facility—at the time operating a 1 × 1, 7EA-powered combined cycle unit and three LM6000 peakers.

Earlier, Dave spent eight years with FW Marsh LLC supporting GE with the commissioning and field service of aero gas turbines, including four years as a technical writer for LM6000 product bulletins.

Steve Worthington, LMS100, is plant manager of Arizona Public Service Co's Ocotillo Power Plant in Tempe, which is equipped with the following peaking units: five LMS100s, 10 LM6000s, four W501AAs, one GE 7EA, and one GE Frame 5. Prior to joining APS seven years ago, he worked at a few eastern utilities and served honorably in the US Navy for 12 years.

Support Staff

Wayne Kawamoto, executive director, was one of the founders of the Western Turbine Users. He served on the first board of directors and was the organization's treasurer from incorporation in 1990 until Dec 31, 2017—the day he retired as plant manager of Corona Energy Partners Ltd and shuttered that facility. Wayne's retirement was short-lived; he was appointed WTUI's executive director Jan 1, 2018. He has a BS in Civil Engineering from the Univ of Hawaii and has held numerous positions in project management throughout his more than four decades of professional employment.

Wayne Feragen, webmaster, serves WTUI in three capacities—as treasurer, board member, and webmaster. Find his biog in the officers section above.

Charlene Raaker, registration coordinator, is Historian/Ambassador Mike Raaker's better half (see officers section). She has been supporting the organization for almost as long as WTUI has been in existence. Charlene's is the "voice on the other end of the line" whenever anyone calls for help.

HRSG FORUM WITH BOB ANDERSON

Exclusive conference report

By Steven C Stultz, Consulting Editor

The *HRSG Forum with Bob Anderson* contributes significantly to industry knowledge on the design, operation, and maintenance of heat-recovery steam generators with its lineup of technical presentations by subject matter experts, plus hands-on discussions among owner/operators, component and service providers, and concerned OEMs. In sum, this premier event encourages the exchange of experience and specifics that keep the industry as dynamic as its markets.

"Dynamic" continues to be a dominant description and theme of the *HRSG Forum.* The fourth annual conference in 2019 showed a growth in registrations and in percentage of equipment users, and in relevance. The agenda was informative, meaningful, and well organized.

This year's sponsors included Dekomte, Precision Iceblast, Vogt Power, Taylor Industrial Coatings, Nooter/Eriksen, Zepco, Questec Solutions, HP Valves, Environmental Alternatives, and Copes Vulcan.

A review of the 2019 event, held July 23-24, in Orlando, follows.

HRSG management

"Controlling condensation is a major HRSG team focus," explained Eugene Eagle, Duke Energy. "Our long-term goal is asset protection and reliability." The company's lead HRSG engineer addressed participants on Duke's extensive experience with HRSGs in North and South Carolina, explaining how it is preparing HRSGs for cycling.

All Duke HRSGs are triple pressure with reheat, equipped for duct firing, and originally designed for baseload and load-following. Most are within 2 × 1 F-class 500- to 800-MW combined-cycle configurations (Fig 1).

His emphasis was damage prevention: "We manage equipment. It does not manage us." In other words, the hardware is there. You just need to use and care for it properly. This focus aligned with a principal theme of every HRSG Forum: long-term system reliability.

Eagle also offered detailed market backgrounder on the increasing need

HRSG Forum expands to include daylong water workshop

The *HRSG Forum with Bob Anderson* expanded the meeting's traditional content and technical depth in 2019 by adding to its program a one-day water workshop and another daylong session in cooperation with the Electric Power Research Institute (EPRI) on HRSG and balance-of-plant technology—the fourth annual event becoming **HRSG Week,** arranged as follows:

Monday, July 22

WATER Workshop MAKE-UP WATER TREATMENT

The Makeup Water Workshop featured discussions on advancements in the treatment of makeup water, the impact of changing raw-water sources, treatment system operation, equipment troubleshooting and layup, and much more.

The agenda included the following presentation/discussion topics, among others:

- Design of water-treatment systems for combined-cycle plants.
- Best practices on makeup water and pretreatment monitoring.
- Dealing with complex makeup water challenges.
- Optimizing water use at a combined-cycle plant operating on reclaimed water.
- Best practices for reverse-osmosis systems.
- Using digital tools to optimize the operation of integrated mobile water systems.
- Layup practices for makeup treatment equipment.
- Challenges in makeup water production faced by owner/operators.
- Considerations in the treatment of municipal wastewater for power-plant use.

Tuesday/Wednesday, July 23-24

HRSG FORUM WITH BOB ANDERSON

Thursday, July 25

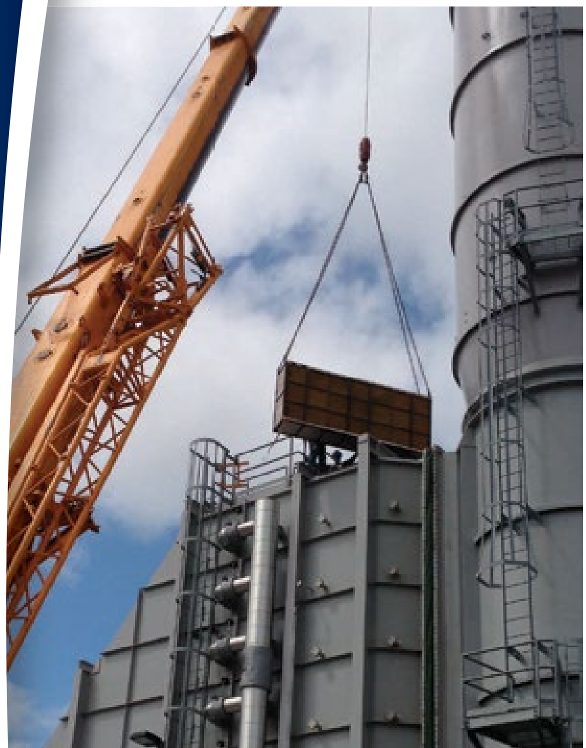
EPRI | ELECTRIC POWER RESEARCH INSTITUTE

All delegates to the *HRSG Forum with Bob Anderson* were invited to participate in EPRI's HRSG and BOP Technology Transfer Day, conducted by experts from EPRI Program 88, *Combined Cycle HRSG and Balance of Plant,* and these related areas:

- Program 64, *Boiler and Turbine Steam and Cycle Chemistry.*
- Program 65, *Steam Turbine-Generators and Auxiliary Systems.*
- Program 79, *Combined Cycle Turbomachinery.*
- Program 87, *Materials and Repair.*

HRSG Week 2020

Visit www.HRSGforum.com for the latest announcements on HRSG Week 2020, July 20-23, at the Rosen Shingle Creek, Orlando, Fla, featuring the *HRSG Forum with Bob Anderson,* a water workshop on film-forming substances, and EPRI's HRSG and BOP Technology Transfer Day.



1. Duke Energy's generation portfolio includes four duct-burner-equipped HRSGs at this 1640-MW combined-cycle complex in Citrus County, Fla

for cycling. Renewable energy continues to enjoy first-dispatch status, he said. Eagle's analysis highlighted solar power, now targeting 2500 MW at Duke Energy alone. A solar-project status report for the continental US showed 35 GW in operation and another 75 GW under construction.

His summary: "On/off cycling, low loads in spring and fall, and flexible operations will become more common" as we are forced to defer to renewables. That means Duke must learn how to operate their combined cycles in cyclic mode while dramatically reducing thermal/mechanical fatigue damage to their components and systems.

A summary chart on expected unit life brought clarity, comparing damage levels for the most common cyclic events (Fig 2). "Units designed for baseload service will need to be modified," he stated, "especially for condensate removal. Proper attemperator operation is also critical."

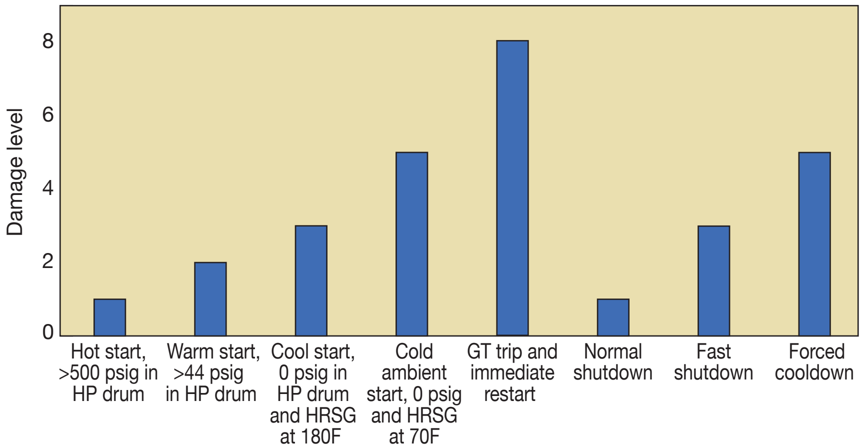
Condensation can cause thermal-transient fatigue damage, as mentioned several times during the *Forum* and in detail in "Trends in HRSG reliability, a 10-year review" published in the last issue of CCJ (No. 61, p 44).

Eagle's focus are as addressed common *Forum* participant concerns:
- Superheater and reheater drains.
- Attemperators.
- Startup and shutdown procedures.
- Heat conservation after shutdown.
- Proper chemistry practice.

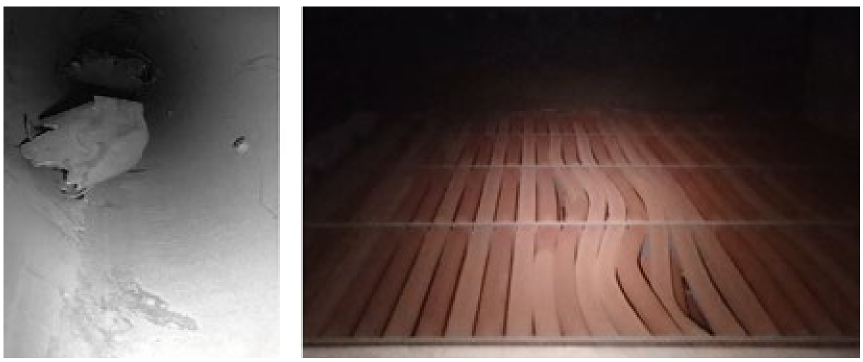
He noted that the HRSG team at Duke makes extensive use of EPRI reports and research, including both #1015464 (startup and shutdown) and #1018003 (thermal transients).

The challenges. Maintaining hot startup conditions with HP drum pressure over 500 psig is difficult for many reasons—including auxiliary steam needs, drain operations, prestart purge requirements, and leaking valves. "About six hours," he said, "is the limit" for a hot restart.

Efforts are underway at several Duke sites to install thermocouples on select high-pressure superheater (HPSH) and reheater (RH) tubes to help evaluate drain system performance, calculate potential tube damage from condensate, and provide input for component life-assessment reviews.



2. Estimated magnitude of thermal fatigue damage per cycle event based on information compiled by Duke Energy



3. Improper attemperator design and operation can cause downstream damage to piping (left) and HRSG tubes (right)

He then displayed severe attemperator damage (Fig 3) and offered some experience-based recommendations:
1. Avoid reducing HPSH/RH attemperator setpoints below 1050F. "It is better to overshoot on steam temperatures than to overspray to saturation."
2. Never place the HPSH/RH attemperator temperature control valve (TCV) into manual control or reduce temperature setpoints. This will cause overspray conditions and significant pressure-part damage.
3. Upgrade attemperator block valves to metal-seated ball valves (bi-directional seats).
4. Use a TCV martyr/block valve master arrangement.

Best practices. During startups and shutdowns, two parameters should be independently controlled: HP drum saturation temperature (HP drum pressure) and HP/hot-reheat (HRH) steam ramp rates.

For startups:
1. Procedures should be divided into hot, warm, and cold using different ramp rates and recommendations for each.

2. Use heat soaks at periods of high stress to minimize thermal fatigue damage.
3. Maintain HP steam and drum ramp rates within limits.
4. Immediately after synchronizing the GT generator, select both the megawatt output and the GT exhaust gas temperature (EGT) to the minimum values to reduce heat input to the HRSG during subsequent HRSG heat-soak stages.

For hot shutdown:

1. If GE 7FA or 9FA, always use exhaust temperature matching (ETM) for every startup and shutdown.
2. If GE 7FA or 9FA, rapid ramp through the hot zone at the low-load isotherm.
3. Steam-cool the HP superheaters within about 50 deg F of saturation.
4. After transfer to bypass valves, build HP drum pressure back to 1600-1800 psig with bypass valves. This will ensure that HP drum pressure will be above 500 psig (hot-start criterion) following a 6-hr shutdown.
5. For Siemens units, Duke is still working through reducing EGT for minimum loads.
6. Complete a final stabilization of approximately 5 min at GT minimum load before cease fire.

This led to Duke's plans for retaining heat in the system during shutdown. The company's program includes the following actions and recommendations:

- Stack dampers are being added to some units.
- For units with installed bypass dampers, close the dampers immediately after the GT has ceased firing to keep cool air off HRSG tubes during coastdown at low load (about 5 MW).
- For units with installed stack dampers, close the dampers and isolate all steam, feed, vents, drains, blowdowns, etc, to retain heat and pressure.
- Avoid topping off drums during layup; top off only just before restart.

Eagle concluded with some broad-spectrum recommendations going forward:

- Review life assessment data.
- Continue to monitor cycling evolutions and make improvements to both operational practices and control logics.
- Install HPSH and RH tube-skin thermocouples; gather data to help refine drain operations and look for thermal damage mechanisms.
- Continue with cycling improvement projects, namely:
  - Drain system upgrades.
  - Stack dampers.
  - Stack insulation.
  - GT purge credits (with low condensate generation).

Participant questions and discus-

FFS applied correctly benefits water/steam cycle: less FAC, less iron

The sixth annual meeting of the European HRSG Forum (EHF), May 14-16, 2019, Athens, Greece, was a global event with representatives from 17 countries. There were more than two-dozen presentations on the agenda, plus a workshop on water chemistry.

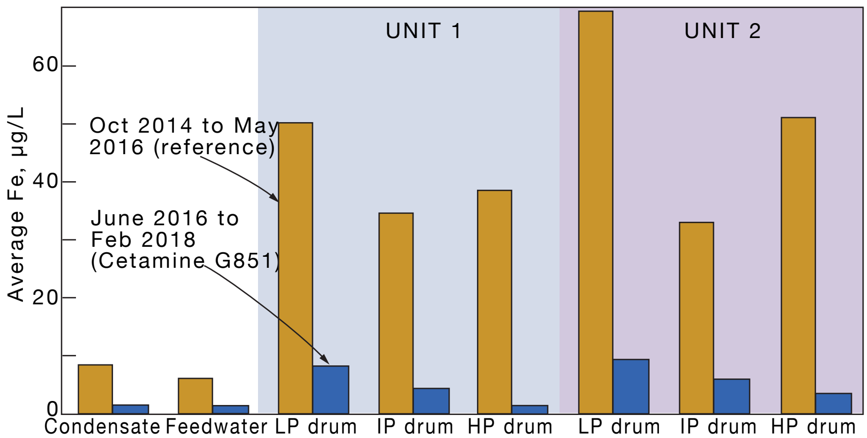
CCJ's recent report on film-forming substances (FFS, CCJ No. 60, p 12) a topic discussed at all recent HRSG conferences, stressed the importance of following the recommendations provided in Section 8 of Technical Guidance Document (TGD) 8-16, published by the International Association for the Properties of Water and Steam (IAPWS), when considering these formulations for use at your plant. Incorrect applications worldwide continue to produce severe complications and damage.

A seemingly correct application was examined in a presentation during EHF 2019 discussing experience at the Marchwood Power Station near Southampton, England. The 890-MW, 2 × 1 combined cycle was commissioned at the end of 2009.

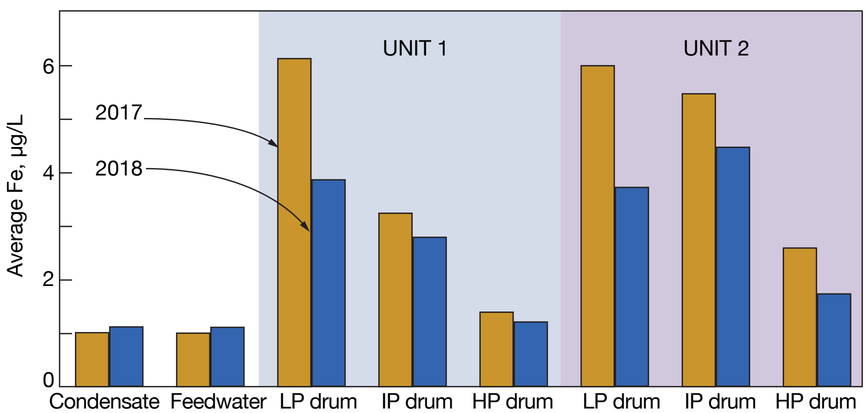
Cycle facts: Feedwater makeup for this plant is provided by a treatment system incorporating reverse osmosis and ion exchange. There is no condensate polisher and the deaerator is bypassed in normal operation. The seawater-cooled condenser is titanium-tubed.

Cycle chemistry evolution. Until 2012, system ammonia was controlled by measuring the specific conductivity of condensate and maintaining a feedwater target pH of 9.8 to 10.0. The plant experienced flow-accelerated corrosion (FAC) issues and iron oxide deposits.

Cycle chemistry was modified in 2012. Trisodium phosphate (TSP)



1. Total iron in the water/steam cycle was reduced dramatically by use of a film-forming substance



2. Use of Cetamine G851 reduced the concentration of iron in the water/steam cycle through 2017 and 2018 sions covered potential benefits of additional automation (less operator input to attemperator spray), proper insulation and thermal seals, stack damper and stack insulation benefits, the possibility of electric-blanket heating for drums, attemperator inspection intervals, header and tube repair techniques (and preferences), and the benefits of complete root-cause analysis (RCA) for damage.

	Temperature, C					
	525	550	575	600	625	650
ASME 2017 t≤75 mm	117	*107*	*88.5*	*65.0*	*45.5*	*28.9*
ASME 2017 t>75 mm	118	*103*	*80.6*	*61.6*	*45.7*	*28.9*
Revised 91 Type 1	117	*98.5*	*75.5*	*54.3*	*36.8*	*24.0*
Revised 91 Type 2	117	*102*	*78.2*	*57.6*	*39.2*	*25.1*

4. Revised allowable stress values for Grade 91 material, in megapascals (MPa), were published by ASME in July 2019

Evolving issues with CSEF steels

ASME recently reduced the allowable stress values for Grade 91 (Gr 91) steel, a topic anticipated and discussed at length in the previous *HRSG Forums*. "It was not a decision taken lightly," explained Jeff Henry of Applied Thermal Coatings—Combustion Engineering Solutions (ATC-CES), Chattanooga, Tenn. Henry currently chairs ASME's Working Group on Creep Strength-Enhanced Ferritic (CSEF) Steels (Fig 4).

When reviewing the table, keep the following points in mind:

- The distinction made between tube wall thicknesses in the 2017 Code no longer is viewed as meaningful.
- Type 2 Grade 91 material has tighter restrictions on certain residual elements—such as copper, arsenic, tin, etc—than Type 1 material. The "cleaner" Type 2 offers better rupture ductility.
- Data presented in Roman type are governed by tensile or yield strength; that in italics by creep strength.

The primary industry and *Forum* participant concern: "What does this mean for owner/operators?" There is confusion at the plant level in the US regarding the impact on future operation of plants with Gr91 pressure parts, and there is concern about the higher cost of Gr91 Type 2.

In China, explained Henry, there is "both anger and confusion" over ASME's action. In Europe, there is "a

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was added to the LP and IP drums; an air bleed to the feedwater (5 to 15 ppb O_2) was introduced in 2014. The corrosion and deposit situations improved but remained unsatisfactory to the owner/operator.

During the first half of 2016, TSP was added to the HP drums, but this practice was conducive to severe hideout and discontinued. In mid-2016, Cetamine G851 (oleyl propylenediamine, or OLDA) was added to feedwater at 1.0 to 1.5 mg/l (ppm).

The presenter reviewed monthly data for pH, phosphate, degassed acid conductivity, total iron, and carryover. Total iron in condensate showed a significant drop, as did total iron in LP and IP drums and in average values for both HRSGs (Fig 1).

Additionally, water/steam chemistry analysis showed a further reduction in iron during Cetamine G851 treatment in 2017 and 2018 (Fig 2). Carryover dropped significantly in 2017.

Inspection photos supported the findings (Fig 3).

The use of Cetamine G851 had no negative impact on the online analyzers; and, maintenance of CACE (conductivity after cation exchange) monitors became much easier (resin columns visibly cleaner and virtually no iron fouling).

Conclusions for this FFS treatment, applied in adherence to IAPWS guidelines, are the following:

- The need for steam sparging or nitrogen capping when the plant is offline has been eliminated.
- Although there was a slight increase in CACE and DCACE readings, both remained within suggested limits.
- Drum carryover was reduced significantly.
- The plant saw a marked reduction in iron levels, especially after off-load periods. Typical levels now are less than 5 ppb during normal and two-shift operation, and below 20 ppb four hours after a post-maintenance restart.
- Inspections show clean appearance of inner surfaces and a reduction in FAC.
- Instrument sampling systems are cleaner and easier to maintain.
- FFS treatment has had no impact on unit availability or startup times.

This is an optimistic look at the potential for film-forming substances, but presentations at the *HRSG Forum with Bob Anderson* and similar events continue to stress the importance of the guidance provided by IAPWS TGD8-16 Section 8.

The ongoing pros and cons of FFS addition for corrosion control will be presented by Dr Barry Dooley of Structural Integrity Associates Inc at the upcoming Water Workshop—an integral part of the *HRSG Forum with Bob Anderson,* July 20-23, 2020, at the Rosen Shingle Creek, Orlando, Fla.

Finally, the seventh annual meeting of the European HRSG Forum will be held May 26-28, 2020, at the Hilton Strassbourg (France).

3. Inspection of the LP drum in 2015 (left) and 2017 (right) revealed a dramatic improvement with the use of Cetamine G851 more muted response" because similar actions have already been taken there.

CSEF steels are metallurgically complex alloys that achieve improved elevated temperature strength through controlled chemical composition and heat treatment. However, the quasi-stabilized structure produced in the CSEF steel during successful processing slowly breaks down under the influence of stress at elevated temperatures.

At last year's meeting, Henry focused on Gr91's history and development, and the original allowable stress rating process that lacked long-term testing and used only a limited number of heats. This year he explained in detail the critical and complex stages of adopting any new code material, using Grade 93 and Grade 23 (and others) as examples.

"In determining allowable stresses," he explained, "the ASME Boiler & Pressure Vessel Code (Code) process reviews tensile, creep, and stress-rupture property data obtained over the temperature range of usage, and applies specific criteria listed in Section III, Part D, of the Code. If alloy properties, and particularly the allowable stress values, are attractive to designers," he continued, "the alloy will be specified for use in new construction and for replacements."

During the process of adopting a new Code material, Henry explained, the original producer generates technical requirements for the alloy to be included in a material specification, adopted by a Standards-making organization like ASTM. This provides requirements including chemical composition, heat treatment, and mechanical properties that any producer can use to make the alloy (as restricted by any patents).

"But," he cautioned, "other producers can offer their versions of the alloy if any patent restrictions can be skirted. The final product will not necessarily be in accordance with the original producer's best practice, and new producers often focus on meeting minimum requirements of the material specification." This could include the most cost-effective heat treatment cycle or production process (continuous cast versus ingot).

And one wake-up call: "To date, failures in Gr91 components seldom have occurred in base metal. Most failures have occurred at welds, where weld-related changes in structure govern life of the pressure part" not factored into the stress values. Also, current inspection techniques may not provide early warning of concerns.

So what does this mean for HRSGs?

1. For the existing fleet, the reduction does not mean the equipment is suddenly at risk.
2. If material problems exist or emerge, they are likely attributed to poor design, poor control of operating conditions, or poor quality control during either manufacture or installation (or both).
3. Assessments should be carried out to determine the significance of the Code reduction (if any) for individual components.
4. The main concern becomes margin, not necessarily material risk.

Henry then walked participants through a typical staged assessment of plant conditions.

But most concerning was a discussion on "implications for operators."

"For new HRSGs and piping systems," he predicted, "designers will look to stronger CSEF grades, particularly Grade 92 or Grade 93 (not necessarily a good outcome)." However, there is limited operating experience with Grade 92, questions remain over the poor damage tolerance of Grade 92, and there is less experience with Grade 93, even in Japan.

"Coupled with increasingly demanding operating conditions in response to expanding deployment of renewables," he continued, "operators will likely face very difficult challenges in the coming years at a time when the resources available to successfully handle those challenges are more limited than at any time in the industry's history."

He repeated that we now have the loss of OEM metallurgy expertise, which is a "game changer," along with elimination of support engineering functions within the utilities and operators. For the OEMs, he explained, this added expense was (in the past) in their own best interest as they "stood behind their designs and products."

Unfortunately, he added, there are some smaller engineering firms that, although good, might not know how to address complex material interactions. "They might not know what they don't know."

Even more troubling was one participant's prediction: "New builds are projected by some to be run by drones, not people."

The reduced allowable stress values were released in July 2019 and are required by year end.

In this editor's view, Jeff Henry's presentations and discussions are timely, thought provoking, profound, and acutely informative. The *HRSG Forum with Bob Anderson* has become a prime venue for important updates to this critical issue. Henry is expected to return to the *Forum* in 2020 with additional updates and critical information.

Oxide growth, exfoliation

Barry Dooley, Structural Integrity Associates Inc, covered the important fundamentals of flow-accelerated corrosion (FAC), optimum cycle chemistry, repeat cycle chemistry situations, and the potential for film-forming substances. He then focused on oxide growth mechanisms in power generation cycles, specifically oxide growth and exfoliation (OGE).

"The morphologies of OGE are well understood for both ferritic and austenitic alloys," he explained, considering superheated steam with temperatures up to more than 1100F.

OGE has become, he said, a major problem worldwide.

"Steam growth oxides are semiconductors and grow by counter flux ionic diffusion processes of Fe_2+ moving outwards and O_2- (oxide ion) moving inwards," he explained. Growth and exfoliation of oxides in steam do not depend on oxygen levels, but on the partial pressure of oxygen and other factors.

Anderson and Dooley then presented data and experience discussed recently at the European HRSG Forum (sidebar) about reheater tube failures apparently influenced by internal oxide growth and exfoliation. The referenced plant is an 800-MW 2 × 1 IPP near Bilbao, Spain, that began commercial operation in 2003.

This installation includes horizontal triple-pressure HRSGs behind 9FA+e gas turbines upgraded to DLN2.6 in 2015.

Since 2011, the plant has been moving toward more frequent starts and fewer operating hours per cycle. Currently, unit operations rotate with one unit down for a week.

Thermal mechanical fatigue was causing recurring leaks in the No. 2 reheater. Typical tube leaks caused by thermal fatigue are shown in Fig 5.

In the case presented, however, a reheater tube failure occurred on the tube side of the tube-to-header weld (Figs 6 and 7). The possible cause investigated was oxide growth and exfoliation.

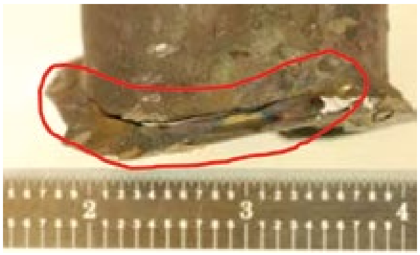
RCA sampling showed an ID surface gouge where oxide was spalling off. See the circumferential crack in Fig 8.

No baffles exist between modules in this HRSG and tubes next to the gaps had operated at higher temperatures than those in the middle of the module. Partial tube blockage with exfoliated oxide was the apparent cause.

As Anderson explained, even a 3- to 4-deg-F temperature increase can accelerate oxide growth significantly. If the tube at the gap is running hotter than its neighbors, this could mean thicker internal oxide which would further increase tube metal temperature. Any resultant tube flexing could cause the spalling.

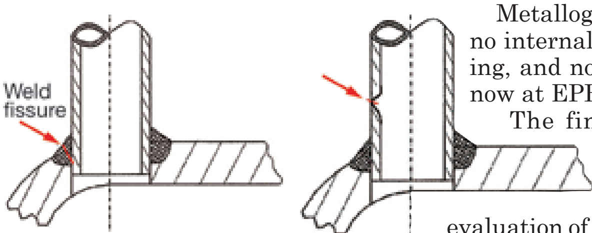
This analysis continues, and thermocouples are being added to tubes at the gaps at the side wall, at the module ends, and well away from the gaps.

Questions regarding this ongoing investigation included ability to deter-



5. Typical tube damage caused by thermal mechanical fatigue

6. Reheater tube failure possibly caused by oxide growth and exfoliation. Note the discoloration of the failed tube and end of header; also, the wide gap between modules



7. Location of the leak shown in Fig 6 is atypical (right). Leaks typically are traced to a weld fissure (left)

8. Closeup of inner surface at failure zone shows circumferential crack between the arrows

mine remaining life of a reheater using oxide scale as an indicator. Another posed question: How do you know whether the issue is temperature rather than geometry? The answer: This particular case is showing a natural progression of a T22 tube impacted by increased temperature.

Blast it?

HRSG tube cleaning experience is typically included in the *Forum,* and the past few years have predicted increased consideration of pressure-wave tube cleaning technology. In 2019, this was the focus of a presentation by EPRI's Stan Rosinski.

He addressed the primary concern of owner/operators—potential tube and structural damage.

Pressure-wave cleaning technology, using methane and O_2, was first applied to HRSGs in Ireland in 2015 based on improved cleaning effectiveness, reduced outage time, and reduced labor. The principal provider is Switzerland's Bang & Clean Technology AG. GE currently holds the US license.

To evaluate potential tube damage, EPRI conducted tests at the Colorado School of Mines Explosive Research Laboratory, and results were reviewed at the *Forum*. Experiments measured blast parameters of both single- and double-bag configurations to understand the performance and effectiveness of the process (including shock-wave physics on finned tubes). High-speed photography captured the processes.

Metallographic analysis showed no internal or external tube cracking, and no fin damage. Tubes are now at EPRI for further analysis.

The final technical report is under review. Anticipated long-term applications also include evaluation of damage to catalysts and air heaters.

Expansion joints, penetration seals

Jake Waterhouse, Dekomte, explained that most expansion-joint problems are with the casings, not with the seals. And he asked some key questions:

- Are the number of cycles specified when purchasing expansion joints?
- Are irregular stresses and movements being properly evaluated?
- What changes have been made since installation (patches, improvements, redesigns)?

He stressed that a key to reliability is technical assessment of current conditions and expected operations. He cautioned that "many HRSG OEMs can get it wrong in the original delivered design."

Both visual and thermographic inspections become critical, creating condition reports that clearly state:

- Evaluation of fixing system and gas tightness.
- Review of adjacent elements for corrosion, cracking, or distortion.
- Internal review of expansion joints, including the flow plates and lining systems.

As combined-cycle plants face greater challenges, owner/operators must be aware of any duct fatigue during thermal transients, irregular stresses caused by movements, and any acid or water dew-point condensation.

The discussion then focused on penetration seals, and the differences between common OEM supply and retrofit options. Metal bellows seem to be favored by OEMs, Waterhouse suggested, but are often not flexible enough for long-term plant operations. Metal in-kind retrofits often must be delivered in split halves, or pipes must be cut and welded.

Fabric retrofits, however, offer greater flexibility in the most compact design, and are favorable for high-movement areas.

Various applications were discussed, with examples, covering metal bellows, sidewall installations for hot and cold reheat, metal-to-fabric retrofits, labyrinth/gland seal-to-fabric retrofits, and limited access roof seals.

Availability and application of online pumpable (liquefied) insulation also was discussed.

Questions and discussions included the pros and cons of insulation inside metal bellows.

Water ingress into insulation

Anthony Cosenze offered Aspen Aerogels' inaugural presentation at the *Forum,* focusing on how water reacts within HRSG insulation systems potentially leading to corrosion under insulation (CUI).

"Aspen Aerogels has been protecting insulated pipes and materials in the petrochemical industry for more than a decade," he stated. Cosenze explained water's behavior within insulation as a "BTU conveyor belt," a process of wicking, evaporation, capillary action transport (vapor), and re-condensation (Fig 9).

He followed with a case study from a US combined cycle involving a pinhole leak and ingress through a penetration seal with mineral-wool insulation. He likened the result to "a wet sock." The insulation was removed, revealing significant OD corrosion (Fig 10). Next, Cosenze showed a photo of a pipe insulated with Aerogel after 10 years of operation (Fig 11).

HRSG examples discussed included penetration seals, HRH line bottom seals, and floor seal/boiler casing insulation integration systems.

A strong feature is reduced thickness and weight. Cosenze explained that a 2.8 in. thickness of aerogel/Pyrogel® offers the same insulating capability as 7 in. of calcium silicate or mineral wool, and is more hydrophobic (organic silicone base). Aerogel is lighter in weight (insulated pipe weight) with less wind loading, and is reusable.

Real-time damage tracking

Structural Integrity's (SI) Ian Perrin discussed real-time health and damage tracking of HRSGs and high-energy piping, with a focus on attemperators.

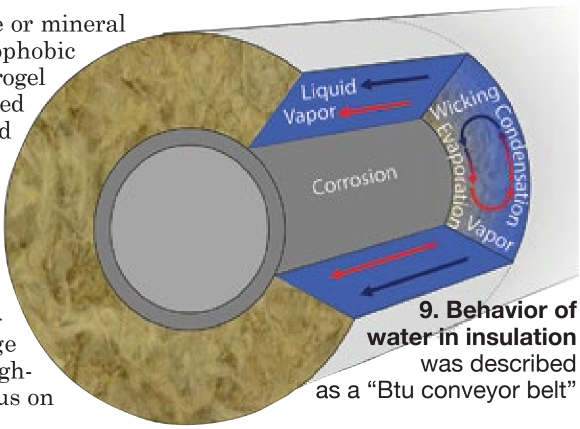
He began with the fundamentals of typical damage and cause:

- Creep: Temperature and pressure.
- Oxidation/corrosion: Temperature, environment.
- Fatigue: Thermal and pressure transients.
- FAC: Temperature and chemistry.

He concentrated on real-time monitoring as a complement to offline inspections, material sampling, failure analysis, and fitness for service. His message: Online health tracking is dynamic rather than a static snapshot, and can take instrumentation well beyond the typical control function.

Virtual monitoring offers calculations based on available operating data (both current and historical), and real-time visualization of damage consumption. Results should be dynamic, based on actual history, and without assumptions regarding operating profiles.

The end goal is integrated asset health tracking directing inspection, repair, and possible component replacement scheduling.



9. Behavior of water in insulation was described as a "Btu conveyor belt"

11. Pipe insulated with aerogel looks almost new after a decade

10. The impact of water ingress is downtime

SI offers an analytics engine that takes plant data in real time and develops lifetime consumption calculations, then displays the information within the company's Plant Track system. The result is real-time, continuous damage tracking based on actual operation.

Such a system, he explained, can be retrofitted on older units. Plus, data from past operations can be collected to improve current life calculations.

Example applications displayed creep-damage development in high-energy piping systems, creep-fatigue and oxidation damage trending in HP and RH headers, and fatigue damage in selected attemperators.

Perrin's specific case study was a

reheat interstage attemperator where the damage mechanism was determined accurately, but would have been missed by a normal DCS with standard instrumentation.

Valve acoustic leak detection

Nick Grigas, Mistras Group, discussed critical valve leak-detection technologies, concentrating on acoustics and EPRI Program #1005285, "Attemperator Monitoring." Plant 1 of the program is the Thomas A Smith Energy Facility in Dalton, Ga, a 1250-MW 2 × 1 combined cycle owned and operated by Oglethorpe Power Corp.

"Acoustic trends have demonstrated the ability to record significant changes in ultrasonic noise as the HPSH and/or RH attemperator valves open and close with spray demand," Grigas explained. "This gives rise to the potential to use acoustics as an alarm for under plug/seat leakage.

Other recorded events have shown cycling of the HPSH block valve with zero spray demand, and what appears to be the RH spray control valve position chasing spray-flow demand. These events could lead to better understanding behavior of the attemperators' control logic and development of potential corrections."

He explained a variety of portable and online leak detection systems for continuous monitoring of attemperators.

Impact of GT upgrades

HRSG topics and concerns focus largely on the transition to cyclic operations. System effects from gas-turbine upgrades can be equally challenging.

Uniper SE's Dan Blood explained that traditional combined-cycle plants "are being displaced in the dispatch order by new market entrants (primarily renewables)." Note that Uniper was formed when E.ON separated the fossil-fuel generating facilities from its asset portfolio.

The new company, based in the UK and Germany, has experience and credibility with more than 37 GW of total generation in more than 40 countries, including 25 years in HRSG/combined-cycle plants. Their profile promotes the following: "Our highly flexible and adjustable powerplants ensure a sufficient and reliable power supply."

Blood stressed that the change from hours-based to starts-based operations can increase the owner/operator focus on startup costs. Gas turbine upgrades can improve a unit's market value by improving speed of response (fast starts, fast ramps, fast shutdowns), by increasing maximum load and cycle efficiency, and by reducing emissions at low or minimum load. Upgrades are designed for enhanced ability to offer "grid services," thereby keeping plants competitive.

"A key question to consider," Blood stressed, "is the GT upgrade's impact on the water/steam cycle and the ability of systems to cope with the new process conditions."

He added a caution: "GT suppliers may not offer a comprehensive assessment or may make assumptions which are not truly valid."

Blood offered a clear and structured approach to full-system impact assessment to mitigate such risks:

- Planning:
  1. Define new modes of operation (for example, new GT exhaust conditions).
  2. Review impacts (plant modeling).
  3. Conduct an initial review of risks (hazards and operability).
  4. Quantify risks (engineering impact assessments).
  5. Integrate risk reduction plans (modify designs or operating procedures).
- Testing:
  6. Undertake plant trials.
  7. Assess plant trials (are the impacts as predicted?).
- Implementation:
  8. Apply, optimize, and standardize.
  9. Re-assess.

10. Adapt/enhance maintenance and inspection regimes (for example, pressure-part integrity strategy).

Uniper offers a thermal-plant modeling program that evaluates key parameters, including saturation and superheat margin.

Blood described a case study, conducted jointly by Uniper and GE starting in 2011. This GE9FA/9FB variable-load-path (VLP) upgrade led to a full commercial product offering by GE.

Note that VLP is a GT control feature that uses inlet-guide-vane (IGV) control to keep exhaust temperature low during startup; allows independent control of GT load and exhaust temperature within an "operating space"; and significantly decouples GT output from HRSG/steam turbine thermal constraints.

Details shown included HRSG heat-balance comparisons, requirements for an "exhaust flow boundary" for plant integrity and safety, potential IP drum safety valve impact, and balance-of-plant risks and mitigations.

Questions from participants included application for low-load units at night, assistance in avoiding overspray during startup, and potential IP moisture carryover risk.

Anderson labeled the discussion "significant" as the industry upgrades turbines and "expects certain benefits or capital expense payback."

Calpine Sutter restart

Andrew Gundershaug, Calpine Corp, discussed the history and restart of the 2 × 1 Sutter Energy Center in Yuba City, Calif. He covered the reasons for cold layup, the restart process, specific challenges, and lessons learned.

Sutter was commissioned in 2001 and became "a gem in the Calpine fleet" using two 501F machines. It then became a stranded asset in 2015, and owners decided to stop operations.

When the plant came offline, it transitioned to cold layup. Staff level was reduced to a small team (from 30 to four) tasked with plant oversight and continued operation of two LM6000 plants in the same area.

Markets turned more favorable for operations in late 2017. Calpine made the call to restart the plant effective April 1, 2018.

"The biggest concern was lack of staff and the short timeline," stated Gundershaug. "A project engineer and HRSG expert were brought promptly to the site."

Major restart projects began January 15 and included DCS checks and enhancements, GT hot-gas-path inspection, steam-turbine minor inspection, HRSG inspection and cleaning, covered piping system survey, electrical system testing, valve inspection, and HRSG/GT1 expansion-joint replacement, among others.

Lessons learned have included the benefit of bringing back former employees who understood operational issues, failure of using shutdown time to make needed (and known) repairs, unanticipated water requirements to rinse and flush the plant, the ability to troubleshoot and optimize an aging DCS system, problems with elastomer parts, calcium complications from lube-oil preservatives, attempts to use an old replacement-parts inventory, benefits of a third-party safety team to monitor and advise, and an onsite purchasing team becoming "overwhelmed with the amount of purchasing required."

Sutter began operations on schedule and has been operating with an equivalent forced outage rate of 0.27%.

Automatic drain control

Updates have been presented at each *Forum* on the development of an automatic drain control system that began in 2011. The EPRI project, managed by Competitive Power Resources and supported by FLEXIM, is expected to go commercial soon.

In stressing the importance of this topic, Anderson highlighted his recently completed, 10-year survey of

54 different units for thermal-transient mechanisms and damage, centering on 31 key issues. His summary: "Attemperators cause the most problems, followed by drains."

During a pressurized startup purge cycle, a large amount of condensate is produced. There is a need to quickly establish cooling-steam flow to SH and RH tubes, but only after the SH and RH are drained of condensate. Draining condensate as it forms during the purge speeds up the draining process. Because it's important to drain condensate only, and not release an excessive amount of steam, there is a need to detect water versus steam. Thermocouples cannot make this determination prior to firing of the gas turbine.

The goal is to detect and remove condensate from superheaters and reheaters to prevent damage to coils and other equipment in the steam path. This reduces damage from thermal fatigue failures, stretching and bowing of tubes, and a host of related issues.

Once condensate is detected, drain piping and valves must be able to remove it while preventing release of live steam. This is a severe service system with large pressure drops and flashing liquid. One solution is a high-flow drain pot arrangement, but there is not sufficient area for this below many existing HRSGs.

Anderson described the FLEXIM high-temperature waveguide system (WaveInjector® and transducers) and its application on various pipe sizes, including thermally insulated installations. He also reviewed various drain-control valve types, listing the modulating control valve as preferred.

An initial permanent installation has four liquid detection systems (two on the HPSH, two on the RH) on each of four HRSGs. One HRSG has a modulating control valve with EPRI-developed control logic to prevent flashing. The other three have ball valves with simple logic. Cold start of the first has been successful, and hot-start testing will follow.

Systems are being installed on two new Nooter/Eriksen HRSGs and results will be discussed in detail at the next *Forum*.

Pre-submitted questions

Specific questions submitted by participants before the event are a technical feature of the *Forum,* interspersed and discussed throughout the event. The questions stimulated a detailed exchange of ideas and experiences among the participants.

For reference, selected topic examples (without participant-confidential discussion comments) from this year's Forum are listed below:

- Use of thermocouples at the attemperator outlet and first downstream elbow to monitor for overspray: Changes in data can indicate nozzle wear or leaking and be used to reduce the margin to saturation.
- Addition of thermocouples to the HP drum to assist in drum cracking investigations.
- Modifications to operating procedures to reduce thermal-fatigue damage during startups and shutdowns, specifically for GE 7/9FA and H units.
- For short- and medium-term HRSG layup during cycling, should a nitrogen blanket be applied to the drained reheater section? At what point should economizers and evaporators be drained?
- Successful mitigation or elimination of liner cracking near the GT exhaust.
- Weld failures on HRH/CRH headers after 16 years: pipe-to-pipe welds versus forged or cast steel fittings.
- What precautions are HRSG/attemperator manufacturers taking to provide reliable piping and attemperators designs for cycling?
- Precautions taken by HRSG manufacturers to assure tube-to-header weld quality and to avoid locating large nozzles on HP drum near or on circumferential girth welds.
- Experience with operators reducing setpoints or taking manual control of HP or HRH attemperator control valves.
- Experience using exhaust-stack dampers.
- Corrosion and pitting on the LP drum door and manway, and remediation experience.
- Vent and drain small-bore piping leaks and experience with under-insulation inspection methods.
- Coking on duct burners: operational impact and RCA.
- Pros and cons of using film forming substances to protect against iron transport from the air-cooled condenser.
- Criteria for hydrogen damage in HP evaporator tubing.
- RCA experience for magnetite exfoliation damage to HRH and HP steam bypass valves.
- Benefits and lessons learned from taking advantage of the NFPA 85 Purge Credit.
- HRSG issues to consider when planning an H-class gas turbine.
- Lessons learned regarding ramp rates for frequent cycling. CCJ

Alstom Owners Group gains widespread support from third-party vendors

Many Alstom owner/operators were left with a feeling of "abandonment" following GE's purchase of their OEM four years ago. Cost-cutting reduced Alstom's field-service capabilities and spare-parts inventory to the bone at a time when GE was reconfiguring its aftermarket organization and developing "cross-platform" capabilities to serve both Alstom and Siemens owners.

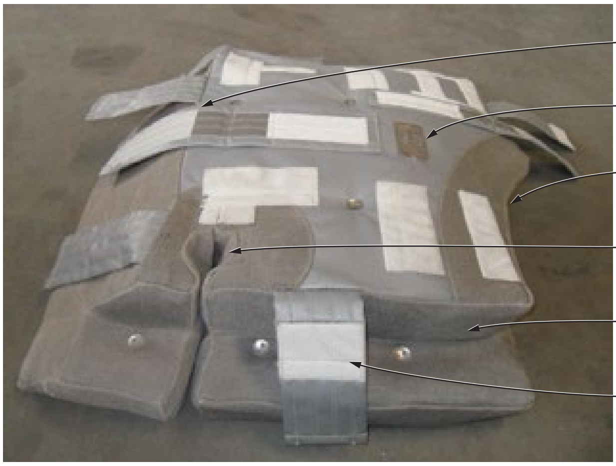
Recall that a vibrant community of third-party suppliers like that serving Siemens and GE users never really developed for Alstom owners because their US engine fleets were relatively small by comparison.

Alstom owner/operators soon concluded survival in the relentlessly competitive electric-power market hinged on their ability to help develop and support a market for third-party replacement components and services.

As a first step, Liburdi Turbine Services Inc, Mooresville, NC, Pioneer Motor Bearing, Kings Mountain, NC, and Arnold Group, Filderstadt Germany, organized and sponsored the first Alstom Owners Conference in early 2018 to review maintenance solutions and strategies pertaining to the repair, service, and maintenance of Alstom engines. Liburdi's Jeff Chapin opened the meeting as the de facto chairman.

The idea of an organization to support the global Alstom community of owners and operators gained support quickly and at the end of the two-day meeting a steering committee was elected and planning was initiated for a second conference. Brian Vokal of Midland Cogeneration Venture, Chris Hutson of Georgia Power, and Robert Bell of Tenaska Berkshire Power now hold positions as co-chairmen on the steering committee.

The user component of the 2019 meeting, held in Raleigh, doubled from the first gathering to more than 50, assuring the asset-ownership com-



1. Insulation blankets of the single-layer shaped type, fit the turbine surface snugly to minimize heat loss.

mitment to support a 2020 meeting in Houston, January 27 – 31. Interestingly, more than 20 Raleigh attendees were international—representing owner/operators of both legacy and late-model engines in Europe, Australasia, and the Americas.

What follows are short summaries of some vendor presentations made at AOG 2019. If you're an Alstom owner or operator and want to dig deeper into one or more of these subjects, contact Chapin by email (jchapin@aogusers.com).

Advanced insulation for Alstom turbines, *ARNOLD Group.*

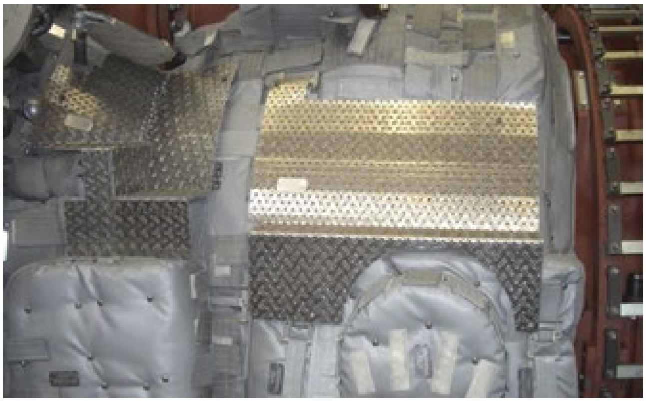
ARNOLD Group's single-layer insulation system was said to be state-of-the-art technology and capable of solving all known insulation-related problems associated with the operation and maintenance of gas and steam turbines.

General Manager Werner Arnold and Global Head of Marketing Pierre Ansmann opened their presentation by describing issues users may face with conventional insulation—such as:

- Replacement lagging not made to the correct specification.
- Insulation blankets that require repair or replacement at each outage.
- Hot spots on the insulation surface conducive to handling and maintenance problems.
- Turbine trips caused by overheated auxiliary equipment.
- High noise level inside the enclosure.
- Loose fibers and dust from calcium fiber blocks that can cause health and safety issues.

Loss of earnings results from poor design/installation of turbine insulation and/or premature wear and tear of blankets. The balance sheet can be impacted negatively by reduced power production, contractual penalties, damage to mechanical and electrical equipment and instrumentation, and shorter outage intervals.

The ARNOLD team said its insulation avoids the stated problems because of interlocking high-performance blankets which conform perfectly to the turbine surface, high-quality materials and manufacturing, and long-term high-temperature resistance (Fig 1). The company guarantees reuse of its insulation system for 15 outages without a decrease in efficiency.



2. Step protection promotes long life for the insulation system (above)

3. Inner insulation at the exhaust diffuser has as its top surface a blanket reinforced with stainless-steel foil and stainless mesh (right)

4. Warming system enables steam turbine to avoid cold starts

5. Consider robotic inspection, when possible, to avoid field removal

Highlights of the well-illustrated presentation (well over 100 high-quality photos showing details important to users) include blanket construction, design of the support structure, ease of access to inspection points, step protection for longer life (Fig 2), piping and flange insulation, insulation for inside the exhaust system (Fig 3), insulation system designs for the GT24, GT26, 11N, 13D, and 13E2, and steam-turbine warming systems (Fig 4) and associated controls.

Wrapping up, Arnold and Ansmann told the owner/operators they can expect a significant decrease in compartment temperatures by installing ARNOLD insulation—sometimes as much as a 50% reduction—and benefit from a commensurate reduction in fuel consumption and increase in power production. Plus, with fewer blankets to remove, repair, and replace, outage time and cost are reduced.

Generator inspections and robotic capabilities, *AGT Services Inc.*

Jamie Clark is a frequent presenter at industry meetings focusing on frame gas turbines. In the last year or so he has been at the podium to share his knowledge of generator design, operation, maintenance, repair, testing, what can be done in the field, what requires a shop visit, etc, during annual meetings of the 6B, 501F, 7EA, 7F, and generator users groups. So, it was not surprising to see this veteran with 20+ years of generator problem-solving experience at the AOG conference earlier this year to speak on inspections and robotic capabilities.

He began by urging attendees to get a baseline condition assessment of their generators as soon as possible and to fix what's required to assure reliable service—even if it takes a major to do it. Clark suggested consideration of robotic inspections (Fig 5) in lieu of field removal where possible and offered the pros and cons of using robots.

He also recommended a re-evaluation of the timeline for future inspections where there have been significant changes in operating duty. Shorter outage intervals, he said, might be a good decision for units that have transitioned to peaking service in the last few years. Of course, baseload and seldom-run units may enjoy longer intervals.

Clark's recommended electrical tests for the stator focused on the following:

- Winding copper resistance, each phase.
- 5-kVdc insulation resistance and PI, each phase.
- Dc leakage, each phase.
- 1-min dc hipot at 38.25 kV, each phase.
- Resistance check and 1-min 500-Vdc megger of all RTDs.

As for what to inspect on the stator, he listed the winding, endwinding support system, wedge system, gas-gap baffle studs, rubber baffles, bushing box, and stator core (for tightness, iron migration, damaged/overheated laminations, and vent duct blockage).

More than three-dozen photographs helped the users understand what to look for and how to evaluate what their level of concern should be. Example, he had a picture of endwinding contamination to show what it looked like and then a photo of heavy contamination (Fig 6) of greater concern. Other photos illustrated bottom-bar insulation damage, global greasing at end wedges, significant connection-ring tie greasing (Fig 7), iron oxide from key-bar rattle, etc.

Moving to the field (rotor), Clark recommended these electrical tests:

- Winding copper resistance.
- Insulation resistance and PI.
- Ac impedance test.

A terminal-stud seal pressure test also was suggested for hydrogen-cooled units.

As for what to inspect on the field, he recommended checking the following under the retaining rings: field winding/brazes, turn insulation, migration of slot insulation, movement of blocking, main lead, coil-to-coil jumper, and pole-to-pole jumper. He also suggested examining the field body for wedge/retaining ring contact, wedge movement, heating, vent blockage, and balance weights.

11N rotor assessment and overhaul, *Doosan Turbomachinery Services Ltd.*

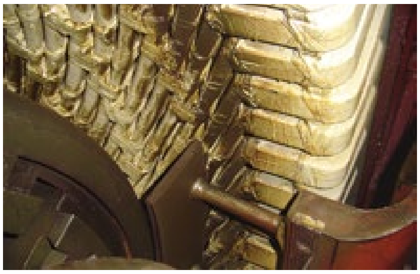
Alex Ford, rotor engineer, and Glenn Turner, VP engineering, focused their presentation on the Alstom GT11N because of that frame's popularity in North America, predominately for peaking service. They said there are more than 150 11Ns globally, about 60% of that number in the US, Canada, and Mexico. The stats: An 11N has a rotor weighing about 30 tons, not including the 1250+ compressor blades in 18 stages and 400+ turbine blades in five stages.

The speakers touted Doosan's comprehensive program to inspect, evaluate, repair, and replace 11N rotors in a true partnership with its customers. They summarized the company's onsite and in-shop rotor inspection and evaluation processes. The goal of the rotor-life evaluation program, which includes nondestructive inspections (Fig 8) and the use of models (Fig 9) for predictive calculations, is to confirm rotor condition is suitable for continued operation.

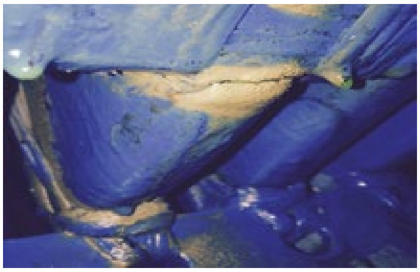
In the event indications are found, Doosan creates the models necessary to determine a repair plan capable of restoring the rotor to good health. Life-assessment simulations are run to estimate remaining life and assure repairs are not life-limiting.

In cases where rotor replacement is necessary, Doosan's LaPorte (Tex) facility has access to the global company's heavy manufacturing shops for steam and gas turbines in Changwon, Korea, and to its Skoda works in the Czech Republic.

Reverse engineering and 3D modeling are among Doosan's core competencies.

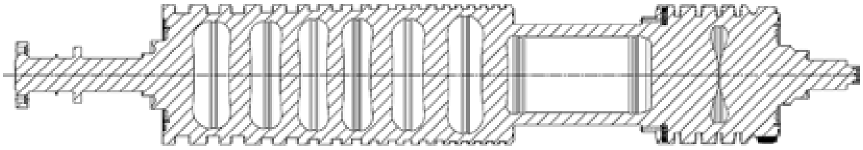


6. Stator windings shown here suffer from heavy contamination



7. Significant connection-ring tie greasing is evident here

8. Inspection is a key element of Doosan's program for evaluating 11N rotors



9. Design of replacement rotors relies on 3D modeling abilities

10. New-rotor manufacturing demands specialized equipment like this for post-weld heat treatment

The presentation illustrated the company's physical facilities for manufacturing replacement rotors—including forging, welding, machining, assembly, and balancing equipment (Fig 10).

Gas turbine controls, *Emerson Automation Solutions.*

The Emerson presentation covered the "waterfront" of the company's solutions for gas turbines and combined-cycle plants while bragging a bit—having earned that right given its involvement in nearly 1500 automation projects involving more than 300 GW of natural-gas-fired generation worldwide. What some attendees likely found most interesting was Emerson's joint activities with Ansaldo Energia—in particular on new-build GT26 and GT36 gas turbines.

For Alstom control systems on gas turbines familiar to many attendees, Emerson offers upgrades for the Alspa 6, Alspa P320, and legacy Alspa systems. For ABB controls on gas turbines, it offers upgrades of the Advent, Procontrol, and legacy systems.

The speaker described the typical steps involved in a controls retrofit project and the design inputs required before summarizing relevant case studies.

Fleet support update on technical and operational capabilities, *General Electric Co.*

GE's presentation was an overview of how the company is investing in the fleet to provide customers increased output/efficiency, flexibility, and lower emissions/turndown. Improved fleet support regarding parts availability, qualified repair procedures for new parts, in-depth training of field services resources, and faster response to customer requests were among the action items identified.

Perhaps the of greatest value to users regarding GE participation was the ability to meet the engineers and managers who can help them regarding field service, inspections, repairs, spare parts, engine upgrades, etc.

Service organization and product portfolio, *Ansaldo Energia Group.*

Ansaldo, the OEM of record for the GT26 and GT36, was not well known to many attendees. But Leone Tessarini, global director of power services, filled the information gap by bringing the users up to date on virtually everything you might want to know about the company concerning its organization, business units, facilities, engineering and manufacturing capabilities, and product offerings for the 50- and 60-Hz markets.

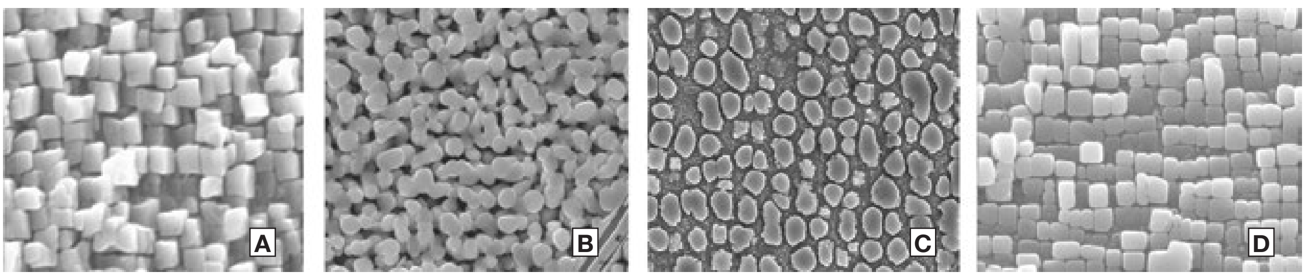
The product focal point for Tessarini's presentation was the GT26 of which there are 42 units worldwide—all outside of North America.

Delivering value through proven cost savings with technology-driven life extensions of HGP parts, *Liburdi Turbine Services Inc.*

Doug Nagy, P Eng, made the presentation on Liburdi's capabilities. The company is well respected worldwide for its advanced component repairs on gas turbines in aircraft propulsion and power production applications.

Core competency includes life extension of critical components for Alstom GT8, 11, 13, 24, and 26 machines—including repairs to: variable vanes, blades, stators, and erosion coatings in the compressor section; EV burners, inlet segments, inner liners, and the hot-gas case in the combustor section; and blades, vanes, and heat shields in the turbine section.

Nagy illustrated the financial benefit of the company's value-driven repair strategies by way of examples that compared the cost of new hot-gas-path (HGP) components (combustors, blades, vanes) to ones repaired as part of a major inspection for a large frame unit. In both cases the result was a



11. Photo array illustrates the value of Liburdi's FSR® rejuvenation repairs. A shows the as-manufactured microstructural condition of the material, B the material's condition after a service run, C reveals the impact of conventional heat treatment, and D shows how rejuvenation heat treatment comes close to restoring the material to its original condition

zero-timed engine ready for another normal service interval. The comparison study illustrated put the cost of Liburdi's repair solution at $0.8 to 1.5 million, the cost of new components in the range of $3 to 8 million.

Nagy then reported on the 20-year history of his company with a 7EA user running a 2 × 1 combined cycle and the cost saving that accrued over two decades by selecting Liburdi's advanced repairs to save parts declared at the life limit or unrepairable by conventional methods. The plant owner was said to have saved $4.7 million in the first 10 years of the program and another $13 million in years 11 through 20—or close to $1 million annually on average.

Liburdi's component repair philosophy underpins its value proposition and success in maximizing the lives of HGP parts. It has these three components:

- *Listen* to what the engine and the parts are saying.
- Do not just repair, but *rejuvenate* (Fig 11).
- *Upgrade* components to mitigate service damage.

Nagy went on to explain its engineering analysis (mechanical and metallurgical) capabilities, component-assessment process, and the repair technologies it employs—including alloy rejuvenation, powder metallurgy for metal replacement, automated welding, and high-performance coatings. His presentation is a worthwhile read for anyone wanting to understand more about HGP repairs; it offers important details yet is understandable for those without a background in metallurgy and gas-turbine repairs.

To dig deeper, plan on attending the third annual conference of the Alstom Owners Group, Houston, Jan 27 -31, 2020, where Nagy will present an 8-hr workshop on technology-driven life extension of HGP parts.

Alstom experience and independent solutions, *Power Services Group.* One reason owner/operators attend user-group meetings is to identify service providers beyond the obvious that are capable of providing solutions conducive to a more robust bottom line. One relatively new entry is PSG Power Services Group. Well, the name may be new to you, but the company really is not, having been formed by combining the capabilities and assets of Turbine Generator Maintenance (TGM), Airco Power Services, and Orbital Energy Services (OES)—names you likely are familiar with.

The presentation was designed to familiarize attendees with the company and its key personnel—including Ellen Guthrie, GM turbine field services; Scott Robinson, director of large utility field service; Jason Johnson, TA/site manager; and Robert Robinson, TA/site manager. All are GE and Alstom veterans and combined have six decades of experience with those OEMs.

You can get most of the information on the company's capabilities and recent gas and steam turbine projects by visiting its website at www.powerservicesgroup.com.

Reverse engineering of bolting, blades, valve parts, pump casings, turbine wheels, rotors, and casings, *Stork, a Fluor company.*

Stork, recently acquired by Fluor, reviewed its considerable reverse engineering and modeling capabilities and its internal processes and procedures for assuring dimensional quality control of the components it makes for gas and steam turbines. At the end of the presentation, attendees got a rundown on the various compressor rotor and stator blades Stork makes for Alstom machines to support owner/operators, including the following:

- GT11N, rotor blades for all stages, stator blades for Stages 8 – 18.
- GT11D5, rotor blades for all stages, stator blades for Stages 7 – 19.
- GT 13E1, rotor blades for all stages, stator blades for Stages 1 – 4.
- GT10B (an ABB machine currently known as the Siemens SGT-600), rotor blades for all stages of both the old and new versions of the engine, IGVs.

Alstom's exclusive bearing repair licensee, *Pioneer Motor Bearing.*

Development and manufacture of hot-gas-path components, *TPC.*

Valve repair and critical spares management, *MegaWatt Machine.*

Vendor verification and specification writing, *TEServices.*

Optimization of gas-turbine maintenance strategies, *SS&A.*

EPRI's upcoming generator workshops promise users a high-value learning experience

The Electric Power Research Institute's Turbine Generator User Group (TGUG) hosts two meetings annually—one in winter and the other in summer. The 2020 schedule is in the accompanying box. If you've never attended one of these conferences, which offer independent turbine and generator tracks conducted in parallel, perhaps you will next year.

This article focuses on the generator track, managed by Bill Moore, PE (bgmoore@epri.com), EPRI's technical executive for electrical generators, and offers good reasons for both engineers new to the industry, and veterans, to attend. Primary among them is meaningful content.

TGUG meetings run from Monday through Friday morning and will introduce you to subject matter on equipment design, operation, and maintenance that you may not get at other industry conferences. One reason is the majority of invited speakers are from owner/operators and relatively small firms with expertise in specific areas of generator technology.

The Monday and Tuesday programs are arranged in an open workshop format; OEM presentations are on Wednesday; extensive roundtable discussions by EPRI members are conducted on Thursday; specialized SME (subject matter expert) training is on Friday morning.

To pique your interest, Moore has provided short summaries below of seven of the nearly two-dozen presentations at last summer's TGUG meeting in Albuquerque, NM. The remaining presentations, identified by title and author, follow the abstracts. Important: All of these presentations are available at no cost to EPRI Program 65 members and to those who attended the meeting.

Electric Power Research Institute's Turbine Generator User Group

2020 Meetings

January 13-14
Omni Amelia Island Plantation Resort
Fernandina Beach, Fla

August 10-14
Venue to be announced
Chicago, Ill

For more information, visit www.epri.com and click on "Events"

Bill Moore, PE
Technical Executive, Electrical Generators
bgmoore@epri.com

Mike Young, SRP (Salt River Project), discussed outside spacer block (OSSB) migration in a GE 324 generator. This was the first reported event of this failure mechanism occurring on this type of generator. The unit had been cycled off and on in summer, twice daily, for about 10 years. The OSSB penetrated the bottom stator bar insulation ⅛ in. as shown in Fig 1. A decision was made to rewind the stator and restack the ends of the stator core to correct the problem. OSSB plates were staggered and additional wedges were added in the dovetail slots on the OSSB.

1. Stator bar cut by outside spacer-block migration

2. Contamination found in stator cooling-water hose was the underlying cause of a generator trip

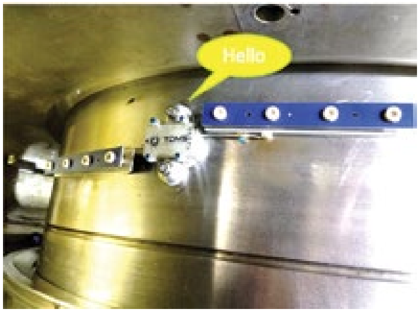
Gregory Howard, Exelon Corp, presented on the use of a hipot test and infrared thermography to identify dc leakage in a stator-winding cooling water hose. The B phase of this 1355-MVA, 25-kV generator first tripped at 50 kVdc, then failed with a subsequent test at 27 kVdc.

The B-phase voltage was reapplied again to produce a small amount of heating in the cooling-water hose, the suspected source of the trip. FLIR thermography was used to view through an open manway and identify the localized heating that was producing the leakage and failing the hipot test (Fig 2). The hose was removed, dissected, and the source of the contamination causing the leakage was eliminated.

3. Blue check on as-found leads showed lack of electrical contact

Mike Bresney, AGT Services Inc, talked about a repair on a generator flex connection. Recall that flex connections are the copper-laminated flexible links that connect the stator winding and the bushings. On some units, they are located vertically above the stator winding, on others vertically below. There have been at least two major flex-link failures in recent

4. Proper layup procedures help prevent plugging of hollow copper conductors in water-cooled generators



5. Turbine diagnostic monitoring system, shaft-mounted, can measure torsional and lateral vibration and acceleration

6. Blistering of copper rotor turn was discovered during field-winding refurbishment

years, so this component is getting increased inspection, maintenance, and repairs. Major issues include overheating attributed to loose bolting and lack of flatness, causing insufficient electrical contact and resistance heating (Fig 3). In some cases, fatigue and fracture of the copper-laminated link occurs.

Bill Moore, PE, updated workshop attendees on an EPRI-sponsored project led by Matt Svoboda and Thomas Bauer of SvoBaTech. Focus of the research: identification and communication of the proper layup procedures to prevent oxide plugging (Fig 4) in water-cooled generators. The EPRI report on this work, #3002016241, scheduled for publication in November 2019, is available at no cost to members of the research organization's Program 65 (Steam Turbines, Generators, and Auxiliaries).

Chris Suprock, Suprock Technologies LLC, covered the inherent risks and wide band of uncertainty related to calculation of shaft torsional resonances. He cited EPRI report #1013460 (publicly available at www.epri.com) which discusses 11 major industry failures (turbine and generator) related to torsional interaction between the grid and the turbine/generator.

Suprock shared the details of a turbine diagnostic monitoring system (TDMS)—self-powered and shaft-mounted—for measuring torsional and lateral vibrations and acceleration (Fig 5). He said measurement of these parameters significantly reduces the band of uncertainty, and suggested that a TDMS be installed when a turbine or generator is replaced or modified.

Steve Reid, TG Advisers Inc, offered three case histories on important lessons learned when rewinding generator rotors. One project involved unusual copper rotor turn blistering as shown in Fig 6. Blistering was not observed until after the rotor turns were removed and in the process of refurbishment for re-insulation and re-installation. Another example included a rotor shaft severely arc-damaged from negative sequence currents. In some cases, events like these are unforeseeable, and no amount of preplanning can eliminate significant outage delays.

Dr Lyle Branagan, Pioneer Motor Bearing Co, provided a tutorial-type presentation on generator and exciter bearings. He covered the fundamentals of generator and exciter bearing design and operation, including some case histories of bearing failures (Fig 7).

Other presentations at the Albuquerque meeting included the following:

- "Shaft Cracking from Grid Disturbances," Neil Kilpatrick, *GenMet LLC*.
- "Advanced Pattern Recognition and Model Development," Aaron Hussey, PE, *Integral Analytics LLC*.
- "NERC PRC Reliability Standards Pertaining to Generators," Jon Gardell, *Patterson Power Engineers LLC*.
- "Stator Water Challenges," Colin Rickets, *Exelon Corp*.
- "AEP Field Trial of H_2 Leak Detection Tape," George Yeboah, *AEP (American Electric Power Co)*.
- "Large Generator Winding Specifications in the Renewable Age," Reza Soltani, *Powertech Labs Inc*.
- "Rotor Slot Liner Cracking," Sachin Sehgal, *TC Energy*.
- "Speed Sensitive Field Ground Investigation, Diagnosis, and Repair," Jamie Clark, *AGT Services Inc*.
- "Rotor Turn Insulation Failure," Tyler Foutz and Joey Martinez, *EthosEnergy Group*.
- "Preparing Generator Rotors for Cyclic Duty," Mark Crittendon, *MD&A*.
- "AVR Failure Modes, Upgrades, and Repairs," Gene Asbury, *Basler Corp*.
- "Pressurized Air-Cooled Generator Factory Test Results," Mike Zborovsky, *Siemens Energy*.
- "Solving Inherent Safety and Reliability Problems with H_2 Cooled Generator Purging," Andy Shurtleff and Andrew Slaugh, *Airgas, an Air Liquide company*.
- "Palo Verde Generating Station Flexible Lead Inspection and Modifications," Douglas Withers, John Myers, and Scott Miller, *APS (Arizona Public Service Co)*. CCJ

7. Wiped exciter bearing got the attention of participants in a bearing design tutorial

Cheaper feedwater systems don't always cost less

By Henry Kwan, SNC Lavalin Constructors Inc

One of the most important systems in a powerplant is the boiler feedwater (BFW) system. When well-designed it can accommodate the wide range of operating conditions required to meet today's varying power demands. Failure of the BFW system to meet expectations results in lost production and plant downtime.

Not all systems are equal. Owner/operators often opt for a particular type of pump system to save money, only to discover the system is not flexible enough to grow with increased demand. Making the right investment in the BFW system, whether a full replacement, retrofit, or new build, can save on maintenance costs, prevent system failure, and maintain production rates.

The top concern is maintaining minimum flow. Every BFW pump manufacturer specifies a minimum flow for its equipment. Operating below this minimum flow creates hydraulic instability, which ultimately leads to cavitation and excessive vibration that can damage the pump bearings and other internal parts.

In addition, running at less than the minimum continuous thermal flow promotes a rapid increase in fluid temperature, potentially flashing the water to vapor. A recirculation line is essential to ensure the feedwater pump is always running above the specified minimum flow. The chart illustrates three typical methods for BFW recirculation systems.

The orifice method is a continuous recirculation system that uses a fixed orifice or a series of fixed orifices in the recirculation line to maintain the required minimum flow regardless of the pump load. The orifice is the lowest cost option; however, it also is the least efficient. Even at full operating load, the system continually recirculates the pump minimum flow, which leads to a higher parasitic load and the need for an oversized pump.

While this system is highly reliable, has a lower installation cost, and requires minimal maintenance, it rarely is considered because of the additional cost for operating the oversized pump. This method typically is used for low-volume, low-head systems.

An ARC valve is a combined, self-contained check valve and recirculating valve requiring no external power. The mechanical design allows the check valve disc to sense the flow and then modulate the recirculation line to ensure the minimum flow is maintained at all times.

With this method, everything is built into the valve so there is minimal maintenance. But there is no flexibility for adjusting the ARC valve during operation. Plus, if you want to upsize, you'll either need a larger ARC valve or a different method.

A modulating control valve gives the most efficient and flexible option for minimum-flow pump protection. This valve is controlled by the plant control system based on flow, temperature, and pressure measurement, ensuring that the specified minimum flow is maintained at all times. When coupled with a smart-valve positioner, diagnostic information is easily accessible for predictive maintenance, which can help prevent unexpected failures and downtime.

Continuous monitoring allows system optimization by way of modifications to the operating parameters. In addition, a control valve equipped with severe-service trim can handle higher pressure drops to the low-pressure steam drum. While the control valve typically has a higher upfront cost than the other methods, some end-users believe this investment will pay for itself with the efficiency and flexibility it provides.

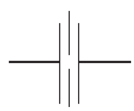
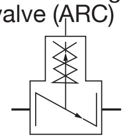
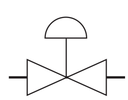
Which method is best? The decision usually comes down to paying more upfront for the flexibility and efficiency of the control valve or going with a less expensive, easier-to-install ARC valve.

Based on the experience of SNC Lavalin Constructors Inc, the control-valve method is preferred by end users, with some plants retrofitting the recirculation system with a control valve that can respond to changing flow conditions. A process engineer can perform a cost/benefit analysis to help you determine the right system for your plant, and then can help you establish a well-defined scope, budget, schedule and identify risks when upgrading your system. CCJ

About the author

Henry Kwan has more than a decade of experience in the design of thermal energy systems. On recent projects he has served as lead process engineer or project engineer.

Pros, cons of alternative feedwater recirculation schemes

Method	Description	Pros	Cons
Orifice plate 	Fixed orifice in the recirc line constantly recirculates the required minimum flow regardless of pump load	■ Lowest overall cost ■ Reliable ■ Minimal maintenance	■ Least efficient ■ Wastes power ■ Extra cost for oversized pump
Automatic recirculating valve (ARC) 	Self-contained combination check/recirc valve that requires no external power	■ Minimal maintenance ■ Typically lower upfront and installation costs than for a control valve ■ No external utility requirements	■ Inflexible ■ No instrumentation to continuously monitor conditions
Control valve 	Controlled from plant control system based on flow, temperature, and pressure to ensure the specified minimum flow is maintained at all times	■ Efficient ■ Flexible ■ Predictive maintenance capability when equipped with a smart positioner	■ Typically higher upfront and installation costs than for an ARC valve ■ Most complex method in terms of design and implementation

7F USERS GROUP

Best Practices

With the 29th annual conference of the 7F Users Group only weeks away, this might be a good time to register for the world's largest meeting of frame gas-turbine owner/operators, assuming you haven't already done so. About 250 users and 150 exhibitors are expected to attend, so the conference hotel could fill up quickly. Check out the meeting agenda at www.powerusers.org and register online. You can book your room through the 7F website as well.

This is the second of three articles planned on the 2019 conference. It completes the editors' coverage of best practices, which began last issue (CCJ No. 61, p 5). Awards were presented to the seven plants below for sharing their proven ideas for improving safety and performance and for reducing emissions.

2020 Conference and Vendor Fair

Fairmont Dallas Hotel
Dallas, Tex • May 18-22

Chair: Matt Dineen, Duke Energy

Vice Chair: Christa Warren, Tenaska Inc

Contact: Sheila Vashi, sheila.vashi@sv-events.net

www. powerusers.org

St. Charles

Pocket guides invaluable to new employees

Challenge. Powerplants can be intimidating to new employees, and bringing a new hire's knowledge up to an acceptable level is a priority. Today there may be only one person assigned to handle all of a plant's outside responsibilities and he/she must be able to respond immediately to direction given over the radio by the control room operator in case of a problem. This requires knowing where every piece of equipment in the plant is located, which takes time; carrying drawings on rounds is not practical.

Solution.Plant personnel created a pocket guide which provides layouts for different areas of the plant and the locations of vital equipment along with simplified drawings. Technicians do not need detailed drawings to know where they are and where to find a specific piece of equipment. The guide consists of multiple laminated cards with drawings on the front and on these drawings are numbered locations. Each number correlates to a piece of equipment and the description for each number is on the back of the card. The pieces of major equipment identified on the cards are those an outside operator may need to attend to or have been problematic.

Results. The pocket guide has greatly improved the knowledge and efficiency of the outside operators and reduced job stress. Their ability to respond quickly during recent freeze conditions proved invaluable.

Project participant: Chris LaBille

Guidelines assist operators in understanding NERC standards

Challenge. To help operators maintain compliance with NERC requirements, plant management sought to improve their familiarity with certain regulatory standards. The goal was to have knowledge on specific topics easily accessible for reference if a corrective action was needed.

During plant starts after cycling, CROs sometimes noticed voltage spikes that would linger on the high side of 238 kV. For a 235-kV voltage schedule, generator output cannot exceed ±4-kV deviation from the set point. The limited information easily accessible to operators was not in keeping with the plant's proactive safe and efficient culture.

Solution. The "Plant Generator Voltage Schedule per NERC standard VAR-002" guideline was created so all operators would be aware of the NERC requirements regarding the plant's specific voltage schedule. It includes the information needed by operators to deal with a regulatory exceedance or near miss.

A PowerPoint also was created to explain NERC's voltage schedule guideline. Operations personnel were required to review this presentation and answer questions afterwards. Any questions raised were answered thoroughly to assure complete understanding..

A plant voltage graphic also was added to the operations screen so all CROs and lead operators could continuously monitor grid pricing and the dispatched generation set point (Fig 1). When the voltage changes ±3 kV, a red light flashes, bringing the voltage schedule to the operator's attention.

Results. The enhancement has proven very helpful. Also, operators are less stressed knowing they have the tools to respond to a regulatory episode in the unlikely event one occurs. Finally, the work described further reflects the culture of St. Charles and the continuous efforts made by staff to make proactivity and forward thinking a priority among all employees.

Project participants: Mario Longmore and Jonathan Bennett.

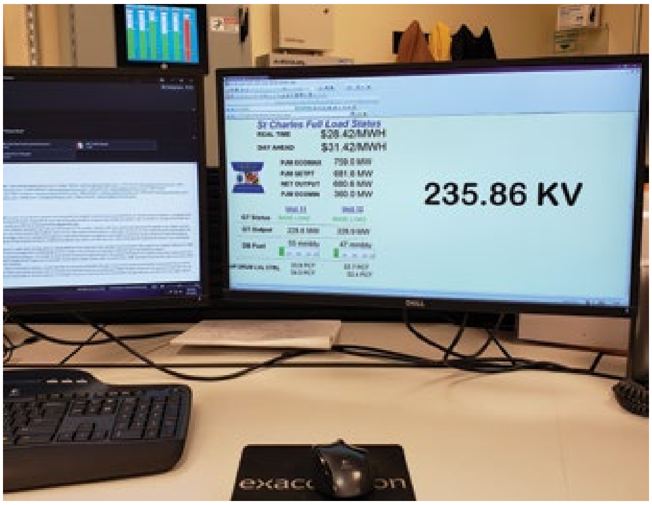
St. Charles Energy Center

Owned by Competitive Power Ventures

Operated by Consolidated Asset Management Services

745-MW, gas-fired, 2 × 1 combined cycle located in Waldorf, Md

Plant manager: Nick Bohl



1. Plant voltage graphic was added to the operations screen (left)

2. Certificates are displayed neatlyand in clear sight (above)

Winter preparation important to successful operation

Challenge. St. Charles Energy Center discovered during the January 2018 "polar vortex" that the plant was extremely deficient when it came to winter readiness. During this period, it experienced many trips and forced outages associated with freezing transmitters, valves, and sensing lines.

Solution. In summer 2018, plant leadership met to address all the issues that occurred during the previous winter to be sure St. Charles Energy Center was ready for the cold weather ahead. They developed a multi-layered plan that would take months to perfect and implement.

First step: Plant personnel identified and prioritized critical components, systems, and other areas vulnerable to freeze-up—including transmitters, instrument air system, motor-operated valves, valve positioners, solenoid valves, and fuel supply. The locations of these critical components and the heat-trace circuits and panels associated with them were identified.

A contractor was engaged to perform a heat-trace audit. Every circuit was tested, and amperage draws were compared to design data. The amperage readings were used to create heat-trace rounds so technicians could compare the live value to the expected value and report or address any discrepancy.

Plant personnel inspected every foot of insulation, verifying thickness, quality, and proper installation. Any missing insulation, gaps, and/or damage were noted. The list of insulation repairs ended up being well over 100 items. A contractor was hired to correct them.

Using the critical components list, technicians identified locations for wind barriers to protect components in winter. Plant management decided to use scaffold-type enclosures wrapped in a fire-resistant tarp. They are sturdy, removable, and cost-effective. Electric heaters, heat lamps, and halogen lights were installed in the enclosures.

Plant personnel inventoried all supplemental equipment onsite associated with freeze protection. Needed items were ordered and added to the inventory. To ensure critical equipment did not freeze under any condition, online and offline equipment cycling lists were created. They directed operators to cycle or exercise certain valves and pumps periodically.

In fall 2018, training was conducted to highlight preparations and expectations for severe cold weather. It included response to freeze-protection panel alarms, troubleshooting of freeze-protection circuitry, identification of plant areas most affected by winter conditions, a review of special inspections or rounds implemented during severe weather, and lessons learned from previous experiences and the NERC Lessons Learned program.

Results included zero lost opportunity attributed to freezing in winter 2018/2019. This significantly helped the plant's bottom line as well as employee morale. The plant has proven it can perform cold starts and remain online during single-digit ambient temperatures and wind chills below zero.

Project participants: Kelly Swann, Jennifer Renner, Mario Longmore, Jonathan Bennett, Mike Williams, James Brown, Rick King, Kenny Boone, Javier Gomez, Josh Plourde, George Sellmon, Ronald Scott, Chris LaBille, Frank Katzenberger, Sidney Potmesil, and Peter Swaby.

Labeling of chemical piping raises awareness, prevents injury

Challenge. Since COD, St. Charles has experienced several leaks in the sodium hypochlorite piping, which runs aboveground from the storage tank in the water-treatment building to the cooling-tower basin. Sodium hypochlorite and sulfuric acid piping are in the same pipe rack as lines conveying water not harmful to employees. Piping leaks are a safety concern because it might not be immediately clear if the leaking liquid is a chemical or water.

Solution. Plant staff labeled the chemical lines that run aboveground across the site. This makes personnel cautious and observant, and allows them to quickly determine the type of liquid discharge.

Results. Operators now respond to leaks more quickly and effectively to protect personnel.

Project participant: Kenny Boone

Site safety pamphlet provides quick access to emergency information

Challenge. Project leaders were having a hard time ensuring vital emergency information was easily accessible and retained by all new personnel who came onsite. This included contact information for management staff and control-room phone numbers.

The previous method of disseminating this information was via Power-

Point. This would require visitors and contractors to take notes in order to have this information readily available or they would have to request it again from plant personnel. There was no guarantee that during an emergency, contactors would remember the information required.

Solution. A site safety pamphlet was created. This pamphlet is a trifold sheet of paper that contains management and control-room numbers on the front panel. Mandatory safety equipment, muster points, and smoking policy are listed on the back panel. Another panel provides the following site-specific safety points:

- Driving and sign-in policy.
- A mandate to stay with plant contact.
- Immediate assistance if separated from plant contact.
- Personnel trained in AED, CPR, and first aid.
- Signal the plant uses to declare an emergency.
- A statement that all work must be preauthorized prior to starting work.

Inside the pamphlet is a full map of the facility with key areas labeled so a person will be able to orientate him/herself in case of an emergency. All fire extinguishers, safety showers, eyewash stations, muster locations, smoking areas, the first aid kit, and the AED are marked.

Results. The pamphlets are available next to the sign-in book in the lobby and during all outage safety briefings. The PowerPoint still has the same information, but with this pamphlet, visitors, contractors, and new employees need not take notes and can concentrate more on all the safety information delivered in this presentation.

Project participant: Jennifer Renner

Control-room display of boiler and pressure-vessel certificates

Challenge. The plant has over 40 state boiler and pressure-vessel inspection certificates that must be displayed in a prominent location and in plain view for review by auditors and inspectors. The licenses were being displayed in a large picture frame that hung in the control room but was in a location that did not allow someone the ability to inspect closely the information on each certificate. Plus, the display was unwieldy and licenses were prone to detaching and sliding down behind other certificates.

Solution. The need for a better organization was a must, along with minimizing space in the control room. The plant acquired a flip and display wall organizer to have all certificates displayed neatly and in clear sight (Fig 2). It also makes it easier when certificates must be changed or reviewed.

Results. Auditors/Inspectors and personnel needing to review certificate information have applauded use of this organizer. The ease of access to the information allows for quick review and reference.

Project participants: Jennifer Renner and Kelly Swann

Armstrong

Unit axial vibration monitoring

Armstrong Energy
Owned by LS Power
Operated by IHI Power Services Corp
625-MW, dual-fuel, simple-cycle peaking facility in Shelocta, Pa, equipped with four 7FA.03 gas turbines
Plant manager: Brent Yatman

Challenge. Plant personnel desired a method for monitoring axial vibration levels during all phases of operation and for recording the results in the site's plant information (PI) system. With known thrust-bearing issues in the fleet, as indicated on the 7F Users Group forum, the site was determined to closely monitor vibration to prevent abnormal wear and mechanical stress on unit components.

Armstrong relies on a Bently Nevada 3500 panel with two axial probes mounted on T1 and T2 turbine tilting-pad journal bearings and two radial probes mounted on both of the generator's elliptical journal bearings. There are also two thrust position probes mounted on T1 and one keyphasor probe on the speed pickup wheel.

Solution. Plant personnel installed jumper wires from the thrust-position inputs to spare channels on the same Bently Nevada 40M monitor card. This enables simultaneous monitoring of axial vibration and rotor position without installing an additional probe or probes. Jumping the input signal did not affect the gap voltage; therefore, plant personnel felt confident this configuration would be successful.

The additional inputs were connected to radial vibration channels and associated with the keyphasor input to provide 1× and 2× vibration levels. By programming the inputs in this fashion, it became a simple procedure to route these signals into the Mark VI Speedtronic panels for display on the HMI.

Alert and alarm levels were arbitrarily set as identical to previously installed components because there was no guidance on these levels.

Results. Now that the plant had readings available on the HMI, it was time to verify them. This was accomplished by performing a rotor-position test (bump test). The rotor was pushed against the inactive face on the thrust bearing using hydraulic rams and jacks and a dial indicator was mounted on T1 bearing housing and set to zero.

The rotor was then forced against the active face and the dial-indicator reading was compared to thrust-position reading both at the Bently panel and on the HMI. The bump test was performed three times with repeatable results.

Additionally, each time the rotor was forced against a thrust-bearing element, hydraulic pressure was raised to 5000 psig and then lowered to 2500 psig in accordance with the OEM's methodology. With three sets of repeatable results identical to the readout of the thrust probe at the panel and on the HMI, the site was assured that there was no issue with their set up.

The units then were operated, and vibration and position levels observed. Again, there were no issues with readings when compared against prior levels. The site then added the new point to the PI system and can now view both real-time axial vibrations and trend levels over time to identify possible issues before catastrophic failure.

Project participant: Peter Margliotti

Green Country

Complex underground water leak repairs

Challenge. Safety is one of Green Country Energy's (GCE) core values. Occasionally, a job like the one described here, challenges the balance among safety, cost, and production.

The details: Operations identified a wet location between the steam-tur-

Green Country Energy
Owned by J-Power USA
Operated by NAES Corp
801-MW, three gas-fired 1 × 1 combined cycles located in Jenks, Okla
Plant manager: Danny Parish

bine building and the HRSG on Unit 3. This area is filled with gravel, so it was not too alarming at first. Some of the gravel was removed to see if we could find the general location of the leak. It seemed no matter where we looked, the leak appeared to be coming from that location.

Tests suggested the water was most likely coming from a breach in the circ-water piping located in that general area. P&IDs were reviewed and an excavation contractor was called to the site. Safety processes were reviewed and digging commenced. It appeared that the leak was somewhere on a line located directly under a major HRSG support platform. How to access the leak and repair the line in such a difficult location was a perplexing challenge.

Solution. Lone Star Hydrovac Co was hired to do the excavation. Its high-pressure water-jet system and high-vacuum truck made removal of the compacted gravel and fill a snap. The biggest attribute of this system was its inherent safety; no employee had to enter the area being excavated under the HRSG support pad. After excavating a small distance under the pad, Eden Structural Engineering installed a set of support pillars and jack stands to support the pad and the HRSG.

Then Lone Star removed the final material to reach the leaking pipe. The water was coming from a dime-size hole in a weld, probably caused by damage to the protective pipe coating during plant construction in 2002. The weld repair was made, the area backfilled, and the circ-water system returned to service.

Results. The leak was found and repaired quickly and effectively, and in a manner that was safe for all involved.

Project participants: All GCE O&M personnel, with special recognition to Scott Helt and Thomas Hedge for leading the project execution.

Nueces Bay

Advanced solutions for securing critical infrastructure

Nueces Bay Energy Center
Owned by Talen Energy
Operated by Consolidated Asset Management Services (CAMS)
667-MW, gas-fired, 2 × 1 combined cycle located in Corpus Christi, Tex
Plant manager: Norm Duperron

Challenge. The Nueces Bay Energy Center (NBEC) has made investments to upgrade its safeguards to protect physical, human, and electronic assets to meet or exceed NERC CIP standards.

Regulations put in place by FERC are approaching final adoption, and they have far reaching implications for many combined cycles. NERC's critical infrastructure protection (CIP) standards require plants to have a physical security plan and program in place to monitor and manage physical access to protect critical infrastructure, cyber assets, and bulk electric system (BES) cyber systems.

Part of the challenge for NBEC was to document every cyber asset that resided within an electronic security perimeter then provide the perimeter with electronically monitored access control, as well as an annual review of its cyber vulnerability.

The next challenge was to provide physical security to all critical infrastructure equipment and a plan that documents physical access and complements the cyber security plan. While meeting these challenges, NBEC took steps to stay ahead of the regulations while identifying ways to improve operational efficiency, site safety, and security.

Solution. In conformance to the CIP-002 standard, "Identification of Critical Cyber Assets," plant personnel broke down critical cyber assets into two categories which included resources that support the reliable operation and delivery of the BES and assets that are critical to and essential for protecting the BES.

A network topology drawing was updated to include details related to the foundational networks to be protected. Additional assets were added to the network topology—including control devices and connected computers not recognized as part of the corporate or critical networks.

All business network switches were replaced and a unified threat management (UTM) firewall was added to the architecture to limit IP ports and services on the business network. To meet the security patch management guidelines identified in NERC CIP, the plant subscribed to GE's cyber asset protection (CAP) service to provide validated patches for the operating system, applications, and anti-virus of the DCS computers.

Additionally, the site implemented password management, backup and recovery policies, removable media policies, network intrusion detection, and provided training on cyber security awareness and recognition of unusual behavior. The corporate network security campaign also heightened awareness by hanging posters, sending emails, and providing training.

The NERC CIP-006-3c and CIP-006-5 standards relate to establishing a physical security program for the protection of critical cyber assets and managing physical access to BES cyber systems by specifying a plan to protect these systems against compromise that could lead to mis-operation or BES instability. The plant previously had locks on all critical access areas but all locks were upgraded to provide the additional functionality of monitoring access, maintaining records of entry (with timestamps) for each individual, keeping physical access logs for a minimum period of time, and allowing unescorted access only to authorized individuals.

Several elaborate electronic access control (EAC) systems were evaluated but the plant ultimately decided installed a cost- and time-saving intelligent key system with data analytics. This was an effective solution because the outdated and uncontrolled mechanical master key system was retrofitted with door hardware that provided the access control, electronic scheduling, and audit accountability specified by the CIP standards.

Additionally, this system eliminated the expense of rekeying and had the advantage of being able to work during a power failure. New processes and procedures were developed around secure access control and all plant personnel were trained.

Beyond the NERC CIP physical security guidelines, the plant installed 13 high-definition, industrial-grade security cameras with many advanced features. The camera system adds to the safety and site security of the plant by allowing control-room operators to quickly view almost every area on the plant grounds from the DCS control board. It also has been useful for continuous monitoring of contractor work and warehouse deliveries when staffing during off-hours is constrained.

The plant upgraded its GAI-Tronics® system to broadcast over every plant speaker from the control desk. Another change to promote better communication was to add phone number fields to the job safety analysis form.

Results. NBEC has shown continuous improvement and an ability to keep ahead of pending regulatory standards. The benefits of training personnel and adopting and implementing the draft NERC CIP standards has allowed the plant to amortize the cost of meeting the guidelines.

Good teamwork between corporate IT and plant personnel resulted in a compliant and fully documented network infrastructure for both the DCS and business networks. Installing the latest security-camera technologies and electronic-key access in the plant provides benefits beyond their intended purpose and contributes safety and productivity enhancements when staffing is at a minimum.

Project participants: Eric Mui, senior ICE technician, and Anthony Martinez, plant engineer.

Barney Davis

Multiple benefits accrue from gas-chromatograph install

Challenge: Getting accurate gas quality data to provide real-time gas-flow readings in BTU. Prior to installing the gas chromatograph, plant would have to wait until the end of the month to get a report from the gas supplier. In addition, staff was having to send out a gas sample monthly for analysis to get the gas composition data need to comply with air permit requirements.

Solution. Install a gas chromatograph and integrate it with the plant's gas-flow transmitters and CEMS.

Results. Once the chromatograph was installed and integrated with the DCS and CEMS, Barney Davis was able to verify its gas supplier's flow data and provide the CEMS with real-time gas composition data to satisfy air-permit requirements and eliminate having to wait for an end-of-month gas report and gas sample analysis.

Plus, by using this information together with market data received from our QSE we can calculate and analyze the combined cycle's economic performance on a real-time basis. Plant personnel also are able to better analyze the performance of each gas turbine and the duct-burner performance for each HRSG.

One of the unexpected benefits was the increase in interest by control-room operators in plant efficiency. Now able to see, in real time, the cost of producing a megawatt-hour, they are more interested in reducing operating costs.

Project participant: Robert Lee Garza, operations manager

Barney Davis Energy Center

Owned by Talen Energy

Operated by Consolidated Asset Management Services (CAMS)

670-MW, gas-fired, 2 × 1 combined cycle located in Corpus Christi, Tex

Plant manager: Gary Clark

Calhoun

Lockwire prevents water-injection and fuel-oil purge-valve actuators from coming loose

Challenge. An RCA conducted after Calhoun experienced an unsuccessful fuel-oil swap found lose mounting screws on fuel-oil and water-injection purge-valve actuators had allowed stem binding to occur during operation. It was attributed to vibration.

Solution. Upgraded actuator mounting screws were installed—ones with pre-drilled holes. Staff connected the screws together with lockwire to prevent them from backing out.

Results. Calhoun has not experienced a trip or unsuccessful fuel-oil swap caused by an actuator hang-up since the installation of new screws and lockwire.

Project participants: Mike Carter, Steve Murray, Rob Fletcher, Neil LaMantia, and Terry Sandefer

Calhoun Power

Owned by East Alabama Generating LLC

Operated by Consolidated Asset Management Services

748-MW, dual-fuel, four-unit simple cycle plant located in Eastaboga, Ala.

Plant manager: Mike Carter

Sounding-cap addition on oil-tank lid

Challenge. Calhoun's 2.5-million-gal fuel tank did not have a safe way to manually sound tank level without opening a 24-in. lid. This created an unsafe condition because a technician could become disorientated from tank fumes. Plus, operators could possibly drop rags, sounding tape, manhole gasket, etc, into the manhole. A worst-case scenario was the potential for an operator falling into the tank.

Solution. Site personnel removed the lid and took it to a local shop to install a 4-in. pipe nipple and cap on manhole cover.

Results. This allows technician to sound tank and pull fuel samples in a safe manner.

Project participants: Mike Carter, Rob Fletcher, and Steve Murray

MEAG Wansley, Unit 9

LOTO upgrade facilitates maintenance of chemical feed pumps

Challenge. The plant has two chemical-feed panels: boiler and cooling tower. Each has multiple pump motors electrically fed from their respective panels. By design, the start/stop switches are on the panel door and the motor starters are located inside.

When work on a single pump was required, this arrangement created two separate problems:

- The entire panel had to be locked out and chemical injection was not possible.
- An electrical technician had to disconnect the pump motor from

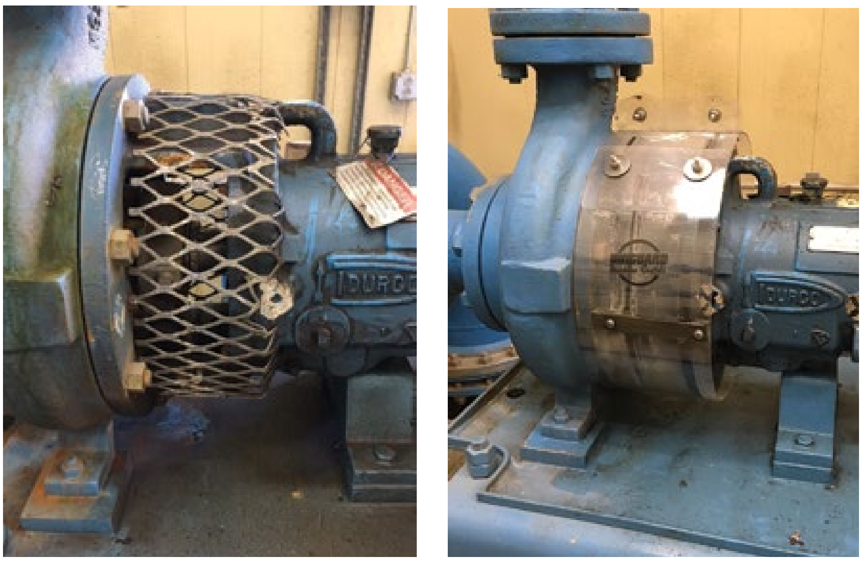
MEAG Wansley Unit 9

Owned by Municipal Electric Authority of Georgia

Operated by NAES Corp

520-MW, gas-fired, 2 × 1 combined cycle located in Franklin, Ga

Plant manager: Timothy Williams



Machine guard installed when plant was built (left), after upgrade (right)

the panel in order to work on the equipment and then restore power to the panel. In doing so, they would not have a physical lock-out/tag-out (LOTO) point on the disconnected motor.

Solution. The answer, while reasonably inexpensive, was to install through-the-door disconnect switches on the outside of each panel for every pump; the newly installed disconnect switches interrupt the line voltage to each pump's motor starter.

Results. The switches each are capable of electrical lock-out devices and may have a lock attached. The system now allows a technician to service any of the individual pumps with a correct LOTO safety device installed and allows each pump motor to be managed individually while maintaining the ability to add chemicals to the process as needed.

Project participant: Jason Land, IC&E technician

LOTO test points

Challenge. During a recent outage, staff discovered that two breakers failed to open completely while LOTOs were being installed. This prompted personnel to research a way to improve the hazardous-energy removal verification method used while implementing a LOTO on electrical equipment, while at the same time protecting employees. Having to open MCC enclosure doors to verify the de-energization of electrical equipment using a "live dead live" verification process exposes the technician to a possible arc-flash event and/or electrical shock.

Solution. By de-energizing the plant electrical system one buss at a time, it was possible to install through-the-door test points. They allow the technician/operator to perform a "live-dead-live" check for the presence of voltage and measure phase-to-phase and phase-to-ground with far less exposure to high voltage and the associated potential for an arc-flash event. In addition, on panels with multiple test points, each was labeled for rapid identification.

Results. Not only do the new test points reduce the possibility of exposing an employee to arc flash, they significantly reduce the level of PPE (personal protective equipment) required in the performance of these tasks. Previously, as high as Category 4 protection was required; now the tasks often can be performed wearing only Category 1 or 2 level protection. Thus, tasks are now completed more safely, effectively, and faster with the enclosure doors closed.

Project participant: Jason Land, IC&E technician

Do your machine guards meet current standards?

Challenge. During a site "hazard hunt" on machine guarding, plant personnel discovered that the guards for many machines were outdated, ineffective, and did not meet OSHA standards.

Solution. A complete engineering study of the site was completed, measurements recorded, and upgraded guards ordered. The new equipment was installed to provide more effective protection for employees and contractors. Rockford and International "Gotcha Sticks" were used to ensure the site met the rule and intent of the OSHA standard.

Results. The new guards were engineered to fit precisely in the affected areas, resulting in a safer and more effective system of protection. Detailed measurements guaranteed that the new guards fit perfectly, and in several cases provided a viewing window for equipment observation while in in operation.

Project participant: Jimmy Shehan, maintenance technician

Together again: 501F, G users to share meeting space in West Palm, Feb 9-13, 2020

The 501G Users Group traditionally has conducted two meetings annually, the first early in the year, the second about six months later. For many years, the winter meeting was held in the same venue and at the same time as the 501F Users Group's annual conference, the organizations coming together on safety, presentations by third-party suppliers, vendor fair, and meals.

The G users hosted winter meetings on their own from 2016 through 2019 but decided to rejoin the 501F users in 2020 because of the benefits that accrue from having a larger group of owner/operators sharing experiences. The 501G summer meeting will be conducted during the Siemens Customer Conference for F, G, and H Technology, as it has since 2016.

Conference registration has opened for the winter meeting at the Hilton West Palm Beach, Feb 9-13, 2020, and all members of the 501G Users Group should have received a registration link by email. If you have not received the link, contact Meeting Coordinator Tammy Faust at tammy@somp.co.

The summer meeting, hosted by Siemens, will be held at the Renaissance Orlando at SeaWorld, the week of June 15. It will be co-located with the T3K Annual Conference.

The G Users Group is a small, but proud organization of engineers and technicians who have "grown up" together—so to speak—and understand each other's perspective. The first G, installed by Lakeland Electric, began commissioning operations in April 1999, but COD wasn't until March 2001—only one month before the second machine began commercial operation at Millennium.

Fleet size is small by industry standards—24 Siemens (Westinghouse) engines at 13 sites in the US and one in Mexico (sidebar). Four plants are equipped with one engine each; seven have two gas turbines; two are equipped with three machines each, arranged in 1 × 1 combined cycles.

User meetings typically host roughly one-third to one-half first-timers, so many discussions are similar from year to year because newcomers have to be brought up to speed. There's not much turnover in the top positions at G facilities which means each meeting pretty much picks up where the last one left off, especially regarding the OEM's presentations. This certainly contributes to presentation efficiency because there's a minimum amount of repetition.

Most users groups serving GT owner/operators organize their technical programs by sections of the engine—for example, compressor, combustion section, turbine, etc. The G users begin with an "annual report" from each plant and follow that half-day program with user presentations on emerging and significant plant-wide issues of importance to the fleet. Notes taken during the plant reports at a recent meeting follow:

Plant 1 with three 1 × 1 combined cycles reported on the steps considered for the layup of one unit because of low demand—something affecting many power producers nationwide. Two units suffered Row 1 turbine-blade failures in the previous six months and one of the steam turbines required replacement of L-0 blades.

Plant 2 found TBC (thermal barrier coating) loss on two R2 vanes during the borescope inspection of one of its two engines and replaced them. A R1 vane was replaced in the sister unit as well. At the time, both machines had operated for less than 40k equivalent baseload hours (EBH) and had fewer than 900 equivalent starts (ES).

Plant 3 found damage to Row 1 turbine blades during a borescope examination at about 90k EBH and fewer than 1000 ES, replacing the entire

Steering committee

Chair: Steven Bates, plant manager, *Wise County Power Plant, Vistra Energy*

Vice Chair: Mark Winne, plant manager, *Millennium Power Partners (operated by NAES Corp)*

Scott Wiley, outage manager, *Vistra Energy*

Guy Taylor, plant engineer, *Lakeland Electric*

John Wolff, technical support/compliance manager, *Ironwood, LS Power*

row and five transition pieces during a modified hot-gas-path (HGP) inspection. A hot-reheat tube failure in the HRSG also was noted.

Plant 4 took a major early to deal with a broken through-bolt and compressor hook-fit wear on one of its two gas turbines. A steam-turbine major for this 2 × 1 facility included rotor replacement and new bolting for the low-pressure cylinder.

Plant 5 reported on the HGP and generator major conducted for one of its two units, plus its experience during a steam-turbine valve overhaul.

Plant 6 was forced into an economic shutdown and shared key aspects of its layup plan.

Plant 7, with two engines having slightly more than 80k EBH/1750 ES, presented its experience conducting a double combustion inspection for the first time, and replacing Row 1 vanes. Also shared were plans for installing NextGen hardware during an upcoming outage.

Plant 8, a 2 × 1 combined cycle with just north of 50k EBH/700 ES on its gas turbines, spoke about a CI on Unit 1 that went to a modified HGP and included replacing four Row 4 blades. Balance shots also were installed to reduce vibration. Unit 2 required an HGP, plus rotor removal to address seal issues. New R1 NextGen vanes were installed. In addition, HP and IP valves and actuators were replaced on the steamer.

Plant 9, approaching 100k EBH/2700 ES on its 1 × 1 combined cycle, shared details of a lost-time accident and replacement of the gas-turbine generator's step-up transformer. The speaker said the following were on his mind: turbine through bolts, HRSG fouling and its impact on gas-turbine backpressure, and Row 1 blades and vanes.

Plant 10, a 2 × 1 combined cycle, reported on the replacement of the exhaust expansion joint for one of its gas turbines and on SCR catalyst replacement in the HRSG for that engine. A steam-piping crack was mentioned as well.

Plant 11 said its gas turbine was closing in on 100k EBH and 2750 starts, reporting that the unit was running well. The only hiccup was rotor-air-cooler leakage at the inlet tubesheet which required plugging six tubes. The takeaway: probably time for a replacement tube bundle.

Plant 12 borescoped its gas turbine and received a clean bill of health.

Plant 13 had nothing but good news to report since the previous meeting. Planning was underway for majors on both of its gas turbines in the following year.

The open discussion portion of the meeting began with safety topics, including the following:

- *Outage planning.* Consider outsourcing confined space rescue; one plant reported this as less expensive than using staff. A user suggested bringing in colleagues from other facilities several weeks prior to an outage to review and comment on your plans and procedures. Might also be a good idea to bring in representatives from selected contractors for the same purpose. To police for safety violations during the outage a user suggested hiring an outside contractor experienced in this work.
- *Grinders/saws/buffers.* Be aware that grinding wheels can explode (don't forget face shields) and that any rotating cutting/grinding tool has a "coast-down" time during which it remains hazardous to operators and others in the work area. One attendee said he surveyed some of this plant's tools and found coast-down times of 11 to 17 seconds. Unacceptable! Quick-stop tools are available and they cease rotating in 1 sec. A contractor contacted after the meeting suggested to the editors that reciprocating saws are an alternative to centrifugal tools. They're safer, he said, but they take longer to make the cut and the cut is not as clean as with centrifugal tools.
- *Rigging.* This is an area that begs for experience. Many experienced riggers have retired and the number of reported near misses and dropped rotors is increasing and very concerning. Be sure no personnel are under any lift and that ground and crane people are in constant contact during the lift, and that the component being lifted is visible for the entire lift.
- *Color coding.* Have vests and/or hardhats of different colors to facilitate identification of critical personnel and to be sure the proper person is working on a particular issue. Example, one color for riggers, one for confined-space rescue, etc.
- *Identify near misses during the outage,* get RCAs done quickly and circulate findings among all who should know about them.

User presentations/discussions focused on turning-gear preventive maintenance, a main relay protection failure and findings, high-vibration trip and findings, and a few other topics. Such discussions often morph into self-help clinics with colleagues offering the benefits of their experiences to anyone who has a concern and is unsure of what he/she should do given a particular set of circumstances. In some cases, users share experiences for "awareness" purposes—situations to avoid, and why. Learning from the experiences of others is a primary goal of all users groups. Avoid mistakes already made. CCJ

W501G fleet: 13 plants, two-dozen units

Ackerman Combined Cycle Plant, TVA, Ackerman, Miss

Athens Generating Plant, Talen Energy (operated by NAES Corp), Athens, NY

Ennis Power Plant, Vistra Energy, Ennis, Tex

Fuerza y Energia Naco Nogales SA de CV (FENN), Gas Natural Fenosa México, Agua Prieta, Sonora, México

Granite Ridge Energy Center, Calpine Corp, Londonderry, NH

Harquahala Generating Facility, operated by NAES Corp, Tonopah, Ariz

Hillabee Generating Station, Exelon Power, Alexander City, Ala

Ironwood, LS Power (operated by EthosEnergy Group), Lebanon, Pa

Magic Valley Generating Station, Calpine Corp, Edinburg, Tex

Magnet Cove Generating Station, Arkansas Electric Cooperative Corp, Malvern, Ark

C D McIntosh Jr Power Plant, Lakeland Electric, Lakeland, Fla

Millennium Power Partners, Talen Energy (operated by NAES Corp), Charlton, Mass

Wise County Power Plant, Vistra Energy, Poolville, Tex

NAES in the news

Orange Grove Energy earns VPP Star status

1. Safety is a high priority at NAES facilities, from deck-plates personnel to top corporate executives, as evidenced by the lineup of guests who assembled at Orange Grove Energy (OGE) for the plant's VPP Star flag-raising. From left to right: Ryo Tajima, J-Power USA VP engineering; OGE's Ramiro Garcia, compliance manager, and John Hutson, plant manager; David Jackson, NAES VP safety; Mark Condon, J-Power USA CEO; Rick Shackelford, NAES operations dirctor, and Paul Peterson, J-Power USA VP asset management and operations

2. Plant Manager John Hutson accepts an award for the staff of Orange Grove Energy from Mark Condon, J-Power USA CEO in appreciation of the plant's VPP Star certification. Other OGE personnel (l to r): Paul Braemer, OMT; Tony Moretto, lead OMT; Ramiro Garcia, compliance manager; Gregg Stephens and Erik Cherry OMTs

Over the last decade, CCJ's best practices program has seen a dramatic uptick in entries pertaining to safety, a few for achieving VPP Star status. If you're not familiar with the acronym VPP, Voluntary Protection Programs is an OSHA initiative that encourages private industry and federal agencies to prevent workplace injuries and illnesses through hazard prevention and control, worksite analysis, training, and cooperation between management and staff.

The certification process is arduous and can take a couple of years in some cases. Success depends to a great degree on the commitment of the personnel involved. It's no mission for the faint of heart.

John Hutson, plant manager of Orange Grove Energy (OGE), a two-unit LM6000 peaking facility in Pala, Calif, shared some highlights of his plant's journey to certification with the editors on a recent call. The flag-raising ceremony, well-attended by owner J-Power USA and operator NAES Corp executives (Fig 1) and plant personnel (Fig 2), took place a few weeks following the 2019 NAES Plant Managers Conference, September 17-19 (see following article).

Hutson recalled that he and Compliance Manager Ramiro Garcia attended a NAES Safe Conference in 2017 where CEO Bob Frishman asked all plants to consider pursuing VPP certification. It was clearly a benchmark for all NAES plants to strive toward in their safety culture. A few months later, J-Power USA CEO Mark Condon asked that all of his company's plants be certified VPP Star.

Hutson and staff accepted the challenge with a desire to improve an already successful safety program while having OGE officially recognized as the elite organization all personnel believed it was.

Garcia served as the plant's interface with Cal-OSHA, Palomar Energy (the VPP mentor facility), and the consultants engaged for the effort. Tony Moretto led his team of OMTs—including Al DeLuna, Erik Cherry, Gregg Stephens, and Paul Braemer—on making the O&M improvements that became evident as OGE worked through the process. Corporate support was provided by David Jackson, VP safety; Boggy Barnett, senior manager of safety; and Chris Trevino, project manager of safety.

OGE addressed and closed more than 300 safety issues and actions identified by plant staff, certified safety professionals, and Cal-OSHA inspectors—this at a plant with an enviable safety record in a company that promoted safety continually. The plant applied for Cal-OSHA VPP Star certification in August 2018; official certification came in August 2019.

Sixteen plants recognized for their best practices

One of the highlights of the mid-September NAES Plant Managers Conference, which focused on safety and operational excellence, was a session dedicated to best practices. Presentations were made by the plant managers from the four facilities earning Best of the Best recognition from CCJ: Dogwood Energy Facility, Edgewood Energy, Elwood Energy, and the

1. NAES plants recognized for 2019 Best Practices

AMP Fremont Energy Center
CCC Tuxpan II and V
Channel Islands Power Cogeneration Plant
Energia del Valle de Mexico I
Ferndale Generating Station
Green Country Energy
Lawrence Generating Station
MEAG Unit 9
Orange Grove Energy Center
Pinelawn Power LLC
Shoreham Energy LLC
Worthington Generating Station

Joe Wood, plant manager, Elwood Energy LLC (holding plaque) is flanked by Frank Keske (left) and by Kelsey Czajkowski and Greg Ponto (right)

Quail Run Energy Center. Another dozen generating plants powered by gas turbines received Best Practices Awards (Sidebar 1).

The NAES Plant Managers Conference is not your typical user meeting; it goes beyond technology into the staffing and training challenges facing plant managers, shares leadership and consensus-building know-how, and digs into HR and environmental initiatives that require a plant manager's attention.

Technical presentations are of a more general nature than one typically finds at frame-specific user meetings. Titles of the vendor presentations in Sidebar 2 illustrate this point. Presentations by plant personnel are much the same, geared for an audience with diverse information needs. The presentations by plant managers in the best practices session, which showcased NAES's experience with 7F, 501F, LM6000, and 7EA engines, offered ideas that could be adopted at most gas-turbine plants. Below are thumbnails of the Best of the Best Practices with accompanying links for greater detail.

Dogwood Energy Facility. To improve operational performance and enhance personnel safety, plant staff designed and implemented procedures and modifications to verify proper seating of gaskets for steam-drum doors and to eliminate the need for hot torqueing (CCJ No. 61, p 70).

Edgewood Energy. Plant staff took an unconventional route to outage success by selecting multiple service providers to perform maintenance and field services which drastically reduced the cost of LM6000 repairs traditionally provided by one company (CCJ No. 60, p 68).

Elwood Energy. Changes in the plant's operating profile prompted management to develop and implement a comprehensive, long-term employee training and retention program to develop the next generation of multi-skill powerplant O&M technicians and supervisors (CCJ No. 61, p 28).

Steve Hilger, plant manager, Dogwood Energy Facility

Ken Ford, plant manager, Edgewood Energy LLC

Steve Reinhart, former plant manager, Quail Run Energy Center

Quail Run Energy Center. Excessive vibration in one of the site's generator rotors caused by thermal sensitivity led plant staff and a vendor partner to conduct comprehensive inspection, testing, and repairs that resulted in a successful return to service within proper design parameters (CCJ No. 61, p 86).

2. Vendor presenters and their topics

- Bruel & Kjaer Vibro, *Gas turbine balancing and vibration analysis.*
- S T Cotter Turbine Services Inc, *The runway alternative for generator rotor removal.*
- The El Group Inc, *NFPA 70E electrical arc flash.*
- Emerson, *New technologies for the global power industry.*
- Nalco Water, *Minimizing iron transport.*
- Orr Protection Systems Inc, *Improving the life safety of CO_2 fire extinguishing systems.*
- Power Emissions Group, *Catalyst 101.*
- Power Plant Services, *PPS reverse engineering.*
- Power Substation Services, *Hot oil reclamation on transformers.*
- SDMyers LLC, *Best monitor or best fit? Selecting between single- and multiple-gas remote monitoring.*
- Sherwin Williams Co, *Corrosion prevention.*

MHPS

As plants strive to reduce operating costs, respond to changing grid demands, and maximize revenue, digital upgrades from controls all the way to artificial intelligence will fuel their progress. Mitsubishi Hitachi Power Systems is responding to these challenges with its MHPS-TOMONI® plant solutions aimed at steadily progressing towards a smart powerplant capable of autonomous operation.

"Creating the Smart Power Plant of the Future" (for instant access, scan QR code with your smart phone or tablet, or type http://bit.ly/tomoni19 into your browser) offers generation-asset owner/operators a roadmap to the digital future and a look at the digital solutions that will be implemented in what the company calls the "world's first smart power plant" under construction at MHPS' Takasago Machinery Works.

The smart powerplant is aware of neighboring plants, grid congestion, power markets, and weather forecasts and able to provide real-time insights and recommendations based on analytics to optimally support the grid and maximize revenue from energy and ancillary services markets.

J-series Americas recap. After installing the first J-series turbine in 2017, MHPS installed 11 more machines in 2018. Four 501JAC orders booked in 1Q/19 were split between Mexico and the US. In early July, J-Power USA ordered two 1 × 1 501JAC power trains for the nominal 1300-MW Jackson Generation Project in Elwood, Ill. A noteworthy feature of this plant will be its ability to operate at less than 25% of full load while remaining in emissions compliance.

In October, Suncor Energy ordered two 501JAC engines and two HRSGs for a future cogeneration facility at the company's Oil Sands Base Plant near Fort McMurray. Finally, PowerSouth ordered a 640-MW combined cycle, powered by a 501JAC engine, for its Lowman Energy Center in Leroy, Ala, to replace ageing coal-fired units.

Siemens

Siemens says it delivered the world's first HL-class gas turbine, its SGT6-9000HL, to Duke Energy's Lincoln Combustion Turbine Station near Denver, NC. The 402-MW engine was lifted to its foundation in November 2019 and is scheduled to begin a four-year testing program early in 2020. It will operate in simple-cycle mode under real powerplant conditions. Efficiency is 43%, ramp rate 85 MW/min, inspection intervals are 33k equivalent base hours and 1250 equivalent starts.

Recent orders. RUE Vitebskenergo (Belarus) orders five SGT-800 gas turbine/generators and auxiliaries for the state-owned utility's new 150-MW Lukomiskaya and 100-MW Novopolotskaya peaking plants.

- Vietnam's Hiep Phuoc Power Co will upgrade its Heip Phuoc steam plant in Ho Chi Minh City to combined cycle with the addition of three SGT5-4000F gas turbines and related equipment, increasing output by about 780 MW to 1200 MW.
- South Korean IPP Yeoju Energy Services selects an HL-class 2 × 1 power island from Siemens to power its new 1004-MW plant in Gyeonggi Province, scheduled for commissioning in mid-2022. This is the OEM's first HL-class plant for the Asian market.
- Pakistan's K-Electric orders a 900-MW combined cycle powered by two SGT5-4000F gas turbines for its Bin Qasim Power Complex in Karachi. Project completion is expected by early 2022.
- PJSC Kazanorgsintez, one of Russia's largest chemical companies orders a 250-MW 1 × 1 combined-cycle plant that will operate on a syngas byproduct of ethylene production. The SGT5-2000E-powered plant will be built in Tatarstan.
- Specialty chemicals producer Evonik Industries orders a two-unit combined-cycle cogeneration plant for the Marl Chemical Park in North Rhine-Westphalia, Germany. The two 90-MW units will replace the last coal-fired units at the site.
- Astoria Generating Co contracts for the turnkey construction of two nominal 300-MW SeaFloat power barges each equipped with eight SGT-A65 (Industrial Trent 60) gas turbines. They will replace four existing power barges located at Gowanas Generating Station, offshore Brooklyn, NY, commissioned nearly 50 years ago.
- Compagnie Electrique de Bretagne, an affiliate of Total SA, contracts for the turnkey construction of a 446-MW combined cycle powered by an SGT5-4000F gas turbine. Location: Landivisiau, France. COD is expected in the second half of 2021.
- PowerSouth repowers the McWilliams powerplant in Covington County, Ala, with an SGT6-2000E gas turbine section replacing the existing V84.2. Results: Power increase from 102 to 114 MW, simple-cycle efficiency increase from 31% to 35%, emissions decrease from 13-16 ppm NO_x to 10 ppm.

Briefs

Generator Users Group, part of the PowerUsers family, elects Dave Fischli of Duke Energy chairman for 2020 and Jeff Phelps of Southern Company vice-chair.

Emerson completes the purchase of Intelligent Platforms from GE, enabling Emerson to expand its capabilities in machine control and discrete applications. IP's portfolio of cloud-connected controllers and devices for smart plants will complement Emerson's Plantweb™ digital ecosystem.

In related news, the city of Fremont (Neb) Dept of Utilities selects Emerson to replace existing controls with automation technology designed for widely distributed assets—including power generation and delivery and water/wastewater collection, treatment, and distribution.

The company also selects Dragos Inc to collaborate on cybersecurity protection for the power and water industries.

Cassa Depositi e Prestiti appoints Ing Giuseppe Marino CEO of Ansaldo Energia, a subsidiary company through CDP Equity. Marino was Hitachi Group's COO.

Conval, a global leader in high-performance severe-service valves for HRSGs and other demanding applications, announced the following personnel changes over the last several weeks: Mike Hendrick, VP global marketing and sales, well respected by powerplant owners and operators, has retired. President Don Curtin has appointed Don Bowers Jr, who had been sales director since spring 2017, to replace Hendrik. Rod Alford is the company's new Midwest regional manager.

Izzy Kerszenbaum and Geoff Klempner, known to generator owner/operators worldwide, announce their five-day technical training program, "Design, Operation, and Maintenance of Large Turbo-Generators." Jan 13-17, 2020, in Irvine, Calif (www.izzytech.com). Course is based on information from their textbook, "Handbook of Large Turbo-Generator Operation and Maintenance," third edition.

Rodger Anderson, perhaps best known in the industry for his compressor-vane pinning repairs, has retired from DRS. Core Tech Turbine Services has been licensed to provide ongoing support for this product line, including new pinning projects. The company's engineering manager, Joel Holt, a former 7F user, was involved in one of the first pinning projects in 2003.

Sal DellaVilla, CEO of Strategic Power Systems Inc, is appointed managing director of the Gas Turbine Association, effective Jan 1, 2020. He replaces William H Day, who served in that position since the group's inception in 1995. Day will serve as a strategic consultant for the GTA going forward. For more insight, please read the commentary on p 3.

Paul Tucker, president of Houston-based TBS Manufacturing/FIRST Consulting & Inspection Services, called to say his company now manufactures accessory couplings for GE Frame 3, 5, 6, and 7 engines, as well as for some Westinghouse and Siemens gas turbines. Product includes the shaft as well as the external shaft hub with an external spline as well as the coupling hub itself, which has an internal spline. Companion service offering includes repairs to shafts/couplings fit for further use.

Tucker, one of the industry's preeminent turbine mechanics, also spoke to the availability of custom 7F and 7EA inner and outer crossfire tubes using a new manufacturing process that is said to offer longer life than the traditional rolled-plate/seam-welded design. TBS's crossfire tubes are made from solid bar stock (L-605) to avoid the typical out-of-round condition near the end of life.

Jeff Bause, a familiar face and frequent participant/presenter on HRSG cleaning at gas-turbine user group conferences, is appointed COO of Groome Industrial Service Group.

MTU Aero Engines celebrates 50 years of service to the industry. Engineers from Daimler-Benz and MAN Turbomotoren GmbH joined forces in 1969 to collaborate on engine technology. The company's journey through a half century of innovation, and a look at the propulsion technologies of tomorrow, are chronicled in articles, videos, photo galleries, and interactive specials at www.aeroreport.de.

Hytorc's Lithium Series II electric torque tool, said to be the next revolution in bolting technology, features a lightweight 36-V battery with built in TorcSense™ technology driven by an all-new brushless motor. Tool is compatible with conventional sockets and the company's washers and nuts. Models go to 5000 ft-lb.

Liburdi's advanced repairs for critical turbine components—including buckets, nozzles shroud blocks, combustion liners, transition pieces, and fuel nozzles—extend the lifetimes of these parts, thereby reducing O&M costs and deferring—possibly avoiding—the purchase of new components.

Protecting electrical insulation against moisture, dirt helps keep outages on schedule

By **Neil Kilpatrick,** GenMet LLC, and **James Michalec,** J R Michalec Consulting LLC

The negative impact of moisture on electrical equipment has been a serious concern since the beginning of the industry. Most senior plant personnel have had experiences with low insulation resistance (IR) and low polarization index (PI) values that have extended an outage.

One example concerned a large outdoor generator alongside a major river in the South. The unit's rotor was removed in August and on the turbine deck.

A retaining-ring inspection was being conducted to check for the possibility of stress corrosion cracking (SCC). Water was found coming out from under the ID of the retaining rings. The rotor appeared dry and had not been exposed to rain. The root cause was condensation on the rotor surfaces, but primarily water stored in the capillaries formed by the winding components.

Water storage in capillaries is a complicated phenomenon, one studied by a major OEM while investigating SCC of certain retaining-ring steels (sidebar). The findings relating to moisture collection in capillaries are the focus of this article.

Where water collects in rotating machines. Water will accumulate on any surface of the machine if that surface reaches dew-point (100% relative humidity) temperature. Water also will be stored anywhere a capillary exists. On the stator, capillaries would include the spaces between layers of tape on conductor insulation, between conductors and core, and between core laminations. On the rotor, capillaries exist between field winding turns, between turns and ground insulation, between wedges and field body, and in any cracks that may have occurred in the metallic parts.

Impact of moisture on electrical insulation. The primary negative impact of moisture is reduction of integrity of insulating materials—that is, a reduction in IR and PI. If these values are low there is risk of insulation failure when operating voltages are applied to the windings. Because insulation failure is likely to lead to costly forced outage, impacts of moisture accumulation can become extremely important.

Moisture contamination. Preventing moisture accumulation on component surfaces and in capillaries is not necessarily easy to accomplish, nor are the prevention requirements necessarily easy to understand. Relative-humidity control alone is insufficient to assure that components do not become contaminated by moisture.

It is necessary that both dew-point temperature and component temperature be known. Keeping the temperature of the components about 20 deg C higher than the dew-point temperature will assure that contamination is unlikely to occur. Otherwise, abrupt changes in atmospheric conditions may result in contamination. Outdoor storage will, of course, be more vulnerable to rapid condition changes.

Prevent moisture accumulation. During generator operation, moisture accumulation normally is not an issue because of the machine's inherent heat generation and ventilation activity. An example of an exception might be a cooler leak spaying raw water directly onto insulation; however, such exceptions are not considered here.

During shutdown, two conditions may exist: machine assembled and machine disassembled. For the assembled condition, there also are two conditions: hydrogen-cooled and air-cooled. For the former, it is necessary only to maintain a positive hydrogen pressure with dry gas.

For air-cooled generators, the challenge is much greater. Many designs

1. Temporary enclosure protects generator field from moisture and airborne dirt

2. Portable clean room is equipped to control atmospheric conditions

The basics of capillary action

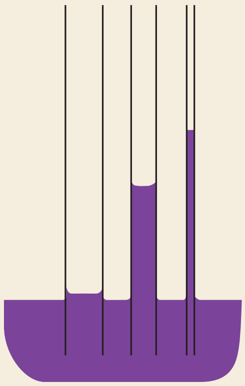
Capillary action is not well understood by many power-industry personnel. Without a strong background in related studies, the intuitive explanation of capillary action almost certainly will be guessed wrong. Capillary action occurs because water molecules want to stay close together. The resulting adhesion causes the molecules to be attracted to each other but also to adhere to other substances.

In a small tube, or a set of parallel walls that are sufficiently close together, this adhesion will cause a force on the liquid at the edges and result in a meniscus which turns upward. The surface tension acts to hold the water surface intact. Capillary action occurs when the adhesion to the walls is stronger than the cohesive forces between the liquid molecules. The height to which capillary action will take water is limited by surface tension, the diameter of the tube (or plate spacing), the relative humidity, and fuel viscosity. The same effect occurs with both horizontal and vertical capillaries.

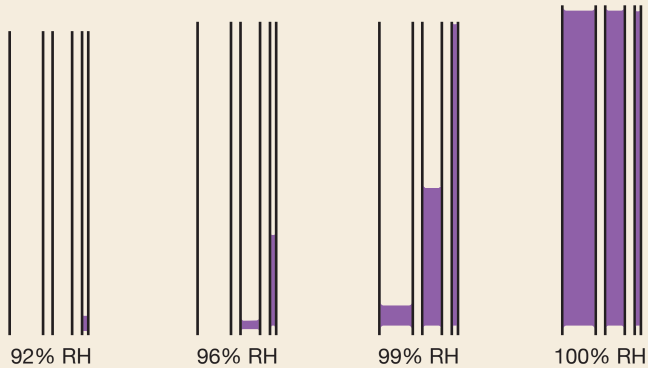
A moist atmosphere (dew-point temperature approaching the equivalent of 92% relative humidity) will allow capillary action to take place. Fig A illustrates capillary action in three tubes of different diameter; Fig B illustrates the effect relative humidity has on capillary action.

The conditions under which filling occurs are peculiar. With dry air (no humidity) at the end of the capillaries, the tubes contain only air; there is no capillary action. With the humidity increased to the point of moisture condensation, water starts to condense inside the smallest tube. This phenomenon only begins to occur at about 92% relative humidity (RH).

Increase the humidity further and water starts to condense in the next larger tube; meanwhile, the smaller tube has taken on more water. With nearly saturated air at the end of the capillaries, water starts to condense in the largest tube; the smaller tubes have taken on more water. Under saturation conditions, 100% relative humidity, the capillaries continue to fill toward maximum.



A. Typical capillary action is illustrated here



B. The higher the relative humidity above the 92% initiation point, the larger the tube capable of supporting capillary action

incorporate heaters, and if they are functioning, and of sufficient size, moisture accumulation is unlikely. If not, moisture accumulation is likely to occur unless corrective action is taken—for example, forced ventilation with heated air, forced ventilation with dehumidified air, or a combination of both.

When a machine is disassembled and the rotor removed from the stator, preventing the ingress of moisture becomes more complicated. For the stator, on designs where the end covers can be replaced by temporary (plastic sheet or wood) covers, forced ventilation with heated and/or dehumidified air should be adequate.

For the rotor, on high-speed generators—for example, 2-, 4-, or 6-pole machines—an enclosure should be provided. This may be as simple as a temporary plastic sheet enclosure or a more complex transportable enclosure (Figs 1 and 2). In every case where humidity can be controlled using dehumidifiers and/or heaters (and cleanliness assured), it should be done. On low-speed units, such as large hydro-generators, control of humidity (and cleanliness) can be challenging.

Drying wet insulation. Because moisture contamination of insulation has been a major problem on rotating machines, manufacturers typically have provided drying instructions with their service manuals. But a few comments are in order:

- In order to dry the machine components, they must reach a bulk temperature higher than the surrounding dew-point temperature.
- Moisture on machine surfaces is relatively easy to remove once exposed to warm dry air.
- The nature of capillary action is such that removal of water from a capillary is difficult once accumulated.
- Perhaps the easiest way to remove moisture is by machine rotation. The windage loss provides heat and rotation provides ventilation. This method, of course, is not effective on a closed ventilation machines—such as hydrogen-cooled generators.
- At standstill, drying can be accomplished by supplying dry air and/or heat. This may become rather complicated and may take several days to accomplish necessary moisture removal to reach satisfactory insulation resistance and polarization index.

Wrap-up. Moisture contamination of insulation systems can have highly negative effects on the insulation. Surface moisture can be removed rather easily, but moisture that has accumulated in capillaries is inherently difficult and time-consuming to remove. In general, it is far better to keep insulation dry than to allow moisture ingress and the need for a costly drying operation. CCJ

Acknowledgement: Clyde V Maughan contributed to this article.

Low-plasticity burnishing steps into limelight for turbine parts repair

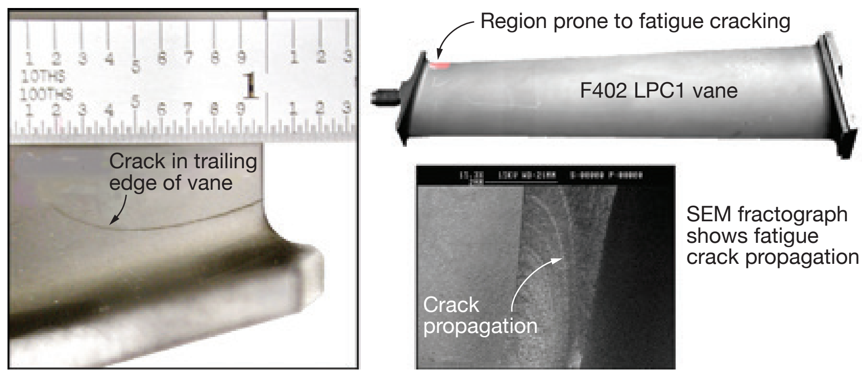
Many combined cycle (CC) turbines working in more and more aggressive operating regimes face the added challenge of shrinking O&M budgets. From an accountant's view, fewer operating hours for older machines equates to less need for O&M funds, however wrong-headed that may be from the deck-plates view. Thus, the hunt for less expensive but reliable, and potentially even superior, component repair services and providers continues unabated.

Focus here is on low-plasticity burnishing (LPB), a patented shop technique to repair a variety of fixed and rotating gas- and steam-turbine parts suffering from foreign particle damage, stress corrosion cracking, fatigue, fretting, many forms of erosion, pitting, and surface defects generally (Fig 1).

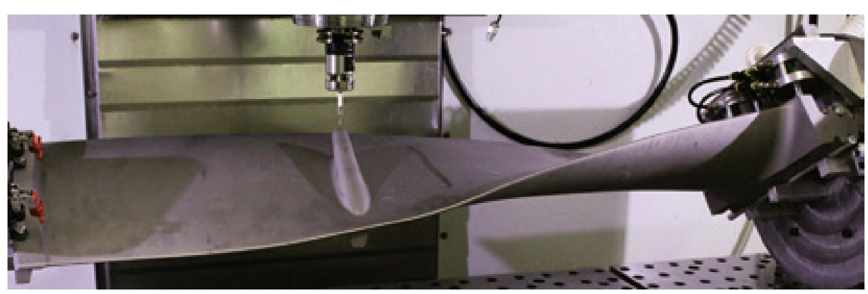
LPB may be unfamiliar to many CC facility staff because it traditionally has been applied private-label, so to speak, through OEMs and other non-OEM services firms. Now, Lambda/Surface Enhancement Technologies (SET), Cincinnati, Ohio, which possesses the patents, intellectual property, machines, and tooling, and two decades of shop experience, is offering LPB-based repairs directly to owners/operators. The company traditionally had been focused on the aviation and defense industries.

LPB has been specifically proven in the field as an effective repair technique for CC plant applications including, but not limited to:

- Erosion damage on R0 compressor blades of the 7FA and 9FA gas turbines.
- Foreign particle object damage (FOD) of seventh-stage compressor blades in 501F gas turbines.
- Stress concentration damage of first-stage compressor blades in Taurus 70 gas turbines.
- Moisture-induced erosion and high-cycle fatigue damage of low-pressure steam-turbine blades (Fig 2).



1. LPB repair has been applied commercially to a variety of turbine components over the last two decades through OEMs, but the repair is now available direct to owner/operators



2. Low-pressure steam-turbine blade undergoes low-plasticity burnishing repair in the shop

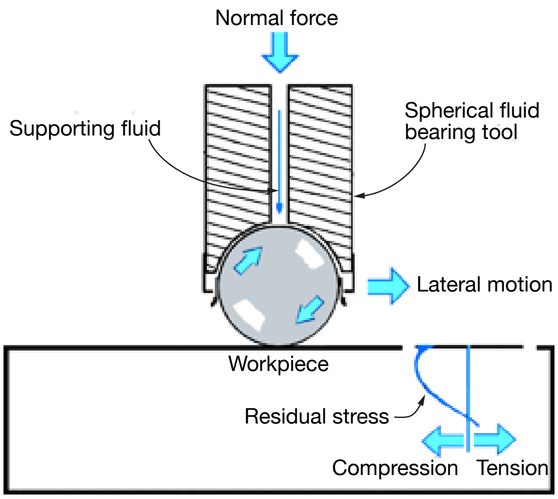
- Fretting damage on rotor through bolts in 501G-class gas turbines.

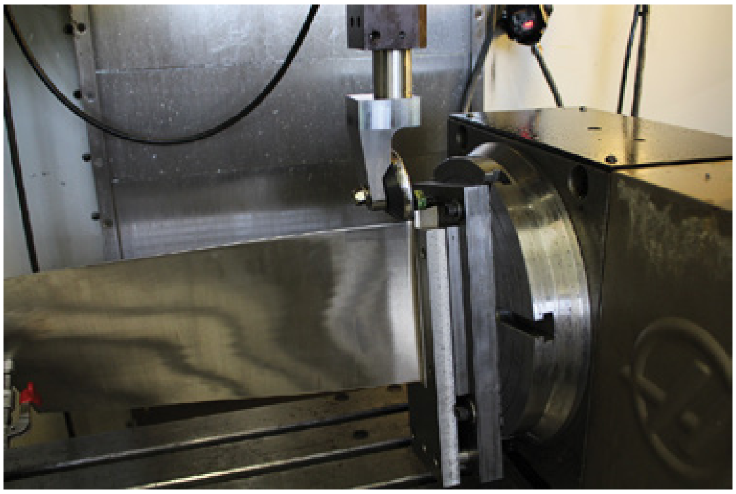
A representative of one 7F owner/operator told the editors that they tested several LPB-repaired R0 blades. . ."ran the hell out of the units" and the blades performed well.

In aviation, LPB has been applied repeatedly for similar damage mechanisms to at least a dozen major components of aero gas turbines—including blades, vanes, and discs at multiple stage locations. Many aeroderivative gas turbines in power applications are based on stationary versions of these same machines.

EPRI conducted a study several years ago with LPB and a competing technique, laser shock peening (LSP), applied to gas-turbine compressor blades subject to erosion, corrosion, and impact damage—especially in machines with evaporative coolers and direct water injection and fogging for boosting turbine output. Lambda/SET did the LPB work for this program.

According to the summary of the EPRI report, issued in December 2015, "LPB was used to apply an equivalent compressive patch to the leading edge of retired blades. The burnished blades' residual-stress measurements met or exceeded the compressive layer depth and magnitude of the originally laser-shot-peened compressive patch." Further, the report notes, "the plant owner could readily implement this enhancement on spare components. Typically components would be shipped to a





3. LPB is a simple, but powerful, repair solution. It is purely mechanical in nature, and the process is highly controllable. Single-point LBP tool is shown at the left, the processing of a 7F R0 airfoil at right

specialized shop to implement the compressive patch."

CCJ covered early results with a rotor through-bolt LPB repair in "OEM engineers speak to issues, solutions, technology developments for F, G, H frames," 3Q/2015. As noted on p 34 of that issue, "Because the most recent bolt fracture occurred on a rotor that had some mitigations applied, robust discussion ensued regarding the effectiveness of those mitigations as well as on the latest recommendation of low-plasticity burnishing. LPB is a surface treatment intended to greatly improve a through-bolt's margin against both fretting and HCF crack initiation and propagation by adding a deep compressive residual stress field to the bolt surface."

A review of LPB testing was provided at Siemens Energy's first customer conference for F/G/H owner/operators in September 2015. It reported favorable results on fatigue resistance tests and open actions for additional ongoing tests—such as material debit and thermal mechanical exposure.

In some cases, owner/operators can reduce the number of times a set of parts (blades, vanes, etc) needs to be overhauled, and correspondingly the amount of time the unit has to be shut down for the work. For example, test results presented at PowerGen 2019 show that R0 blades nominally exhibiting only 0.008 in. erosion damage tolerance without any surface treatment can be LPB-treated to increase the damage tolerance to a 0.040 in. depth and be reused instead of being replaced. This could lead to the huge cost benefit of reducing the total number of shutdowns for this repair from five to two over the service life of the compressor blades.

Simply, in the LPB technique, a ball or rounded wheel is pressed into the component surface to deform the surface layer in tension, so that the material is left in residual compression after the tool passes (Fig 3). The required magnitude and form of the residual stress field are achieved by controlling the force and tool position. It is purely a mechanical repair.

LPB was honored as a NASA Spinoff technology for 2010 and earned recognition as one of the "R&D 100," a list of the top 100 inventions of the year. An article on NASA Spinoff's website with the unlikely title, "Burnishing Techniques Strengthen Hip Implants," notes some of the important product outcomes of LPB:

"Capable of being applied to all types of carbon and alloy steel, stainless steel, cast iron, aluminum, titanium, and nickel-based super alloys, and many components with odd shapes or forms, LPB can be performed in a machine shop environment, in the field, and by using robotic tools. One important feature of the LPB application method is that it is highly controllable and can be validated to ensure that the process is applied to every part."

Other attributes of LPB, compared to other options, are:

- Depth, magnitude, and distribution of the compression are designed specifically for the geometry and stresses applied to each component.
- Compression ranging from a few thousandths of an inch (comparable to shot peening) to over a full centimeter.
- FOD- and erosion-prone blade edges can be put in through-thickness high compression.
- Minimal cold work, which keeps the compressive layer more stable at high temperatures and not prone to mechanical relaxation under momentary tensile overload.
- No residual surface damage, and therefore no finish machining or grinding; LPB leaves a mirror-like finish on all processed parts, and metallographic examination reveals no damage to the grain structure following treatment.
- Closed-loop control process with minimal operator intervention is continuously monitored with typical six-sigma statistical process control, ensuring a uniform repeatable production process.
- Only one processing cycle is necessary to achieve full depth of compression, which reduces costs and shop time.

Finally, to introduce LPB and its applications to CC facility staff, Lambda/SET plans to participate in the following user groups in 2020: 501F, Western Turbine Users Inc, 7F, Combined Cycle, and CTOTF. CCJ

TURBINE TIPS, No. 5 in a series

How to conduct a firing check on a fuel pump to confirm proper operation

By Dave Lucier, PAL Turbine Services LLC
www.pondlucier.com

Turbine Tip No. 5 from the PAL O&M solutions library applies to General Electric Frame 5 models L, LA, and M equipped with Oilgear fuel pumps, Frame 5N machines with New York Air Brake pumps, and 5P and 5PA gas turbines with Roper Pump Co equipment.

This is a follow-up to Turbine Tip No. 4 in the last issue (CCJ No. 61, p 42). That article dealt with a failing pump operating at 100% speed (full speed/no load, 5100 rpm). This article looks at a fuel pump that does not function reliably at "firing" speed (20% of rated speed).

GE control specifications provide valuable information for testing at firing speed. For a Frame 5L operating at 1000 rpm, expected fuel flow from the flow divider to the 10 combustors is 2.2 gpm. This means each combustor should receive 0.22 gal (approximately one quart) for a 60-sec firing attempt.

First steps: Remove all 10 check valves from the engine and divert fuel flow (Fig 1) to the test rig (Fig 2). By rerouting fuel via the clear plastic lines, the "false firing" attempt will collect all the fuel. Without check valves, fuel pressure is negligible.

Safety tips: Disconnect spark plugs and flame detectors before the test. Also, warn personnel that the CO_2 fire protection system remains charged in standby.

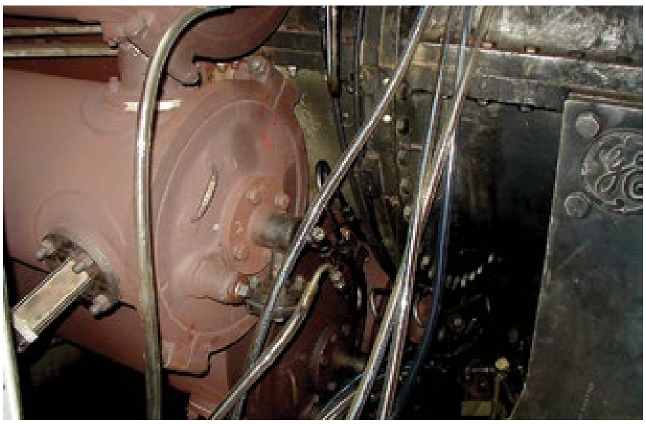
The test is conducted as follows:

1. Start the gas turbine with selector switch **43** in **CRANK** and run up to 1000 rpm.
2. Confirm firing time is set for one minute on timer **2F.**
3. Move the switch to the **FIRE** position, and time for 60 sec using a stopwatch.
4. Fuel is diverted to the 10 jugs shown for the "false firing" period (Fig 3). The fuel flow expected is 10 × 0.22 = 2.2 gpm. Thus, each container should collect approximately one quart of fuel. Final step is to empty the fuel lines into each jug. Note that the expected maximum rated fuel flow with the engine operating at 5100 rpm is 37 gpm.

Figs 4-6 show the three types of fuel pumps (Oilgear left, New York Air Brake center, and Roper Pump Co right) GE used on its Frame 5 gas turbines during the US production period from 1965 to 1990.

The test described works equally well for all GE Frame 5s manufactured during this 25-year period. In all cases, fuel flow at "firing speed," which depends on the engine model, will be less than 3.5 gpm.

Of course, Frame 6B and Frame 7B, C, and E machines all require more fuel flow at firing speed, but not so much that this test rig would not



1, 2. Check valves removed, fuel is diverted from the engine via clear plastic lines (left) to the holding jugs at the right (one per combustor). Acknowledgement is due retired Plant Operator Art Sulham of Central Vermont Public Service Co who conceived and built the first such test apparatus, which he demonstrated to Dave Lucier three decades ago in Rutland, Vt. PAL Turbine Services' rig is a variation of the original

EXPECTED OPERATING STROKES AND SYSTEM PRESSURES

LOAD CONDITION	VCO PSIG	STROKE-V1 INCHES	GOV. STAB. CURRENT-MA	NOZZLE PRESS PSIG
Firing	90	.100		65
0 FSNL	80	.08	4.5	170
2/4 (Base)	115	.15	9.0	230
2/4 (Peak)	120	.16	9.5	240
4/4 (Base)	160	.24	14.0	345
4/4 (Peak)	175	.27	15.0	390

3. Control system settings for the Frame 5L fuel flow test as found in the OEM's control specifications

4-6. Three types of fuel pumps found on GE Frame 5 gas turbines: Oilgear is at left, New York Air Brake in the center, and Roper Pump Co at the right

be useful. Roper Pump Co and IMO Pumps are found on the 6B, Denison Hydraulic equipment on 7Bs, and Warren Pumps on 7C and 7E engines.

In conclusion, the value of this test is in confirming that the fuel pump and flow divider are working properly. The check valves removed should be disassembled, cleaned, reassembled, and tested. Electricians should test the spark plugs and UV flame detectors.

This definitive test is easy to perform and produces indisputable results. PAL Turbine Services recently brought its test rig and a spare fuel pump to a Frame 5 outage in Pennsylvania. Good thing. The existing pump was tested and found lacking in fuel flow at the 1000-rpm firing speed. It was replaced with the spare (reconditioned) pump and tested before system recommissioning.

Lesson confirmed: Proper preparation is critical for maintaining planned outage schedules. CCJ

Adapt advanced process control for tighter regulation of SH, RH temperatures

By Steve Seachman, Electric Power Research Institute

Many combined-cycle units originally designed for baseload operation are now required to cycle frequently, with still more starts and more rapid ramping over a wider range when in automatic generation control (AGC) mode. As a result, a significant number of heat-recovery steam generator (HRSG) failures experienced worldwide have been at least partly attributed to inadequate steam attemperator control.

To avoid HRSG damage caused by poor control of steam temperature, some combined cycles operate at reduced steam temperatures and pay a thermal-performance penalty. Inadequate temperature control also can result in excessive spray flow reactions, risking damage from saturated steam and large variations in steam temperature at the attemperator outlet.

The two major objectives in the control of steam temperature are minimizing both the extent and periods of high temperature, and avoiding spraying to saturation temperature.

The former reduces component life because of thermal creep; the latter often is associated with cracking in downstream piping and in uneven tube heating and cracking.

To improve thermal performance and reduce damage industrywide, a need exists to demonstrate better process control of combined-cycle attemperation.

The temperature control design typically installed in HRSG systems is very similar to that used in baseload drum boilers, and it has been the standard control structure for several decades. Improvements to distributed control system (DCS) technology have allowed enhancements—such as the calculation of steam properties, inclusion of nonlinear parameter adaption, and improved filtering and dynamic feedforwards.

Nonetheless, the operating strategies demanded of many combined-cycle units—including very fast startups and V-style load ramp profiles—have brought steam-temperature control to the fore as an operational limiting factor.

By introducing an advanced steam-temperature control strategy, HRSG operators might avoid periods of high temperature through the anticipatory action of sprays that can operate over a smaller flow range and have complementary influences to the main-steam temperature and pressure setpoints to reduce heat uptake disturbances. Benefits might include reduced temperature deviations, improved stability, and reduced actuator activity—all of which provide support for more flexible operation.

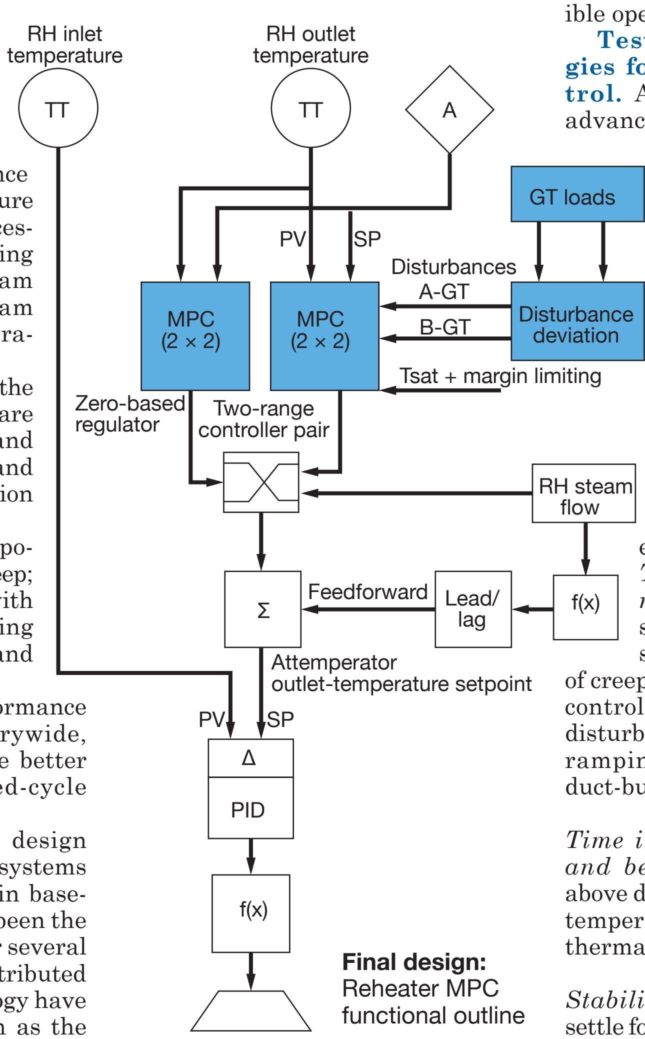
Testing of advanced strategies for steam temperature control. A study by EPRI surveyed advanced control system strategies for combined-cycle units. The project then selected two approaches for testing through simulation, subsequently testing one on a 2 × 1 combined cycle. The study and its findings are described in the EPRI report "Steam Temperature Control for Combined-Cycle Units: Survey and Testing of Advanced Strategies (3002106316)."

The following five performance criteria were considered:

Temperature deviations during ramps and disturbances—measured as peak deviation from setpoint. This is an indication of creep-life cost and the ability of the control to respond quickly to large disturbances—such as fast start, load ramping, frequency response, and duct-burner operation.

Time in temperature ranges above and below design. Temperatures above design produce a creep-life cost; temperatures below design produce a thermal-efficiency cost.

Stability is determined as time to settle following a load ramp or setpoint



Final design: Reheater MPC functional outline

change. Settling time is commonly defined as the time to fall and stay within defined steady-state deviation limits.

Operation at or near saturation. The controls should successfully steer the attemperator outlet temperature away from saturation by holding to a set margin above saturation, without causing instability or large excursions.

Actuator activity. Excessive activity of motorized actuators can cause overheating and early wearing of bearings and gearboxes. Pneumatic actuators can also suffer premature wear and loss of accuracy with high levels of activity. In both cases, valve glands can wear and leak if operated more than the design duty.

The typical design of steam-temperature control on HRSGs is a cascade configuration, whereby a primary (outer loop) PID (proportional, integral, derivative) controller regulates the superheater (SH) outlet temperature by generating a setpoint for the attemperator outlet temperature.

The attemperator outlet temperature then is controlled by a fast secondary (inner loop) PI (proportional plus integral) controller that modulates the spray-water valve opening to attenuate any upstream disturbances (such as duct-burner operation) and to track the setpoint generated by the primary controller.

The computational capability of modern DCS processors has enabled the introduction of advanced algorithms to improve the control of complex, high-order, and interactive processes. A feature of all these algorithms is a model of the process and associated influences (either implicit, as an approximate inversion, or explicit) that direct the controller's corrective actions with greater accuracy than a conventional PID controller, provided an appropriate set of process and influencing models has been determined.

The potential advantages of advanced HRSG steam-temperature control lie with the ability to reduce temperature deviations during startups and load ramping and other disturbances and to reduce overspray events by beginning to act earlier.

These four controller options were considered for the study:

Smith Predictor. A well-proven, dead-time compensation design that would use a standard block in the DCS to augment the PID controller.

Modified Smith Predictor a/k/a Advanced PID (A-PID). Similar in design to the Smith Predictor but with a plant model that also reduces the time of the response presented to the PID controller. The model compensation block is built up from existing DCS blocks. It has been applied successfully on several coal-fired plants.

Model Predictive Control (MPC) is well-proven in process-industry applications and already applied on some thermal plants. The controller has a concise response-model definition capable of capturing high-order response dynamics, with inherent capabilities to include limits and cost metrics in the control design. MPC control of combined-cycle plants and HRSGs has been the subject of modeling and research, but little exists in the way of published test methods and results from practical plant applications.

State Feedback with Disturbance Observer, which is offered as a module by some DCS vendors. It has been demonstrated on SH temperature controls for drum and supercritical units. It could be built up from standard DCS blocks, but no published procedures exist for setup and tuning.

A-PID, MPC. The project team selected two controller designs for the study: A-PID and MPC. The former was chosen because of its successful application on coal-fired boilers and because it required no advanced control modules (provided the DCS has a delay function block). A-PID is an extension of the well-known Smith Predictor, a model-based controller that effectively eliminates process response dead time, enabling controllers to be tuned with higher gain.

This is achieved by estimating the expected response to a controller output change, but with the dead time removed. The resulting signal is added to the process feedback so the controller "sees" a response to its output actions very quickly and responds appropriately.

Then, after the dead time has elapsed, and the actual process begins to respond, the Smith model's output is progressively removed with the same time constant as the process. This mechanism gives a smooth crossover from model to actual process input.

The MPC was selected for its potential to model and reject two independent disturbances, because it is capable of modeling "inverse" SH outlet temperature dynamics seen during load ramps. Plus, MPC modules were available for testing at the host site's DCS, provided as part of an advanced control suite.

MPC has been growing as a powerful control concept, with many applications over the last three decades. The most prevalent application has been in chemical, refinery, and other process industries, but its capability to deal with interactive processes and its inherent ability to compensate for dead time and high-order processes lead naturally to powerplant control applications—such as steam temperature, steam pressure, and drum level control.

Simulation tests. Both the A-PID and MPC designs initially were tested with a PC-based plant/controller simulation (with Simulink™ modeling environment) to ensure the control structures functioned as expected and potential implementation issues were identified. The advantage of PC-based simulations is having unrestricted access to the models and enabling scenario testing faster than in real time. Success of this phase to test the controllers depends on the level of process model static and dynamic accuracy and controller emulation fidelity.

Subsequently, the two designs were configured on virtual DCS controllers and tested at the host site's replica operator training simulator. Goals of the onsite simulator tests were the following:

- Compare the control performance of the options.
- Check practical aspects of the implementation (signal tracking, override functions, bumpless controller switching, etc).
- Establish procedures and methods for process model identification and controller tuning.

Following extensive testing, the MPC design was selected for deployment at the plant. The design was installed and commissioned on one HRSG reheater temperature control loop. This arrangement enabled a comparison between the performance of the MPC (A-HRSG controls) and the original PID (B-HRSG controls).

A control switching facility also enabled a comparison to be made between a retuned PID control and the new MPC design on the same HRSG. Wide-range load-ramp tuning and benchmark tests were performed, providing data for a quantitative performance comparison.

Results

Following MPC tuning, A-HRSG reheater MPC performance was demonstrated as significantly superior to the existing PID control still operating on the B-HRSG. It was also shown to be more stable and faster responding than the retuned and optimized PID control of the A-HRSG.

The A-PID controller was relatively easy to tune with the system identification tuning calculation tools. The design gave a fast, stable control capability. Some tracking issues related to cascade control windup and resetting contributed to the inclusion of a saturation protection limiter were particular to the DCS and not necessarily an impairment to the design concept.

The A-PID design, based on a modified Smith Predictor, is best suited in applications with large dead time and high-order process responses, as noted earlier—such as those found on large drum boilers with a single-stage desuperheater. Investigators found that the final stages of the HRSG superheater and reheater have lower-order responses; however, they are more prone to disturbances because of their relatively lightweight tubing and rapid variations in gas temperatures during startups and load ramps.

For the SH controls, the split-range valve design performed well, but in its present form, the A-PID did not achieve significantly improved disturbance rejection on the simulator. The reheater (RH) temperature control with the A-PID was superior to the standard PID for both stability and disturbance rejection. This is because the response model of the RH was of higher order, and so some of the features of the delay and order-reduction functions came into play.

The MPC facility's capability to input two independent disturbance variables inputs was used to advantage on the reheater to reject the disturbance caused by load changes on both the A and B gas turbines (GTs). The SH outlet and disturbance response models vary significantly over the GT load range. Because the MPC is not adaptive, two MPCs were used with a fuzzy blending (weighted average) function to slide between controllers, which were sufficient to cover the entire load range.

For the MPC design to provide significantly superior performance during load ramps, the structure must include an output feedforward signal predicting the expected attemperator outlet temperature. The MPC design, as implemented for the tests, provided significant improvement to temperature disturbance deviations, time to settle, periods away from setpoint, and overall stability. The final design for the reheater MPC functional outline is shown in the figure.

Benefits

Improved temperature control. When the MPC controller is applied in a regulator configuration with attemperator outlet setpoint feedforward, and full use is made of the disturbance inputs, the MPC provides a stable and very responsive control design.

Opportunity to improve steam-cycle efficiency. The MPC provides a significantly narrower band of temperature deviations over time. Such an outcome allows operators to raise steam temperature setpoints without decreasing creep life, thereby reducing unit heat rate and fuel consumption.

Reduced actuator activity. The MPC can be adjusted to reduce reversals in the attemperator outlet temperature direction without compromising temperature control performance. Thus, actuator activity can be reduced, together with valve and actuator wear. For motorized modulating actuators, this capability would reduce bearing and gearbox wear as well as the risk of motor overheating.

Supporting unit flexibility. Implementing MPC may provide an effective strategy against damage risk to both high-temperature HRSG components and field actuators. Therefore, it could play a significant role in supporting flexible operations, particularly if the need for more frequent ramping and startups increases as more unregulated generation enters the energy mix.

Reduced saturation events. MPC provides the opportunity to increase temperature setpoints, thereby reducing the number of saturation events in steam piping and tubing and prolonging the service lives of these components.

The bottom line: The study demonstrated the application of advanced steam-temperature control strategies on a combined-cycle plant, and provided quantitative assessments by benchmarking performance against the classical cascade control structure previously applied at the host site. CCJ

About the author

Steve Seachman is principal technical leader in the Instrumentation, Controls, and Automation Program for the Generation Sector at the Electric Power Research Institute.

How to make sense of a water analysis report

By Wendy Wong, SNC Lavalin Constructors Inc

In successful powerplant projects, either in the early project bidding or the engineering execution stage, before designing any water distribution, production, or treatment system, you must know the water. The only way to fully understand the water type and its characteristics is with a thorough study of the water analysis report.

You must recognize the reliable parameters, know which data need re-examination, and understand the water's traits. Working early in the planning stages with good data from the water analysis report reduces engineering risks and ensures reliable water systems will support plant operations.

Water can be defined by its physical appearance (for example, color, suspended solids, and turbidity) and its biological and chemical properties. Water analyses should be performed by certified water laboratories. Be mindful that not all laboratories can perform all the tests required. This can be an issue when specific toxicity tests (such as for the surfactant Triton X-100) are needed, or when a minimum detection limit is required.

This was the case for a combined-cycle plant in Connecticut. A zinc detection level of two decimal points or better was required for the water supply to the cooling towers because the plant's towers had a zinc limit for wastewater discharge of 1 mg/L or less.

Best practices to mitigate water collection challenges:

- Properly collect, sample, or preserve samples for accurate water quality to avoid plant design errors.
- Obtain sample bottles and preservatives from the laboratory conducting the required analyses.
- Use glass containers where oil or grease is present.
- Use amber-colored plastic containers (where use of plastic containers is permissible) to protect sample constituents, which can break down in sunlight.
- Pack samples in a cooler with ice for immediate shipping to the laboratory.
- Confirm maximum holding time with the lab to ensure representative results from the tests.

Another lesson learned: Sample residual chlorine, pH, and temperature at the sampling point with calibrated instruments to best reflect actual properties. Residual chlorine may be consumed by the living organisms in the water sample during shipping.

Water analysis report. To make sense of the water analysis report, it's important to know the water source that feeds the sampling points, and where and when the samples were taken. All the physical characteristics should be examined together to provide an overview on corrosivity, particle's physical size, scaling potential, and fouling tendency of the water. The biological and chemical properties indicate the choice of chlorination, biological organism activities, dissolved salts content, scaling potential, fouling potential, reactivity, salinity, and toxicity of the water.

Missing parameters. Many powerplants in the US and Canada use a city water supply. Unfortunately, only a few parameters are required to be reported to the public—such as residual chlorine, conductivity, coliform, etc. So even if the water supply comes from a city's potable water network, which is a good and clean water source, use of a water-treatment-system design based on a limited water analysis can spell disaster.

For example, the system may not satisfy power requirements under all operating conditions, perform the various operations needed, or hold to certain parameter limits in the wastewater discharge permit because the concentrations of some constituents in the water supply are unknown.

Quality variance. Seasonal and weather-related changes and facility production schedules (for grey and wastewater) can impact water quality. While drastic changes in water temperature occur between the cold and warm months, not checking water temperature onsite can create problems, especially when designing the biological treatment, cooling water, and reverse osmosis (RO) systems, or any treatment process that depends on water temperature.

To illustrate: The capacity of high-pressure RO pumps/motors may be insufficient when operating in winter if the design temperature is based on warmer samples taken in summer. The design team should obtain at least one water sample per season or at varied days/times to ensure representative samples are collected.

The design engineer also should consider weather-pattern changes and the future impacts to water quality when designing a new plant and using surface-water data 10 years or older. They may not be representative of the current water condition. New land developments in the area can impact surface water analysis as well.

Worst-case scenario. The design's technical specifications in a request for proposal sometimes summarize historical water analyses and provide only the worst-case scenario based on the peak value of each constituent without providing the individual water analysis. Result: Water-treatment bidders likely will offer larger or more complex equipment than necessary, and it will cost more.

Also, when the source water's characteristics and trends are not fully understood, unnecessary equipment and more complex, high-maintenance systems could be added to a new plant and they may produce more wastewater.

When design engineers have sufficient water data and recognize the trends, they can design a plant to accommodate the worst-case scenario with minimum impacts to costs. Whether by recirculation, blending, providing temporary storage, or operating the standby water-treatment trains, they can provide sustainable, cost-effective solutions.

Other general guidelines. A water analysis report can be unreliable. Typos, use of the wrong units of measurement or confusing nomenclature (for example, mg/L versus mg/L as $CaCO_3$), expired samples, or simply the wrong analysis can result in incorrect reports.

Guidelines circulated in the industry for verifying the reliability or plausibility of a water analysis report that you may find helpful are provided below. Listed in decreasing order of reliability, they were published in 1991 by G Solt under Dewplan (WT) Ltd, which later became part of Veolia Water.

1. Natural water from the streams, ocean, and underground where pH is around neutral, the water shall be chemically balanced—that is, the sum of the cations equals the sum of anions.
2. Conductivity should roughly equal the total cations multiplied by 1.6 if in ppm $CaCO_3$.
   If a total-dissolved-solids (TDS) value is given, it should equal the total cations, assuming equivalent weight of between 50 to 70.
3. Bicarbonate, HCO_3, is often about the same as the calcium ions, Ca_2+. If it is more than the total hardness (Ca_2+ and Mg_2+), be suspicious.
4. Ca_2+ concentration is generally between four to eight times the Mg_2+.
5. In the absence of reliable data, Na+ and Cl- concentrations can be assumed the same, especially if either of them is high.

In sum, designing water distribution, production, and treatment systems requires reliable and accurate data. Bid requests with limited parameters or insufficient water analyses may bring in proposals with big cost differences from water treatment vendors based on assumptions and their experience with the water source, with some proposals possibly being double the cost of others.

Taking the time to work early in the planning stages with experienced engineers, studying the water trends, and defining sampling parameters and frequency pays off. The good, reliable, and representative water analyses become the foundation of an adaptable and sustainable system to support long-term powerplant operation for both normal and upset water supply. CCJ

About the author

Wendy Wong, PE, a senior process engineer at SNC Lavalin Constructors Inc, has 26 years of global experience in chemical and water-treatment processes for the power, oil and gas, and pharmaceutical industries. Her expertise includes treatment of cooling water and demineralized water, plus seawater desalination and cycle chemistry for boilers.

IAPWS

International Association for the Properties of Water and Steam

IAWPS is a global non-profit association involving 25 countries in all aspects of the formulations of water and steam and seawater, as well as in power-plant cycle chemistry. It provides internationally accepted cycle-chemistry guidance for power generation facilities in Technical Guidance Documents freely downloadable from the organization's website at www.IAPWS.org. Specific TGDs for combined-cycle/HRSG plants include the following:

- Procedures for the measurement of carryover of boiler water into steam.
- Instrumentation for monitoring and control of cycle chemistry.
- Volatile treatments for the steam-water circuits of power plants.
- Phosphate and NaOH treatments for the steam-water circuits of drum boilers.
- Steam purity for turbine operation.
- Corrosion-product sampling and analysis.
- HRSG high-pressure evaporator sampling for internal deposit identification and determining the need to chemical clean.
- Application of film-forming amines in power plants.

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Advanced Turbine Support

Has delivered unbiased fleet experience and superior customer service for more than a decade. Company provides users high-resolution borescope inspections, cutting edge ultrasonic and eddy-current inspections, and magnetic-particle and liquid dye-penetrant inspections in accordance with OEM Technical Information Letters and Service Bulletins.

Aeroderivative Gas Turbine Support

AGTSI offers a full range of aeroderivative gas-turbine, off-engine, and package parts from the most basic to the most critical. An expansive inventory of spares and replacement parts is maintained at our warehouse for all models of GE LM2500, LM5000, LM6000, and LMS100, as well as P&W GG4/FT4.

AGTServices

Over 200 years of combined, proven OEM engineering, design, and hands-on experience; known in the industry for its schedule-conscious, cost-effective solutions with respect to generator testing and repairs.

American Chemical Technologies

Provides state-of-the-art synthetic lubricants to the power generation industry. Founded more than 30 years ago in the US, ACT has grown to become an international supplier of value-added lubricants that provide superior benefits to equipment, the environment, and are worker-friendly.

AP+M

One of the largest worldwide independent stocking distributors of both heavy-duty and aeroderivative gas turbine parts. A reliable partner with an extensive inventory of more than 10,000 parts quickly delivers genuine OEM parts for operators, end-users, depots, and repair facilities.

ARNOLD Group

With more than 550 installed insulation systems on heavy-duty gas and steam turbines, company is the global leader in designing, manufacturing, and installing the most efficient and reliable single-layer turbine insulation systems.

Bearings Plus Inc

Provider of repairs and custom technology upgrades for turbomachinery. Designs and manufactures an integrated solution to meet specific requirements for every operating environment, applying the latest fluid film bearing and high-performing seal technology to legacy equipment to optimize performance.

Bremco

Full-service industrial maintenance contractor since 1976. Company experience in combined-cycle projects includes header, tube, and complete panel/harp replacements. We also have significant experience in liner repairs/upgrades, duct-burner repairs, penetration seals, and stack-damper installations.

C C Jensen Oil Maintenance

Manufactures CJC™ kidney-loop fine filters and filter separators for the conditioning of lube oil, hydraulic oil, and control fluids. Our extensive know-how ensures optimal maintenance of oil systems and equipment reliability.

Caldwell Energy

Power augmentation, including inlet fogging and wet compression solutions, boosts the output and efficiency of gas turbines. With more than 400k hours of operating experience in power generation, these systems offer proven performance and are backed by a three-year warranty.

Camfil

A world leader in the development, manufacture, and supply of clean air and noise reducing systems for gas turbines. A correctly designed system minimizes engine degradation, leading to lower operating costs, optimum efficiency, and less environmental impact.

Catalytic Combustion Corp

Designs, engineers, and manufactures the catalyst – the heart of an effective emissions system. CCC also manufactures the housing and all the critical components at our Midwest facility. Our process of producing folded catalyst substrates is a proven method to quickly manufacture robust catalysts.

Chanute Manufacturing

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

Cormetech

The world's leading developer, manufacturer, and supplier of catalysts for selective catalytic reduction (SCR) systems to control emissions of nitrogen oxides from stationary sources. Cormetech SCR catalysts are highly efficient and cost-effective where systems must be capable of reducing NO_x by more than 90%.

Crown Electric Engineering & Manufacturing

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.

Cust-O-Fab Specialty Services

Provides the latest technology in exhaust plenums, exhaust ductwork, and exhaust interior liner upgrades that will drastically reduce external heat transfer, making the unit safer and more efficient and easier to operate and maintain.

Cutsforth

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.

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.

Environex Inc

Engineering and consulting experts in post-combustion NOx and CO control technologies. Primary focus is SCR and oxidation catalyst testing and system maintenance, catalyst management and selection, troubleshooting, and design.

Emerson Automation Solutions

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.

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.

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.

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.

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.

National Breaker Services

Industry leader in switchgear life optimization, life extension, and system upgrades. Manufactures new, highly customized low- and medium-voltage switchgear and provides on-site troubleshooting, maintenance, and testing of existing systems.

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.

Nord-Lock Group

World leader in secure bolting solutions, strengthening industrial and public infrastructures with high-quality, safe, and innovative solutions. Products include wedge-locking washers, mechanical tensioners, hydraulic tensioners, and expander systems.

Parker Hannifin Gas Turbine Filtration

With over 50 years of experience delivering innovative solutions for GT inlet filtration and monitoring fleet-wide performance data, our industry and applications experts will select the appropriate filter for your site designed to meet specific operating goals.

Power and Industrial Services

P&I was founded in 1978 with the goal of providing improved replacement parts for the electric utility market. P&I offers a complete range of duct burner solutions from simple replacements to complete turnkey projects as well as a complete line of HRSG access door solutions.

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.

Proco Products

Global leader in the design and supply of expansion joints for piping/ducting systems. For over 30 years, Proco has manufactured the highest quality rubber and molded PTFE expansion joints, braided flexible hose assemblies, low torque sealing gaskets, and rubber check valves.

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.

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.

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.

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-

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cycle facilities where operating flexibility is beneficial.

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.

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.

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.

Trinity Turbine Technology LP

Provides innovative, cost-effective and reliable gas and steam turbine maintenance solutions to industrial operators worldwide. We provide high quality and reliable turn-key outage support and component repairs with unmatched responsiveness and dependability.

Umicore Catalyst

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.

ValvTechnologies

Global leader in the design and manufacturing of zero-leakage metal-seated ball valve solutions for severe service applications. Committed, dependable partner providing the best isolation solutions to ensure customer satisfaction, safety and reliability, and improved process and performance.

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.

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.

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Index to advertisers