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CCJ COMBINED CYCLE Journal

In-Person Conferences

In-person conferencing for gas-turbine users returns August 23-27, at the Marriott St. Louis Grand, with Power Users welcoming members of its 7F, 7EA, Steam Turbine, and Power Plant Controls groups to the industry's first live meeting in over a year. Click QR codes for details; see p 33 to register.

7F USERS GROUP | 7EA Users Group | STUG STEAM TURBINE USERS GROUP | POWER PLANT CONTROLS USERS GROUP

2021 Virtual Meetings

MENA Combined Cycle Powerplant User Symposium, May 25-27. Connecting users in the Middle East and Africa, and elsewhere.

HRSG Forum with Bob Anderson, now meeting monthly on-line (see p 67).

Western Turbine Users Inc, June 7-10, 15-17, and 22-24 (details, p 28).

Combined Cycle Users Group, July 13, 20, 27 and August 3.

Generator Users Group, July 15, 22, 29 and August 5.

User Group Reports and Feature Articles

User Group Reports

Features

INDEPENDENT VOICE OF THE GAS-TURBINE-BASED GENERATION SECTOR


HIGH-EFFICIENCY DESIGN WITH CUSTOM BACK-END WASTE HEAT RECOVERY.
HIGH-PERFORMANCE EMISSION CONTROLS – FOR THE LOWEST LEVELS OF CO AND NOX AS LOW AS 2PPM.
COMPLETE SYSTEMS CUSTOM DESIGNED FOR THE MOST STRINGENT CUSTOMER SPECIFICATIONS.
RENTECH BOILERS.
AS TOUGH AS TEXAS.
PRODUCTS
Heat Recovery Steam Generators
Waste Heat Boilers
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Important update from Power Users

Power Users, like everyone else in the world, is excited about the Covid-19 pandemic coming to an end. We may not be there yet, but these users are hoping the end of Covid-19 is near. We have kept busy during the pandemic transitioning to virtual conferences, but also in some other ways as we adapt and look toward the future. Power Users has some exciting news to announce that will be beneficial and welcome to users, vendors, and OEMs.

Powered-up user forums. Many in the industry have been using www.users-groups.com over the past two decades to access their primary engine-specific discussion forums. Power Users has obtained them and is in the process of modernizing and refreshing these forums which are becoming available at www.powerusers.org/forum. Currently, the 7/9HA, 6B, and Frame 5 have been migrated, and 7EA is next up.

As each forum is relocated, an update will be sent to every member on the forum to let them know how to post, update their password, and any other details that a user may need to log on to www.powerusers.org.

We hope that by integrating these forums in one location it will be easier for all users to access the information they need to better operate and maintain their equipment. As always, being a user, accessing the forum history and receiving the forums over email is free.

Growth spurt. The last year has seen more than a few existing GE engine-specific user organizations join Power Users to better serve the owners and operators of this equipment:

- HA Users Group (both 7HA and 9HA technology)
- 7EA Users Group (7B-EA technology)
- Frame 6B Users Group
- Frame 5 Users Group

Introducing LTUG. Starting in 2022, in-person conferences of 7EA, 6B, and Frame 5 Users Groups will be held collectively under the banner of Legacy Turbine Users Group (LTUG). There is a great deal of information, experience, and training that can be shared across these fleets by users and vendors, which we see as an undeniable value proposition for the success of LTUG. SV Events (Sheila Vashi) will assume the meeting planning and conference coordination for this event. Stay tuned.

The here and now: 2021. While a return to "normal" conferencing is not quite here yet, the transition back to in-person meetings is in effect. Power Users will be hosting conferences both in-person and virtually over the course of this year. Here's the lineup:

In-person meetings

- 7F Users Group, 30th Annual Conference, August, St. Louis*
- 7EA Users Group, August, St. Louis*
- Steam Turbine Users Group, August, St. Louis*
- Power Plant Controls Users Group, August, St. Louis*
- HA Users Group, September, Detroit

*Meeting at Marriott St. Louis Grand, August 23-27

Virtual meetings

- Frame 6B Users Group, May
- Combined Cycle Users Group, July
- Generator Users Group, July

We hope this gets you up-to-speed on the progress and enduring mission of Power Users to grow this community through quality interactions through a variety of platforms both in-person and virtually. Remember to bookmark **www.powerusers.org** and visit frequently to become familiar with the bounty of resources available at your fingertips.

From the Power Users Board of Directors, we sincerely wish everyone the best of health and a prompt return to the good old days.

Jake English, *Duke Energy*
Phyllis Gassert, *Talen Energy*
Sam Graham, *Tenaska*
Edward Maggio, *TVA*
Ben Meissner, *Duke Energy*
Peter So, *Calpine*

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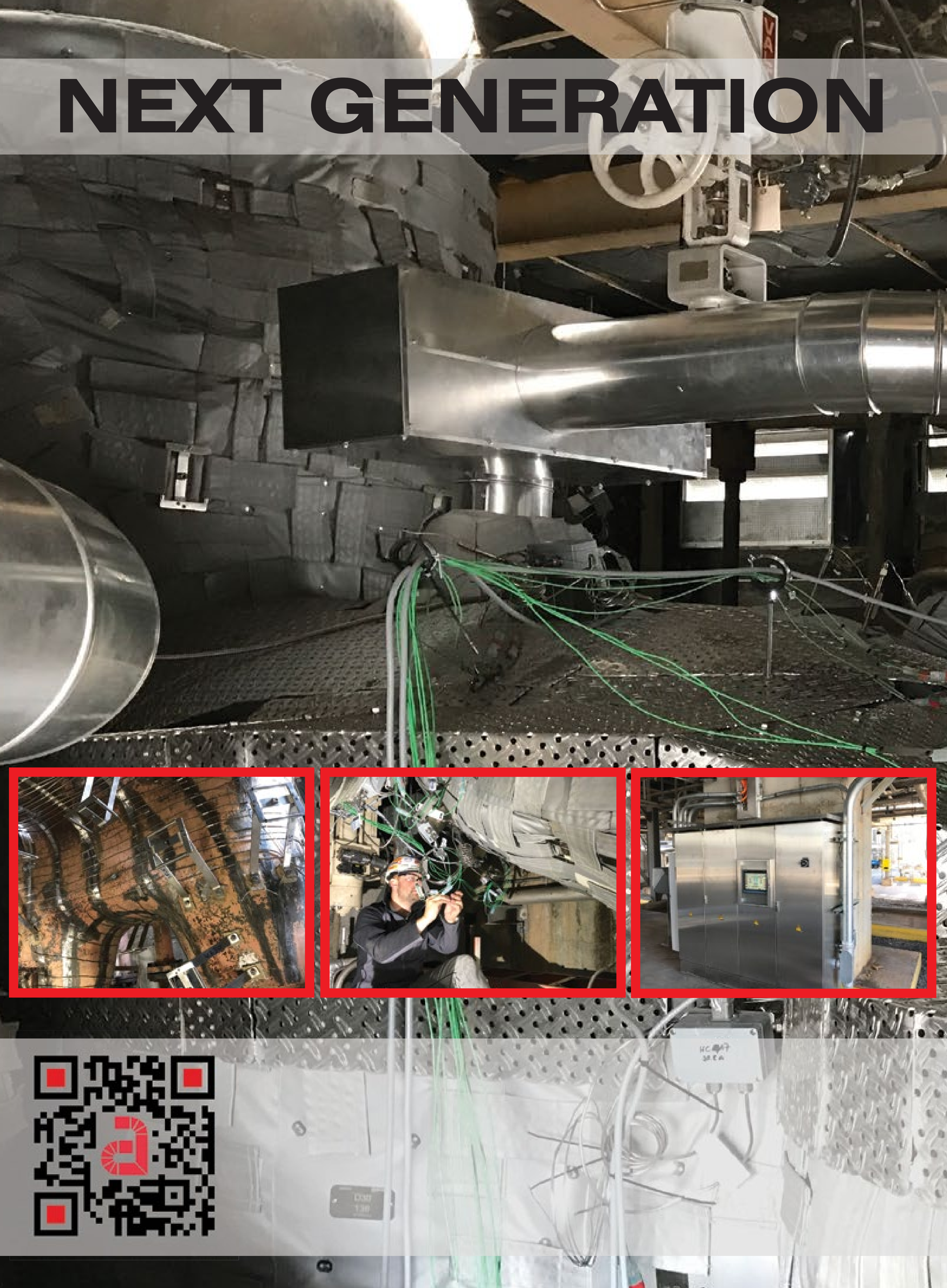
NEXT GENERATION



CCUG™

COMBINED CYCLE USERS GROUP

The annual conference of the Combined Cycle Users Group (CCUG), was conducted online for the first time in 2020. Talen Energy's Phyllis Gassert chairs the group; Calpine Corp's Brian Fretwell is vice chair. The four-week virtual event was broadcast each Tuesday from November 10 through December 8, with a Thanksgiving break on November 24.

The Week One program, November 10, offered user experiences and vendor breakout presentations. All of these presentations are available to registered owner/operators on the Power Users website (www.powerusers.org).

Week Two, November 17, was reserved for GE presentations, Q&A, and open discussion on topics of interest to the user community. Highlights are presented below with the full presentations available to users on the OEM's MyDashboard website (https://mydashboard.gepower.com).

The programs for Weeks Three and Four were similar, starting with two hours of user and/or consultant presentations and ending with two one-hour live vendor presentations. All of these presentations, summarized below, are available to owner/operators on the Power Users website (www.powerusers.org).

Week One

User presentations

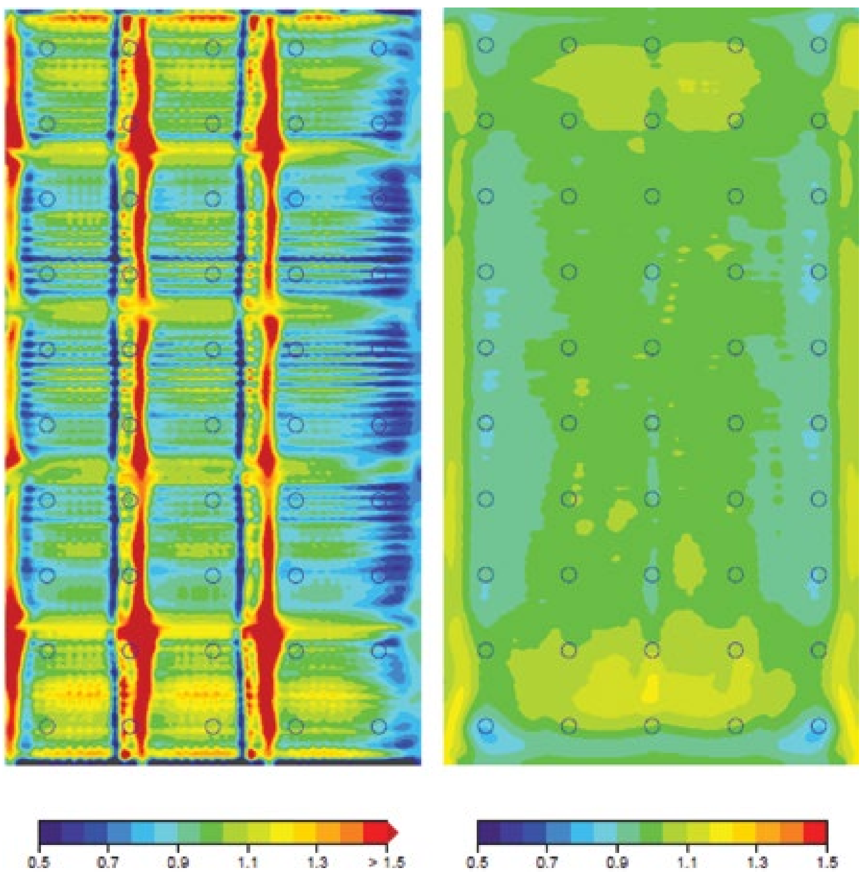
Natural gas systems: Lessons learned and recommendations from design to O&M, can be thought of as a tutorial for ensuring safety and performance of gas supply and delivery in combined-cycle facilities, one which also addresses compliance with applicable specs—including ASME B31.1, NFPA 56, and NFPA 85.

Coverage includes LEL (lower explosive limit) detection and monitoring in general, mechanical- integrity inspections, buffer capacity, nitrogen purging, above- versus below-ground piping, change management and integration with the CMMS (computerized maintenance management system), and perhaps most importantly, analyzing all "near-miss" events, performing drills, and making sure your emergency plans are "dusted off."

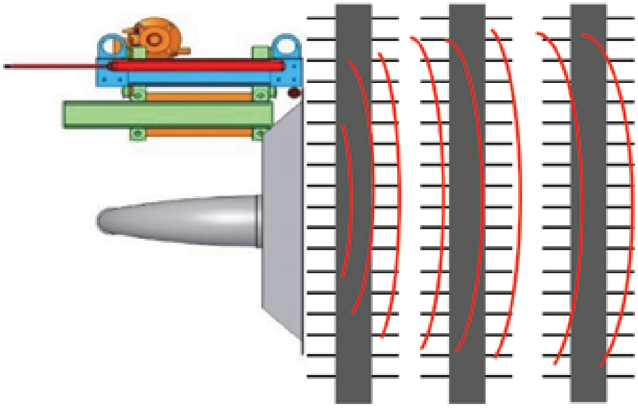
A great "near-miss" real-world example illustrated is 500-psig fuel gas being trapped between two butterfly valves after shutdown and before some maintenance activities were about to commence in the area.

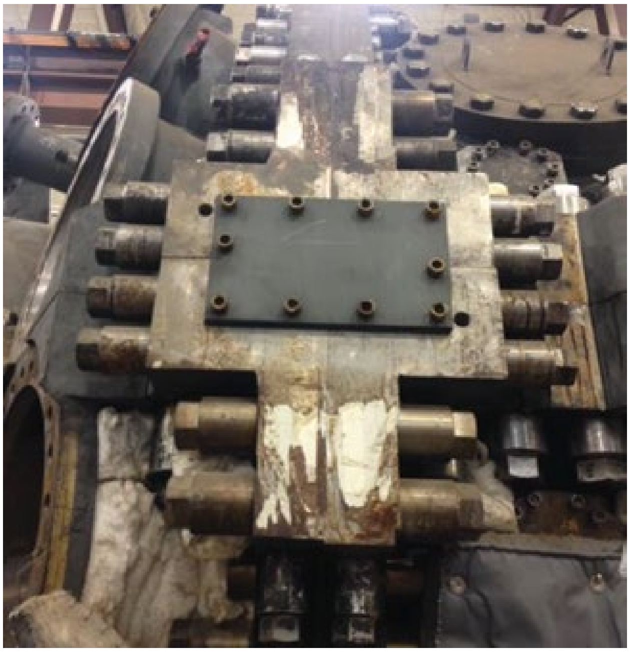
Understanding oil analysis likewise covered the tutorial aspects of contamination, fluid condition, and machine wear. Within each of these broad areas, the presenter reviewed the efficacy and cost of specific test procedures, and aspects of testing that can cause problems. For example, the temperature at which a demulsibility (ability to separate oil from water) test is performed can affect the results, something that is especially important for steam-turbine systems. Presenter recommended that someone at the site "needs to have formal third-party or in-house training" in all aspects of oil analysis.

HRSG pressure-wave cleaning. This writer's jaw dropped to the floor faster than the material removed from an HRSG during a pressure-wave cleaning when he heard that 25 to 30 tons of rust and scale were removed, the pile at the HRSG floor was 14 in. deep, and the HRSG differential pressure dropped from 21 in. H_2O to 8-10 in. Some important points for a successful cleaning: Allow only permitted blast-



1. SVI Dynamics relies on CFD modeling to improve SCR performance. Poor distribution of ammonia (26.4% RMS) at left was greatly improved by redesign guided by modeling (5.7% RMS at right)





2. Thompson's cleaning technique for HRSG tube bundles relies on repeated shock-wave impulses to dislodge deposits (above)

3. Nord-Lock's Superbolt helps solve the leak issue at the 4-way joint of 501F gas turbines with product improvements (right)

ing crews to access HRSG during the procedure, notify your neighbors, cover the backside of the SCR with a tarp, cover manway access doors, and clear CEM lines to make sure they don't get plugged up.

Cold layup and restart. Powerplants want to be run. But when the market dictates otherwise for long periods of time, the plant has to go into cold layup. When the market further dictates that half of the plant capacity is sold into the market before the balance, well, the complications grow. The litany of issues which had to be addressed for a California plant under these circumstances are reviewed in "Plant Extended Layup and Restart Guidelines." This presentation is a veritable study guide for the next plant that has to do this.

One of the most important lessons learned is that the turbine lube-oil preservative recommended by one vendor and applied was a poor choice and caused significant issues. Another is that calcium products from the vapor-phase corrosion inhibitor used for metal surfaces can get into the lube-oil system. Removing it is similar to removing varnish from lube oil.

A third is that zero liquid discharge and air-cooled condensers can contribute to significant issues managing rinse and flush water. This plant also reported experience with GE's proprietary pressure-wave cleaning method for HRSGs as part of the restart.

Vendor breakout presentations

SVI Dynamics/SVI Industrial

Defining and implementing SCR improvements on gas-turbine exhaust

Stringent regulations on NO_x, CO, and ammonia slip are dictating the need for highly efficient SCR systems. Although CO and SCR catalyst designs are advancing to meet these new regulations, SCR system designs are not always equipped to manage the performance requirement improvements.

Industry veteran Bill Gretta, SVI Dynamics' SCR product-line director, understands. His company, he says, has incorporated years of knowledge and experience gained from work on SCRs manufactured by all of the major vendors into SVI's new SCR. If new is not optimal, SVI can provide in-depth analysis of your SCR to suggest enhancements that will improve reliability and efficiency.

Part of Gretta's presentation illustrates the benefits of CFD modeling in guiding performance upgrades (Fig 1). He also explains how SVI would conduct a design review of your system and how to develop a PM inspection plan for your SCR.

Thompson Industrial Services

How to regain significant pressure drop utilizing offline HRSG impulse cleaning

Vince Barreto and Carl Wise opened their presentation on gas-side cleaning of HRSG tube bundles with a review of the traditional alternatives—dry ice and "open detonation"—moving quickly to introduce Thompson's impulse (pulse detonation) cleaning system. They said the offline application of their proven technology has shown the potential for dramatic improvements in the cleaning of fouled HRSG tube surfaces.

How it works: A cyclic combustion events creates supersonic impulses as illustrated in Fig 2. Injection of fuel and air into an integral mixing chamber followed by ignition and combustion creates a high-energy shock wave that dislodges deposits on the heat-transfer surface.

Barreto and Wise said the highly compressed pressure front is followed by a low-pressure zone: The instantaneous pressure swing produces the cleaning energy. The system is operated at two impulses per second for a total burst of 80 to 120 impulses at each location as the business end of the device traverses the tube bundle on a rail.

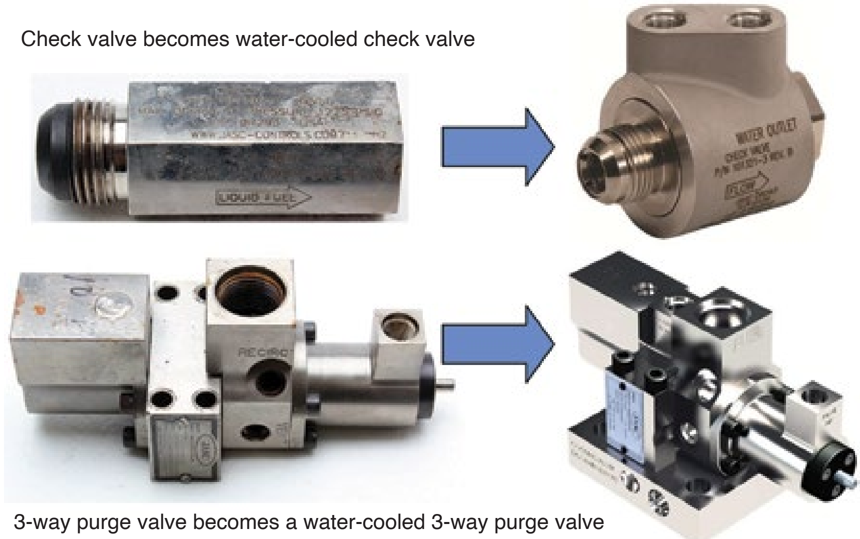
Parker Hannifin Corp

Reduce maintenance concerns and cost associated with GT fuel control valves

Jim Hoke, Parker's capital projects manager for power generation, provides users technical information on the company's line of electrohydraulic servo valves required for decision-making. The valves are approved by GE for use on its gas and steam turbines for the following applications: control of gas and liquid fuels, steam-valve actuators, inlet guide vanes, and stop/ratio actuators.

Key takeaways from the presentation include these:

- Parker's "soft-fail" Abex electrohydraulic servo valves if plugged will not cause the downstream actuator to fully extend or retract—it will remain in place. However, the valve can be spring-biased to move the actuator to a preferred safe position.
- The product is a drop-in replacement for many servo valves in use—including hydraulic mounting and electrical connections.
- Large orifice diameters allow contaminants to pass through instead of obstructing flow.
- Hydraulic spool, designed with a significant chip shear force, enables continued operation in hydraulic systems experiencing varnish



4. JASC's water-cooled components for gas-turbine liquid-fuel systems contribute to much improved reliability of generating units

5. HRST Inc's duct liners of Type-304 stainless steel feature controlled expansion by way of fixed points, guide points, and free-floating points

buildup.

- The robust design allows extended intervals between PMs, calibrations, and tests.

Nord-Lock Inc

Solutions for coupling-bolt issues, 501F 4-way joint leaks, and casing tensioners

Steve Busalacchi opened the presentation by explaining how his company's EZ Fit coupling bolts have eliminated the costly, time-consuming challenges presented by seizure-prone fitted coupling bolts during outages. He noted the downsides and risks of using conventional bolts for turbine/generator couplings and explained the principles of mechanical expansion bolts—what they are, how they work, and how they mitigate the problems associated with conventional bolts.

Features of the company's multi-jackbolt (MJT) tensioners for both horizontal and vertical joints were discussed next, followed by an overview of the 501F 4-way joint leak solution (Fig 3). The latter eliminates forced outages caused by leak-by damage to instrumentation and assures a safer environment inside the turbine enclosure.

Installation of the 4-way joint solution takes the field-service crew performing the outage about three shifts to complete. Nord-Lock provides all necessary components and equipment as well as a qualified TFA.

JASC

Pitfalls to avoid for enhanced liquid-fuel-system reliability

Schuyler McElrath, one of the electric-power industry's leading experts on liquid fuel systems for gas turbines, has new product development as one of his responsibilities at JASC Controls. His presentation simplifies the complexity inherent in liquid fuel systems and focuses on what design features owner/operators should be aware of to assure reliable starts on oil, reliable transfers from gas to oil, and vice versa, and reliable operation on both fuels (Fig 4). McElrath stresses that while some issues can be addressed with hardware upgrades, system infrastructure changes are an equally important part of the performance improvement process.

HRST Inc

Diffuser duct liner retrofit: Common issues and solutions for a reliable system

Scott Olson reviewed typical problems associated with diffuser-duct liners and HRST's proven methods, components, and tools for improving liner-system reliability (Fig 5). You can access Olson's presentation on the Power Users website (www.powerusers.org) or get the details from CCJ's article on the subject, based on HRST's experience (CCJ No. 60, p 53).

Parker Hannifin Gas Turbine Filtration

Understanding standardized testing to help in filter selection

Paul Barron, North American regional sales manager, and Sales Manager Abby Rowe updated users on the company's line of inlet air filters and systems capable of superior performance over a wide range of environmental conditions. They reminded the owner/operators of the company's two popular brands of filtration products: Altair® and clearcurrent™. Parker's GT filtration options include the following: cartridge, vCell, pocket or panel filter. Complete gas-turbine inlet filtration systems, including evap coolers, also are offered.

The speakers reviewed traditional filtration standards (ASHRAE and the European EN) and compared product test results while explaining the differences between similarly rated filters.

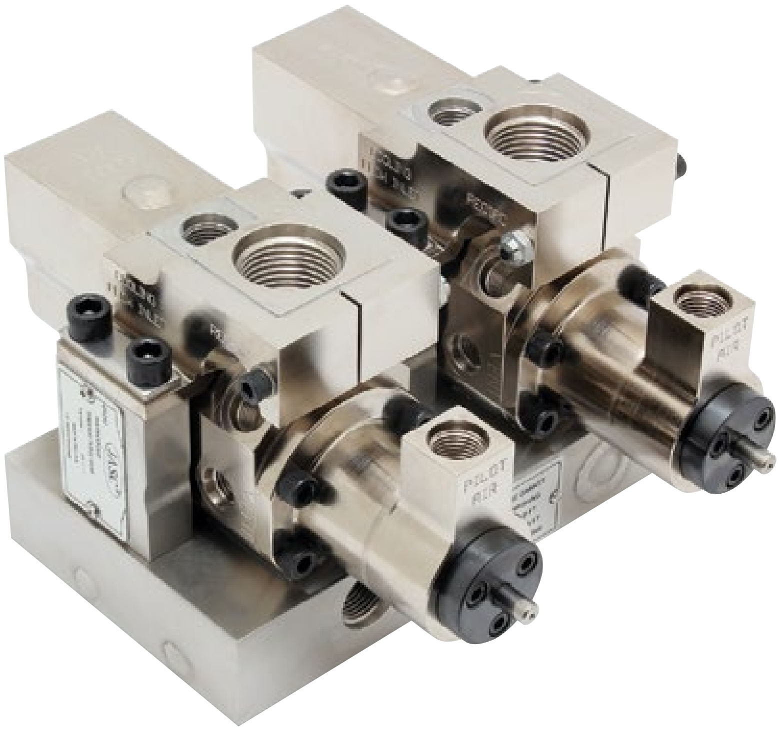
Groome Industrial Services Group

Keys to better AIG tuning and permanent sampling grid

Steve Houghton focused on tuning of ammonia injection grids (AIG) and the value of installing a permanent sampling grid before diving into related case histories that included financial benefits.

A clean AIG is important to optimal tuning, he said. Verify that valves are

THIS IS RELIABILITY



JASC Water Cooled 3-Way Purge Valves

7+ years between hot gas path inspections with zero valve failures*

JASC Water Cooled Liquid Fuel Check Valves

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Non-water cooled 3-Way Purge Valve spool after less than 1 year of operation

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in working order and that flow gages on the valves are functioning. Having a permanent sampling grid solves the issue of blocked sampling ports and allows for a complete traverse measurement. Additional benefits: Sample without need for a manlift or scaffolding; tune the AIG faster and more precisely. Break even on the installed cost after two or three uses.

Case study 1: An AIG/SCR replacement project for a G-class combined cycle reduced ammonia consumption by 10% and cut ammonia slip in half (Fig 6). Case study 2: At an F-class combined cycle, Groome reduced ammonia consumption by 26% and reduced ammonia slip to 25% of the permit limit, saving $44,000 annually.

6. Groome replaced the ammonia injection grid and SCR catalyst in this HRSG

Certrec Corp

Winning strategies for managing NERC regulatory requirements

Certrec's presentation provides owner/operators the essential steps for NERC audit preparation and completion. It's important to prepare early for your audit, the speakers noted, and to be at the ready to achieve the desired outcome. Technology (think web-based solutions) can be your greatest resource, they continued, because it saves time and money.

The company's NERCSuite, a comprehensive compliance platform of web-based tools, was said to provide complete support of a plant's NERC compliance efforts, to reduce regulatory risk, and to minimize the overall cost of compliance programs.

ARNOLD Group

Advanced single-layer turbine warming system

Pierre Ansmann and Norm Gagnon covered the basics of steam-turbine warming for increased startup flexibility in their breakout presentation, which began by answering the question, "Why install a turbine warming system?" Highlights of their PowerPoint, available on the Power Users website, include the following:

- Maintenance and operational benefits.
- Differences in warming-system arrangements.
- System durability and reliability.
- Importance of proper insulation for a warming system.
- Controls.
- Cost and schedule of the initial installation.
- Periodic maintenance plan.

In their review of alternative warming-system arrangements, the duo rejected those integrating heating circuits in insulation blankets, installing the heater on a thin mattress below the blanket, and using glass-fiber-insulated heating cable. The optimal system for the upper casing, they said, is a heater on a metal-mesh baffle; for the lower casing, permanent mounting of heating cable below the split line (Fig 7).

Ansmann and Gagnon explained that the ARNOLD system features interlocking high-performance blankets which conform perfectly to the turbine surface. High-quality materials and manufacturing, and long-term high-temperature resistance, allow the company to guarantee reuse of its insulation system for 15 outages without a decrease in efficiency.

More than five-dozen thermocouples, strategically located on the turbine, ensure proper heating. Each of the 18 or so heating zones has t/cs installed on the heating wires to double check if the zone is responding correctly and at the specified temperature. Below every heating zone, multiple t/cs are mounted on the casing to confirm even heating of the turbine.

The speakers said the ARNOLD warming system can maintain your turbine in a hot-start condition for at least four or five days after shutdown. No preheating of the turbine is required prior to a restart within this time period, reducing startup fuel consumption and auxiliary power.

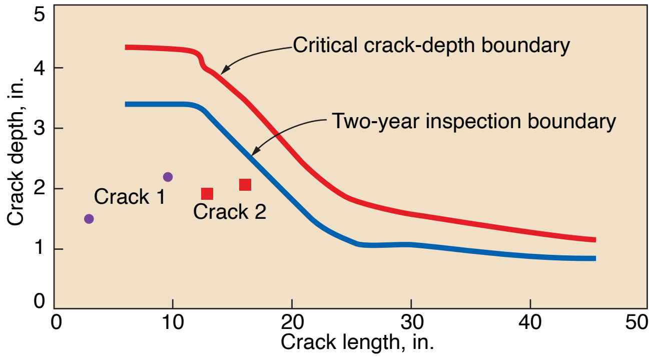
C C Jensen, Oil Maintenance

Remote monitoring of lube oil and diesel conditioning

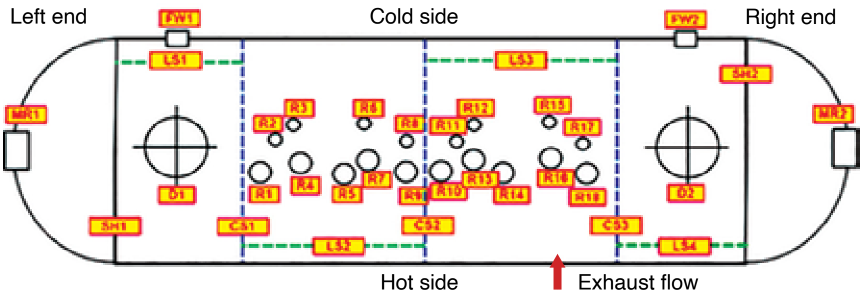
Oil conditioners/kidney-loop filters are known for their ability to keep oil, and the machines relying on it, clean

7. ARNOLD Group believes the "heater on metal-mesh baffle" (left) is the optimal configuration for turbine upper casings, offering easy removal, good contact; "heater on surface body" for lower casings (right), provides good contact and heat transfer

8. C C Jensen's oil condition monitor displays historic data, produces continuous data curves, triggers alerts via email or text, routes information to control room or M&D center



9. Crack size assessment for an 8-in. riser shows how length and depth of Cracks 1 and 2 had growth during the previous operating period, and how the growth should be considered relative to the critical crack-depth boundary (above which repair is necessary) and the two-year inspection boundary (below which operation can resume without repair). In-between these two lines requires additional assessment



10. Weld map for HRSG HP drum should be prepared in advance of the inspection crew's arrival, and used to organize inspection data

and healthy. In his presentation, Axel Wegner shows you how to keep lube and diesel oils in top condition; plus, how to receive alerts as soon as anything oil-related drifts out of spec—such as cooling-water temperature, excessive wear of machine parts, ISO particle count, etc.

Wegner's message is clear: The optimal condition-monitoring and filtration system for any machine and oil type allows you to identify problems remotely and to take action before they get out of control (Fig 8). This presentation is one you might want to consider sharing with your plant's O&M staff during a lunch-and-learn session.

Week Two

Team GE discusses performance improvement, operational flexibility, upgrades

The first thing to note about the GE presentations is that you're probably going to want to listen to the recordings, if you're approved to access them on the OEM's MyDashboard website (https://mydashboard.gepower.com).

A blizzard of information swept through the virtual room, along with a virtual army of presenters and technical support folks at the ready. The overarching message was that if you're seeking to adapt your plant to changing market or operating circumstances, GE can help.

To set the stage, Tom Freeman, chief customer consultant, and Blair Van Dyne, South Region sales director, reviewed basic market forces—mainly the continued surge of renewable energy into the market and decline of coal. Van Dyne said, "US wind developers will add 23 GW of new capacity this year. The previous record was 13.2 GW in 2012. Solar PV accounted for 3.5% of US total energy generation in July. About 31 GW of US coal has retired since 2018. Coal generation dropped 30% in the first half of 2020."

John Sholes, value solutions leader, discussed myriad ways to "make your plant better," breaking down the options into short-, mid-, and long-term frames of concern.

A common short-term issue is getting sufficient turndown without exceeding attemperator limits. Options include software changes to lower exhaust temperatures, upgrading the HRSG attemperator to increase spray-water flow, and adding a ring-style second-stage attemperator, which could require up to a one-week outage. GE now offers a standalone "smart attemperator" box that biases the attemperator to current operating data by "buffering" the current instrumentation.

Sholes then discussed a variety of upgrades to "nudge ahead," including a dry low NO_x (DLN) 2.6+ combustor upgrade, advanced gas path (AGP) technology, and extended-turndown valves. Such "technology infusions" on the gas-turbine side can boost capacity by up to 20% but will require balance-of-plant (BOP) upgrades, possibly even a transmission-line upgrade and generator nameplate capacity uprate.

The mods can be phased in over time for plants seeking significant performance-shift goals. Generators have lots of design margin, Sholes added, although cooling capacity is critical.

Responses to audience questions addressed the following:

- Changes required to condensate recirculation systems.
- Wet compression on hot days.
- Retrofitting safety valves versus replacing them.
- When to involve the HRSG OEM.
- Excitation-system and voltage-control limitations.
- Steam-bypass considerations in event of a steam-turbine trip.

John Korsedal, product manager, GE Digital Worker Solutions, talked on flexible mobile and remote operations to achieve mission goals. Digital solutions are available to assist leaner, less-experienced workforces with expertise accessed remotely, inside or external to the owner/operator organization.

Korsedal dwelled on GE Remote Operations, a "packaged software and appliance solution" with much of its recent functionality derived from Covid-19 responses. Goals of the package are to enhance worker location flexibility, promote reliable remote operations, extend monitoring and contingency operations, and achieve multi-plant control flexibility. The package includes a "purpose-built" mobile HMI with view-only access as the default mode and a "pop-out for control management."

Communications capabilities available with GE's Remote Operations includes voice, video, text, content-sharing, hands-free broadcast, and group messaging through WIFI or cellular access.

In addition to Remote Operations, GE's Asset Performance Management Portfolio will shortly introduce a next-generation Rounds product which will be called Rounds Pro. This will be available for large and small BYOD (bring your own device) screens with a new, intuitive, interface to complement work processes.

The presentation includes remote operations use cases.

To close the CCUG portion, Freeman returned to the virtual stage for "Adapting Plant Maintenance with Operational Changes in an Aging Portfolio." Broad topics included:

- Conducting a pressure-wave (HRSG cleaning technique) value study by monitoring differential pressure

across the HRSG. Freeman noted that typically 0.25 MW (0.35 MW on 7FA) is gained for every 1.0 in. H2O recovered in HRSG differential pressure. An easy check in your historian.

- Generator reliability and uprates. Freeman cautioned that you don't want to be forced into a rewind at the wrong time as this requires a lengthy outage. Generally, rotors need a rewind after 15 to 20 years, stators between 25 and 30 years.
- Impacts on the steam turbine/generator from greater cycling, such as the following: inlet-valve throttling and solid-particle erosion; low-cycle fatigue on HP/IP shells, last-stage blades (LSB), and valve casings; and moisture-induced erosion of LSBs and the turbine casing.
- Subsystems, including valves, fire protection/hazardous gas, lube oil, and inlet/exhaust plenums.

Week Three

Focus was on Covid best practices, safety, HRSGs, emissions control

Subjects covered during the CCUG's Week Three session ran the gamut from what you can bring into (or catch at) the plant to what your facility discharges out the plant—and much in-between.

Pandemic viruses. Probably nothing was top of mind like Covid-19 and so the day began with the presentation, "Covid Best Practices." First slides reviewed the Covid personal practices we've been seeing and hearing about for eight months in the news.

Then the presenter drilled down to in-plant practices, specifically changes to outage execution. Some of the basic steps include the following:

- Daily site employee and worker temperature monitoring for fever.
- Segregating day and night shift staffs and decreasing shifts by one hour to avoid overlap.
- Phone- or digital-based shift turnover.
- Increased social distancing during the shift by holding morning toolbox and shift turnover meetings outside (weather permitting) or in rented trailer, separating crews into teams with different break schedules, and adding a separate trailer for work crews.
- Increased personal hygiene and addition of wash stations around the site.
- Wipe down of tools at the end of each shift for the next crew.
- Additional personnel protection equipment (PPE) in areas where 6-ft distance could not be maintained (confined spaces, for example).
- All vehicles limited to one worker per trip.
- Frequent cleaning of all high-traffic surface areas like refrigerators, microwaves, coffee pots, door handles, etc.

The presenter underscored the need to be aware of heat-related stress from wearing masks for long periods in hot environments (such as above 90F), and a need for a solution to crowding at emergency muster points.

The Q&A session got interesting. Illustrating a non-obvious tradeoff of one safety issue for another, one plant rep noted that they had to back off on safety audits and suspend fire drills to minimize person-to-person contact. One user expressed frustration that they couldn't get the right tech-support folks into plants because of local, state, and national restrictions. In an extreme case, this caused scheduled hot-gas-path (HGP) maintenance to be deferred.

Another facility modified smoking areas and port-a-potty units to keep groups isolated. At least two plants added portable heated-water hand-washing facilities, one said to include a tankless water heater, to encourage longer hand-washing.

Unfortunately, no one had any good way to track workers offsite, behavior that could nullify whatever good practices were occurring onsite. Craft-labor supervisors, the presenter said, were responsible for ensuring that crew members only traveled from hotel to site. Lunches were served onsite to avoid unnecessary offsite travel.

Safety. The next presentation, titled "You Have to Be Present to Win," addressed safety issues, with Covid-19 being the most recent challenge added to the safety basket. It's worth getting the slides for the photos of a GT major outage during a pandemic. Some of the specific steps taken at this plant:

- Substituted a safety-orientation video and a downloadable Excel spreadsheet for the in-person site orientation session.
- Replaced break trailers with tents, provided by a local contractor, equipped with lights, heat, tables, chairs, floor, etc.
- Added two remote hot-water hand-washing stations.
- Held daily contractor meetings in an open, ventilated shop area.

Speaker opened with the personal experience of an injury during a family outing to illustrate "what we do at home affects our work," and then recounted the experience of a serious accident at the plant as a reminder that "we work in a dangerous environment."

That set the stage for a discussion of six enemies of safety: *complacency,* stepping through the motions without thinking about what you're doing; *poor housekeeping,* taking the time to clean up and avoid shortcuts; *fatigue/lack of focus,* especially during long outages and when workers are offsite; *deadlines,* distinguishing between real and implied; *lack of training,* "feeling" what's happening with the equipment in addition to "knowing"; and *trusting without verifying,* such as taking the time to know what is going on in a LOTO area.

Reporting "near-misses" is key, the speaker stressed, and with follow-up training on the precursors to them.

Two slides list a baker's dozen of "items to consider." While most are the usual reminders when plant safety is addressed, a few of the most salient are these:

- Require workers to state what they are doing instead of just doing it when signing off on work permits.
- Consider taking the most conservative option when making an on-the-spot decision about safety.
- Encourage an open mind when personnel suggest solutions and "hear" employees' safety concerns rather than just listening to them.

One listener encouraged attendees to adopt OSHA's Voluntary Protection Program (VPP) process to strengthen their safety programs. VPP plants invite OSHA representatives into the plant to guide them in how to do things more safely. Presentations at previous CCUG conferences have addressed the OSHA VPP process. Access them on the Power Users website (www.powerusers.org).

Another attendee conceded that training new employees during a pandemic presents opportunities for improvement. One concrete idea is to upload a virtual orientation to YouTube with a QR code for workers who didn't see a video before they arrive at the site.

Inspections. Remotely inspecting high-risk areas is another facet of safety. The next speaker presented experience with remote camera inspections of LM6000 and 7EA peaking-unit compartments. This is a specific solution based on a GoPro camera and a digital monitoring device.

Craft labor in this utility's peaking-turbines department sought a system that would be safe, avoid unnecessary tag-outs for things like oil leaks, and not violate the gas-turbine OEM's requirements—such as the prohibition of entering a turbine package during operation. The solution selected features off-the-shelf components costing at most $1500, rather than expensive stationary cameras. The camera sits in a mag base with remote mounts, while the monitor stands outside the GT housing.

This was also a case where putting the minds of your younger workers to bear on the problem pays dividends, the speaker noted.

The apparatus has already proved its value in detecting water leakage in a GT package following a shutdown and confirming its source (NO_x injection water line), detecting smoke emitted from the turbine compartment and confirming its source (vent fan), as well as for conducting condition assessments of inlet-house fogging nozzles and evaporative cooler media, and for monitoring an oil-consumption sight gage.

Generally, any piece of equipment inside a housing can be monitored and recorded externally during operation for an extended period.

Questions included whether the components are explosion-rated and "intrinsically safe" and what the high-temperature limit is (answer, 400F for direct contact, but does not actually contact hot surfaces). One commenter noted that such cameras have also been used in place of borescopes for "troubleshooting insight."

Market competition. As if it wasn't yet clear, the presentation titled "Renewables Are Coming" made unassailable the coming competition to gas-fired plants from solar and wind. And if you don't like that, you can no longer blame it solely on government mandates.

Eight states now require 100% renewable energy by 2045 and five others have 100% renewable "goals." Large high-profile corporations like Facebook, Google, Microsoft, and other digital-economy leaders, the speaker noted, plan to either build or buy 72 GW of renewable energy by 2030 for their electricity-hungry server farms and other needs.

That's the demand side. On the supply side, the presenter noted that solar photovoltaic (PV) systems have dropped in cost from $3.50/watt to 50 cents over the last 12 years, and their active-power control capabilities have greatly improved. Grid-scale battery systems, which assist in load management, also have dropped in price by 70% between 2015 and today.

"Lots of states already show solar and wind to be the least-cost capacity options," observed the presenter, "and only a handful of states show gas-fired generation as the least cost option in 2030."

There are unintended consequences, however. For example, smoke from the California wildfires this past year decreased solar generation from existing facilities by around 30%. Guess which plants would be making up that loss on a moment's notice? Yup, gas plants.

Another consequence of the strange year called 2020: Utility system loads shifted dramatically, because of Covid, from commercial facilities to residential units. Zooming takes electrons.

Most of the bulleted items on four slides about how to adapt GT units to this coming onslaught are probably more than obvious to most users and have all been topics of one or more presentations during prior CCUG conferences, including the future potential for hydrogen produced by renewable sources as a GT fuel.

Drum-weld critical-crack-size pre-outage assessment and application experience

Anand Gopa Kumar, analysis manager, HRST Inc, coached the audience through a relatively new onsite crack-size assessment technique, conducted along with ALS Industrial Services, that has now been demonstrated "on a few HRSGs." The technique, which follows API 579 and ASME-FFS-1 standards, combines transient thermal simulation (based on finite-element analysis) crack growth under drum operating conditions with standard NDE crack inspection methods—including magnetic-particle and ultrasonic testing.

The deliverable, if you will, is a failure assessment diagram (FAD) of the areas under investigation which reveals critical crack size (Fig 9) as a basis for decisions about remaining life, additional run time, etc. In other words, measure the crack dimensions (length and depth) and project their growth (assuming other variables are fixed) over the next operating cycle.

"All high-pressure drums should be periodically inspected but the thicker HP drums are most at risk," Kumar said, with the area of greatest risk being the surfaces exposed to the 0-400-psig pressure range where the fastest temperature rises are experienced. "Thick cold drums plus fast pressure ramp equals stresses at the large nozzles," Kumar noted. The shell-to-head area is also susceptible to cracking.

A typical F-class HRSG HP drum needs around eight different FADs, one for each of the major weld locations. The technique is best performed before an outage, so that relatively quick decisions can be made on repair during the outage versus continued monitoring.

The technique is applied to ID wall cracks, since removing insulation from the OD side usually is impractical or not possible. However, Kumar said, some cracks at OD weld areas can be detected from the inside. The analyst also has to consider adjacent cracks and the potential for crack interaction. "Sometimes cracks close together should be considered a single larger crack," he said.

Many of Kumar's slides were devoted to pre-outage, start of outage, and in-testing work.

Pre-outage work includes organizing the information—such as design drawings, operating profile data, historical repair procedures, photos, and any other previous inspection results or condition reports. Drum weld areas need to be properly exposed, cleaned, and prepped for NDT, and drum internals removed. Less obvious: Install snug-fitting foam plugs in nozzles to protect them from foreign objects and install lanyards on all tools if open holes exist.

At the start of the outage, inspect surface prep before the NDT crew arrives, label each weld location with paint stick per the drum weld location map (Fig 10), and protect nozzles from falling objects.

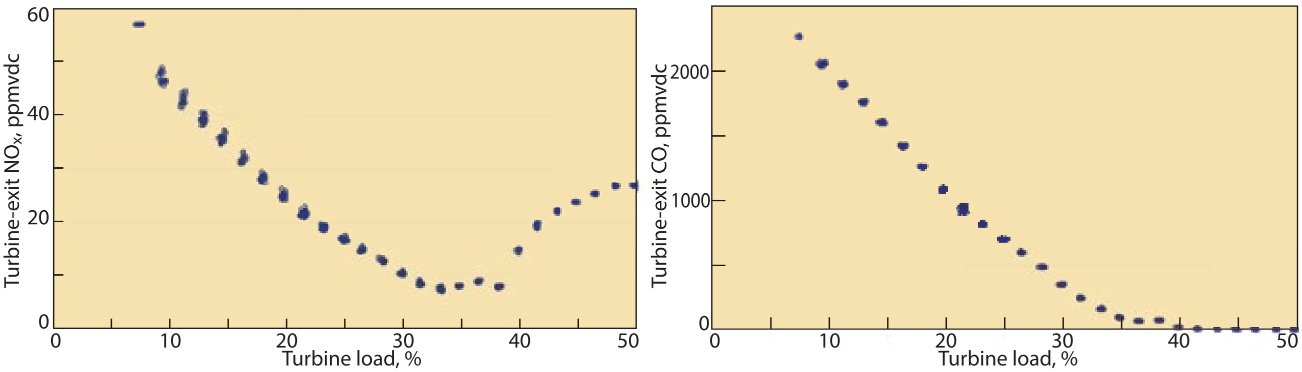
During testing, the technician performs mag-particle tests first, then the phased-array ultrasonic tests to accurately document the start of cracks, while being aware of multiple crack interactions. Length and depth of cracks must both be determined to decide whether more run time without repair is prudent. Decisions whether to leave as is or grind out shallow cracks must be made as well. Minimum wall thicknesses should also be calculated ahead of the outage, using ASME methods.

In response to questions, Kumar stated that fatigue-life calculations are not part of this exercise—these components typically do not operate in the creep temperature range—and it is uncommon to see cracks slow down or stop rather than continue to grow. Performing this technique before a unit enters cycling service can be especially valuable.

Is your SCR/CO system ready for turndown?

Moving through the combined-cycle system to the NO_x and CO emissions catalysts, Andy Toback, Environex, asked in his presentation title, "Is Your SCR/CO System Ready for Turndown?" If your SCR was designed for baseload operation, the answer is probably not.

Chemical constituents change at temperatures typical of low-load operation. NO_2 from the gas turbine gets elevated and CO from the GT exhaust can "grow exponentially at low loads," because the operating-temperature range has shifted. Toback then turned



11. Low-load limit with present catalyst is about 35%. Both turbine-exit NO_x (left) and CO (right) rise quickly at lower loads and a different catalyst would be required to maintain compliance

to two case studies to illustrate his points.

The plant in the first case was experiencing ammonia flows higher than design, sometimes twice as much, even at low loads, and low NH_3 vaporizer temperatures at high NH_3 flows. The NO_2 fraction of NO_x was measured consistently higher than 50%, and as high as 70%, during startup. Normally, it should be around 20% NO_2/NO_x.

Nevertheless, both CO and NO_x catalysts were performing well. However, the CO catalyst was also oxidizing NO to NO_2, so the SCR catalyst had to work harder neutralizing the elevated NO_2 levels, acting as if it was near the end of life, asking (through the control logic) for additional NH_3 spray.

"The catalyst was behaving perfectly for the baseload conditions it was designed for," Toback reported, "but to operate at lower loads and meet permit limits, it would require 20% additional volume and 0.6 in. H_20 additional pressure drop."

Toback called the second case study a "turndown field exercise." The test crew measured steady-state catalyst operating temperatures and CO and NO_x concentrations in the GT exhaust down to 8% load. The goal was to determine what turndown levels the plant could run at with available catalyst configurations. It turned out that 35% was the load limit with the present catalyst. Both turbine-exit NO_x and CO levels (Fig 11) rose precipitously below this point.

"This plant could get to a 28% load limit if they replaced the present CO catalyst with a dual-purpose formulation," Toback concluded. While this approach could prove worthwhile for some plants facing extended operation at extreme turndown levels, this plant opted to stick with what it had. In addition to the larger catalyst volume, there is a pressure-drop penalty.

One questioner asked what the catalyst concerns would be running the plant at higher-than-design loads. Answer was that the anticipated life of the catalyst would have to be modified based on the operating data post-uprate.

Another asked if catalyst degradation is gradual or "falls off a cliff." Answer was that NH_3 consumption tends to increase exponentially and catalyst deactivates quickly near end of life. Short answer, probably. Catalyst needs to be tested periodically, and "married up to operating data," to keep from approaching the cliff, especially after the OEM's warranty period, to establish a baseline. "Early catalysts were over-designed," Toback noted, "while later CC/GT facilities have catalyst supplied more competitively on volume."

In the Environex virtual breakout room, discussion continued on topics such as these:

- How often to clean NH_3 heaters. One plant cleans with acid every three years, while another plots wattage to vaporizer exit temperature to predict when the next cleaning should be.
- Options for running at lower capacity factors when your NH_3 flow is capped. Check for plugged nozzles in the ammonia spray array, and try to tune the unit by measuring NO_x and ammonia slip at each point in a traverse (assuming you can reach the sampling ports or add a sampling port grid), and selectively increase the ammonia flow in trouble spots.
- Plants having issues with operation below 40F and above 85F can consider seasonal tuning.

Week Four

Cooling towers, tank inspections, water chemistry, fire suppression, pump vibration

With one exception, the CCUG Conference's final-day presentations covered components that, as the first presenter joked about cooling towers, are in the "back 40," whether that means physical location or in the minds of the staff. All the more reason to pay close attention, as these are still components which can impact financial, safety, and other performance factors.

Cooling-tower fans and drives. Batting leadoff was EPRI Technical Consultant Sam Korellis, who reviewed a cooling-tower (CT) fan-motor-drive and gearbox field evaluation program and its implications for CTs serving more than 800 units at around 300 powerplants.

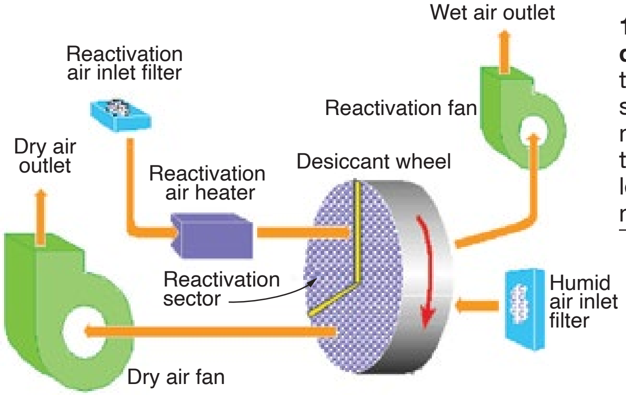
CTs are equipped with multiple fans which start and stop depending on load and fans out of service. With many plants cycling more and more, these fans cycle on and off more as well. Since each draws auxiliary power, excess fans in operation penalize heat rate.

Korellis noted that the criterion to start or stop a fan is simple: If it allows an increase in net power. Starting a fan improves CT thermal performance and unit efficiency but draws additional power. Stopping a fan has the opposite effect.

Starting and stopping fans leads to gearbox failures. Gearboxes suffer failures at a 10% to 20% annual rate industry-wide, said Korellis, and they are costly. A new one costs about $30,000, plus about $5k in labor. They also require replacement power while out of service, can damage fan blades and other components, and can lead to oil contamination of the tower water.

Objective of the drive optimization project was to evaluate the start/speed regime under unit cycling. Operating wet-bulb temperatures ranged from 35F to 85F and steam-turbine load from 200 to 900 MW during the test program.

Three starting/speed regimes were tested: one-speed (on/off), a soft start (two-speed), and a variable frequency drive (VFD) capability. Under a variety of operating conditions (load, cold-water temperature, ambient temperature, fan speeds, number of fans in operation, etc), the VFD option offered the greatest net benefit in optimizing performance, and was similar in cost to



12. Circulation of dehumidified air through the turbine steam path prevents moisture condensation; deposits cannot lead to pitting without moisture

the two-speed option, even if the latter is of a simpler design.

For the gearbox evaluation, project team purchased several new right-angle gearboxes, and installed and operated them in one CT, with additional monitoring capability, where they would be subject to identical operating conditions. Objective was an attempt to determine causes of frequent failures, effect of repeated start/stop cycles on gearbox reliability, and the relative reliabilities of gearboxes paired with the three start/speed regimes.

During the evaluation, four gearbox failures were experienced in one year. Elevated lube-oil failures also were noted. There were signs of low oil level, moisture contamination of oil, and high oil-pressure levels which caused vaporization and loss of oil. Oil temperatures greater than 200F were observed in the winter, and as high as 300F in the summer.

Near-term modifications suggested by the results include the following:

- Upgrade to synthetic oil or higher-grade mineral oil.
- Check oil level and condition during warm operating months.
- Develop oil sampling and analysis to detect early degradation.
- Impose quality threshold levels for oil rejection and replacement.
- Continuously monitor gearbox temperature.
- Deploy real-time vibration monitoring sensors.
- Reduce dead air space around gearbox to promote better cooling.

Longer term and more involved/costly solutions include an automated lube-oil refill system and lube-oil sampling; addition of an external lube-oil filter and cooling system; or convert to a direct-drive system and eliminate the gearbox.

One attendee asked how to feed this knowledge into a design spec and Korellis said to add fins and/or a diverter to improve gearbox cooling, and add instrumentation to monitor temperature in the bottom of the gearbox. Another asked whether there was any difference in the performance of the soft-start versus VFD and the answer was "no." A third asked about the oil sampling and the suggestion was to sample and analyze weekly, but cautioned that sampling apparatus could contaminate the water if the sampling tube leaks. Best to locate the sampling apparatus outside of the CT internals, he added.

Ammonia storage tanks. Batting second was an owner/operator presentation on aqueous ammonia (NH_3) tank inspections. According to the governing standard API510, a "fitness for service" assessment should be conducted every 10 years (or half the remaining life calculated during the last inspection) for pressure tanks. The method results in a calculated remaining life, and typically the work is performed by a specialist contractor squad including an API specialist, NDE technicians (typically two), a confined-space entry team, standby rescue team, environmental contractor, scaffolders, and the ammonia supplier.

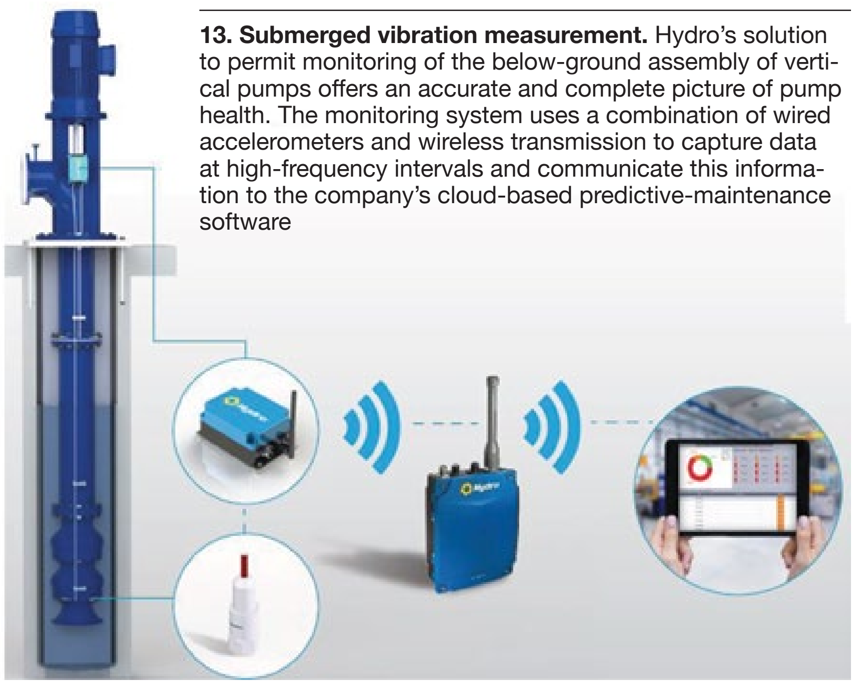
The owner/operator or plant should assign a point person to the project who coordinates with the contractors, prepares the tank documentation, gathers previous inspection reports, etc.

Since tank wash-down water must be disposed of as hazardous waste, an accurate estimate of the residual NH_3 is necessary ahead of the work. You can expect between 2000 and 3000 gallons of RCRA-type waste which will have to be disposed of or stored onsite in a tanker. Plant should allow a full day for tank cleaning.

Once cleaned, the actual tank inspection is "pretty straightforward." The NDE inspectors divide the tank surface into a grid and record thicknesses from ultrasonic transmitter (UT) readings at each location. Allow a second day for the inspection work. Plant staff should take the opportunity to service pressure relief valves, vacuum breakers, and other ancillaries, and leak-check the manway ports (easier for vertical tanks). Make sure to have on hand sufficient calibrated air monitors and extra ammonia sensors.

In response to questions, the presenter said that (1) they had not considered neutralizing aqueous NH_3 prior to opening the tank, (2) the dump valve should be inspected and/or replaced at each inspection, and (3) the tanks are carbon steel, piping is stainless, and that iron can mix with the NH_3.

Steam/water chemistry. Typically, you want your heavy hitters batting third or fourth. The third presentation, Steve Shulder (also of EPRI) addressing chemistry-related damage from flexible operations, belongs in the "heavy" category; most slides are laden with bullet points likely summarizing



13. Submerged vibration measurement. Hydro's solution to permit monitoring of the below-ground assembly of vertical pumps offers an accurate and complete picture of pump health. The monitoring system uses a combination of wired accelerometers and wireless transmission to capture data at high-frequency intervals and communicate this information to the company's cloud-based predictive-maintenance software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chapters of larger EPRI reports on water and steam chemistry issues. In fact, it's almost impossible to condense the 45-slide deck into useful highlights, so review online at www.powerusers.org. It's packed with good material for whoever is responsible for plant chemistry.

Two areas worth reviewing here, however, are (1) maintaining sampling and online analyzer systems and (2) plant layup and storage. Keeping the former in top working order is critical because, during operation, "you can't control what you can't see," stressed Shulder.

Of course, online analyzer systems are also impacted by cycling operations and improper layup. Debris in the water/steam circuits can plug sample lines. Sample lines should be equipped with blowdown lines; lines and analyzers should have de-ionized water flowing through them so they don't dry out. Other checklist items are shown in Table 1.

The table on best available techniques for layup and protection (Table 2) is a convenient guide organized by plant subsystems and components. Of note as well is a recently developed dehumidified-air system (Fig 12), proven at several combined-cycle plants in the south, which protects the turbine steam path from moisture condensation when offline for long periods. "Deposits cannot lead to pitting without moisture," Shulder reminded the audience.

Improving the life safety of CO_2 fire extinguishing systems

The main messages from the "batting cleanup" presentation on fire suppression systems, by ORR Protection's Chuck Hatfield, are that NFPA Code requirements include the life (human) safety and reliability of suppression

Table 1: Mitigating the impacts of flexible operation on sampling and online analysis systems

Ensure key components for temperature, flow, and pressure regulation are designed into the system

One resource recommended by EPRI: "Monitoring cycle water chemistry in fossil plants, Vol 1 (GS-7556-V1)."

Protect against excessive corrosion products in sample lines

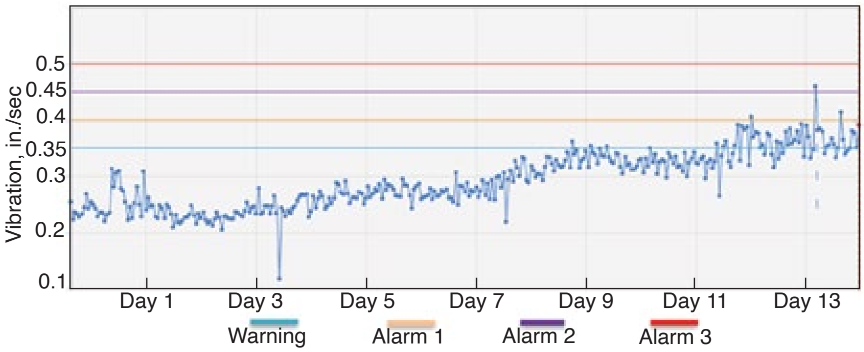
- May require isolating the sample panel at the root valve.
- Consider blowing down sample lines between the root valve and sample panel. Restrict purge velocity to less than 125% of the normal 3.3 liters per minute.
- Consider using a magnetic sample filter.

Protect components against pressure and temperature

- Ensure sample coolers have adequate cooling-water flow during transient conditions. Be mindful of sample temperatures; ensure high-temperature shutoff valves are in place.
- Vent/purge air from sample lines to avoid damage from water hammer to gages, regulators, and rotameters.
- Protect from freezing: heat trace and blow down until components/lines are free of water.

Protect analyzers during layup to ensure prompt return to service

- Do not allow sodium, pH, and dissolved-oxygen analyzers to dry out. Ensure flow cells don't siphon by adequately venting drains.
- Provide a source of condensate-quality water to panels.
- For long periods of shutdown, be sure to follow probe-manufacturer layup guidelines. Removal and storage may be necessary.
- Ensure pH probes are recalibrated within a few days following unit restart to account for any shifts in calibration.



14. Vibration trending proved its worth over two weeks, indicting movement above "warning" and towards a second alarm level

Table 2: Best available techniques for asset protection

Technologies recommended for asset preservation by system and time offline

Shutdown duration,hr	Hotwells	Drum HRSGs/boilers, including superheaters	Reheaters	Steam turbines
8 - 12 (hot standby)	Maintain vacuum	Keep boiler above saturation temperature and bottled up at more than 50 psig and 300F	Open vent and allow clean, dry air to flow through the reheater to the condenser air-removal system	Inject dehumidified air or dry compressed air to dry out the LP turbine
12 – 72	Maintain vacuum	Keep boiler above saturation temperature and bottled up at more than 50 psig and 300F as long as possible. When pressure decays to less than 10 psig, implement wet, circulated layup with nitrogen cap	Open vent and allow clean, dry air to flow through the reheater to the condenser air-removal system	Inject dehumidified air or dry compressed air to dry out the LP turbine
More than 72	Drain	Drain hot under nitrogen. If nitrogen is not available, use dry compressed air to assist with steam removal prior to cooling	Open vent and allow clean, dry air to flow through the reheat to the condenser air-removal system. Alternatively, nitrogen blanket	Circulate dehumidified air

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equipment, whether low- or high-pressure type; and that the industry is "moving away from CO_2 based suppression to water-mist systems."

One reason for the shift is that life safety risk is higher with CO_2. Another is the psychological effects—there has been a higher level of deaths in confined spaces protected by CO_2 in recent years. A third is that water presents an effectively "unlimited" supply of suppressant compared to CO_2.

The presenter distinguished among three types of areas with respect to fire: those requiring LOTO for entry; normally occupied areas, those not governed by LOTO; and normally unoccupied areas, those which cannot be occupied by a person. NFPA has new requirements for equipment to enhance life safety in normally occupied areas. Visit www.nfpa.org for details. An odorizer is an option and is very expensive, according to the presenter. Lockout valves must be monitored.

NFPA 750 and FM 5560 apply to water-mist systems. Fundamentally, all convert water mist into steam which acts like an inert gas, and promote three extinguishing mechanisms—inerting, cooling, and fuel wetting. System varieties include self-contained cylinder units, or diesel engine, gas engine, or electric power drives.

Attributes include the following: They incorporate smoke scrubbing devices, consume a relatively small amount of water, one pump/system can serve multiple generating units (for example, three gas-turbine units), and can be equipped with plug-and-play releasing panels.

The presenter responded to questions on the following topics:

- Sources of water—fire water main loop if potable water, cooling water, or demineralizer water (if the tank is large enough).
- Spent water collection—generally not required; some fire-prone skids like lube oil have a containment wall around them.
- Testing spray heads for atomization—test on system commissioning, then blow air to make sure nozzles are free-flowing. NFPA requires blowout with air annually, annual water bottle inspection, and backup-battery tests every six months.

Innovations in vertical-pump vibration monitoring

Based on sheer number of slides (87), this presentation by Hydro Solutions fulfilled batting-order slots five through nine. The first presenter, Ares Panagoulias, reviewed a relatively new, but proven, capability to monitor vibration of submerged vertical pumps using a single-axis piezoelectric accelerometer directly wired to a wireless transmitter with its own power source (Fig 13). Data go to a "cloud-based" app.

Included is a case study of a problem pump with a history of unexpected failures. Two different sensors were mounted 90 deg apart at the motor/pump interface with guard brackets to keep them in place. Specialists were able to "see" a significant vibration trend moving upward over a period of two weeks (Fig 14). Vibration is, of course, a direct indication of wear and fatigue. All three main components—sensor, data transmitter, and data collector gateway—require batteries which are said to last up to 36 months depending on data-collection frequency.

Pump performance under load cycling. Ares' co-presenter, Michael Mancini, essentially delivered a primer on pump design and operation, specifically the relationship of best efficiency point (BEP) to changing unit load output. Needless to say, or at least good to be reminded, the farther your pump operates from its design BEP, the more performance problems it will experience. Geometry of pump internals (like the impeller) are fixed, and therefore cannot accommodate significant changes from design flow parameters.

Some problems may stem from original design, said Mancini, especially older pumps which didn't have the advantage of computer-aided design, or were specced out by inexperienced young engineers in applications engineering.

The presentation includes spectacular video clips from lab plexiglass test stands showing how non-optimum flow conditions create waves, stall areas, back vortexes, and thick swirls. At 40% to 50% flow points, backflow grows dramatically, and significant reliability impacts occur at 20% below BEP, the presenter stressed.

This slide deck is a must for any young engineers on your staff or older engineers who have forgotten all this stuff. Not only does it provide dramatic illustration of pump issues at less than design parameters, it also includes practical solutions to common issues. The presenter has over 45 years of experience in design, operation, troubleshooting, and repair of pumps worldwide.

If you are hesitating, consider this analogy: A pump operating at its BEP is like a professional diver entering the water with almost no wake; a pump operating away from its BEP is like doing a belly-flop. Not only are significant waves created, but it hurts like hell. CCJ

WTUI

2021 Virtual Conference

June 7– 24

Western Turbine Users Inc, the world's largest independent organization of gas-turbine owner/operators, was to have celebrated 30 years of service to the industry at its annual conference and expo in Long Beach in spring 2020, but Covid-19 nixed that plan. A brief virtual meeting a few months later brought members up to date on what the OEM and its licensed authorized service providers (ASPs) were doing. However, that didn't qualify as a 30th anniversary meeting—at least in the minds of the editors.

But the 2021 virtual conference, which opens Monday, June 7, certainly will. The technical program is robust and provides plenty of time to get your questions answered. As you read through the agenda outlined below you'll see that it mirrors WTUI's in-person conferences in the following ways:

- Presentations by the OEM and the ASPs, focusing 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 solutions providers invited by the organization's leadership team (p 31).
- 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 at a virtual vendor fair and in special breakout rooms.

The only things missing from a traditional live conference are the golf and bowling tournaments and other group functions important to the comradery that benefits interaction among users and suppliers. Next year!

Register today at www.wtui.com at no cost to qualified users. Registration is required for access to the conference.

All times in the program that follows are US East Coast.

Week One

Monday, June 7

9:00, Welcome, *President John Hutson, plant manager, NAES Orange Grove Energy*

9:15, LM engine refresher workshop, *Andrew Gundershaug, plant manager, Calpine*

10:15, Engine session chair introductions: LM2500, *Garry Grimwade, utilities generation technician, Riverside Public Utilities;* LM5000, *Perry Leslie, plant technician, Wellhead;* LM6000, *Dave Fink, I&C technician, Onward Energy, Fountain Valley Power;* LMS100, *Steve Worthington, plant manager, APS, Ocotillo Power Plant*

10:30, WTUI discussion forums and website content, *Wayne Feragen, plant manager, Noresco Colton*

10:40, ORAP overview, *Sal DellaVilla, president, Strategic Power Systems*

10:50, Break

11:00, MTU introduction

11:10, TCT introduction

11:20, ANZGT introduction

11:30, IHI introduction

11:40, GE Gas Power introduction

12:00, Day One concludes

Tuesday, June 8

LM6000 focus

9:00, ORAP analysis of fleet performance and Top Ten causes of forced outages,* *Tom Christiansen, SVP, Strategic Power Systems*

9:30, MTU field/shop updates,** *Ralph Reichert*

Presentation topics to include LPT failure (solutions and experiences); contamination handling, post-overhaul vibrations during test run, and nitrided bearings.

10:15, TCT field/shop updates,** *Robert Smans*

Presentation topics to include LPT S1 nozzle new distress feature, LPT B/P seal premature distress, HPT S2 nozzle spoolies and nozzle distress, LPC corrosion, combustor distress primary/secondary swirler (SAC), and DOD event.

11:00, IHI field/shop updates,** *Hiroshi Aoki*

Presentation topics to include wrapping leaf seal found around LPT S1 nozzle, difficulty removing LPT module and resulting damage, jacking-oil hose found disconnected inside generator, fuel-nozzle sealring failure, cleaning of HPC rotor blades and vanes to address silica deposition, VIGV case corrosion, LPC and HPC damage, oil leak attributed to RDS housing in the incorrect position, cracks in the aft flange of the combustor outer liner (these are not repairable)

11:45, Open discussion

12:00, Breakout rooms for MTU, TCT, and IHI for continued discussion

1:00, Day Two concludes

Wednesday, June 9

LMS100 focus

9:00, ORAP analysis of fleet performance and Top Ten causes of forced outages,* *Tom Christiansen, SVP, Strategic Power Systems*

9:30, GE field/shop updates and solutions,**

Presentation topics to include parts and shop fixes, critical bulletins, Mk VIe counters, spare parts on hand and forecasting methodology, intercooler seals, and RAM programs for FOD screen, HPC VSV and blades, IPT S2N, IPT frame hardware, PT S5B

12:30, Day Three concludes

Thursday, June 10

LM2500 focus

9:00, ORAP analysis of fleet performance and Top Ten causes of forced outages,* *Bob Steele, VP, Strategic Power Systems*

9:30, MTU field/shop updates,** *Oliver Eckert*

Presentation topics to include first experiences with nitrided main bearings, early rub-coat exposure on HPC stator S15 and S16, TMF damage attributed to exhaust t/c failure, new leakage detection system, CRF/B-sump oil leakage when engine idling, CFF cracking

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at welds with resultant air leakage, HTP S2 nozzle-support air tube misalignment.

10:15, TCT field/shop updates,** *Ian Andrew, CET*
Presentation topics to include IGB horizontal duplex bearing events, HPC stator corrosion and VSV bushings, HPC stator S15 and S16 blades, TMF No. 5 bearing event, SL2500-IND-21-001 and SBs 284 and 285 with regard to the liquid fuel manifold, hexavalent chromium update on identification process.

11:00, ANZGT field/shop updates,** *Chris Martin*
Presentation topics to include HP system lock-up/seizure (TMF stationary seal/HPTR aft shaft seal), CRF cracking/bolt-hole elongation, dovetail cracks in HPTR S1 blades (Xtend), HPCR S1 blade failure, various bearing failures and issues pre-nitride, assembly issues with PT rotor blades/disk, CFF cracking.

11:45, Open discussion

12:00, Breakout rooms for MTU, TCT, and ANZGT for continued discussion

1:00, Day Four and Week One conclude

Week Two

Tuesday, June 15

LM6000 focus

9:00, GE field/shop updates and solutions**
Presentation topics to include HPC S1 blades, HPC S3-S5 blades plus HPC S3-S9 spool, 4B bearing nitride, 5R bearing nitride, HPC S1/S2 inner shroud (Metco), LPT vibrations after overhaul, improved material for LP Sprint nozzle, enhancement for end of VBV rod, LPT PCC flex joint, S11 legacy and PF+ check valves, T48 tip liberation, VSV bushing durability, ejector-nozzle thrust balance, PG HTP S2N in PC, Rad-Rad, SBs 345 and 346 related to HPT S1 and S2 disks.

12:00, Day Five concludes

Wednesday, June 16

Concurrent presentation/discussion sessions for each engine*—LM2500, LM5000, LM6000, LMS100—conducted by their respective engine chairs (p 31)

9:00, Sessions start

11:00, Day Six concludes

Thursday, June 17

LM2500 focus

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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 individuals in this army of volunteers dedicate hundreds of hours of personal time annually to keep you informed on engine technology, operation, and maintenance.

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.

9:00, GE field/shop updates and solutions**

Presentations on completed programs to include IGB spline wear, VSV turnbuckle wear, debonding of HPC air-duct wear strip, tip losses on HPC S12-S14, platform corner loss on HPC S15 and S16, CRF baffle cracking (DLE), bearing events caused ty hard-particle contamination, HP recoup algorithm V4.2 for LM2500+G4, field limits for HPT S1B.

Presentations on active programs to include gas-manifold distress (SAC), trailing-edge oxidation on HPT S1 blades, high-vane-count HPC, HPC corrosion, HPT rubs and unnecessary engine trips, axial shift of TMF liner.

12:00, Day Seven and Week Two conclude

Week Three

Tuesday, June 22

9:00, Industrial gas turbine market update,*** *Anthony Brough, president Dora Partners & Company*

9:20, The Axford Report,*** *Mark Axford, president, Axford Turbine Consultants*

10:00, State of the combustion turbine: A CAISO perspective,*** *Erik Youngquist, VP reliability engineering, and Jason Miller, PE, director reliability engineering, GridSME*

11:00, Virtual vendor fair with breakout rooms for the solutions providers identified below; participation is restricted to users and personnel representing these companies: Advanced Filtration Concepts, Aero Land & Marine, AGTSI, AP+M, Catalytic Combustion, Cormetech, Donaldson Company, ECT, Gastops, GTC Control Solutions, GustoGen, HPI Energy Services, Nord-Lock Group, ORR Protection Systems, Parker Hannifin, Relevant Solutions/Switch Filtration, SSS Clutch Company, Strategic Power Systems, Suez Water Technologies & Solutions,

and ProEnergy.
3:00, Day Eight concludes

Wednesday, June 23

Special technical presentations*

9:00, Total repair solutions—ROI, *Nelson Rouette, VP, and Tom Watson, SVP perations, EthosEnergy Group*
9:30, The evolution of the LM gas-turbine inlet cartridge filters, *Mcleod Stephens Jr, GM, Braden Filtration*
10:00, Maintaining and upgrading LM-series GTs to reliably meet the demands of today's grid, *David, Cicconi, turbine business development manager, Emerson*
10:30, An easy upgrade to peaker bearing condition monitoring, *Simon Wilson, sales director, Gastops*
11:00, Field results: HPC efficiency improvements and life extension, *Bobbi Monacelli, president, US Cleanblast*
11:30, Turbine upgrade methods and their impact on performance and profit, *Dan Stankiewicz, engineering manager, Liburdi Turbine Services*
12:00, Breakout rooms for follow-on discussions staffed by the day's presenters
1:00, Day Nine concludes

Thursday, June 24

Special technical presentations*

9:00, Grid stability and frequency-response testing, *Mike Toll, John Stulp, and Eric Freitag, Woodward*
9:30, LM predictive maintenance put into practice by Decide, *Patrick Jansen, chief services officer, VBF Turbine Partners*
10:00, Advanced long-life thermal insulation for LM2500 and LM6000 exhaust collectors to reduce package temperature, *Pierre Ansmann, global marketing director, ARNOLD Group*
10:30, Guaranteed emissions compliance for your ageing asset, *Jeff Bause, CEO, Noxco*
11:00, Better filtration pays for itself: The impact of (H)EPA filters on gas-turbine performance, *Florian Winkler, marketing manager, EMW filtertechnik GmbH*
11:30, How to avoid forced outages through site-specific preventive maintenance based on operating condition and environment, *Jon Neal, head of global field service, BRUSH Group*
12:00, Breakout rooms for follow-on discussions staffed by the day's presenters
1:00, Day Ten and the 2021 WTUI conference conclude

How duct burners can affect downstream tube metal temperatures

By Bryan Craig, PE, HRST Inc

Metal temperature is, perhaps, the variable most affecting the service lives of superheaters and reheaters. Long-term overheating of these components can result in failures necessitating multi-million-dollar repairs There is an upward trend for overheating failures in the industry, and many HRSGs are approaching the time in their respective lifecycles when this is becoming a significant risk.

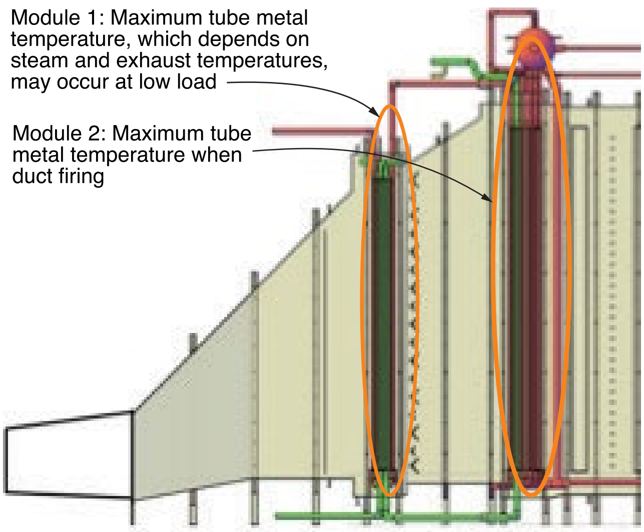
Fig 1 shows a typical configuration of a large HRSG with a duct burner. In HRSGs with duct burners, maximum tube metal temperatures in Module 2 occur when duct firing. An increase in the operating metal temperature of 15 to 20 deg F can reduce equipment life by half in some instances.

The overwhelming majority of superheater and reheater overheating failures seen to date by HRST engineers have been downstream of duct burners (Fig 2). Poor exhaust-gas and/or fuel-gas flow distribution at the duct burner can lead to local areas that are fuel-rich, resulting in long flames and local overheating in the downstream tube bundles.

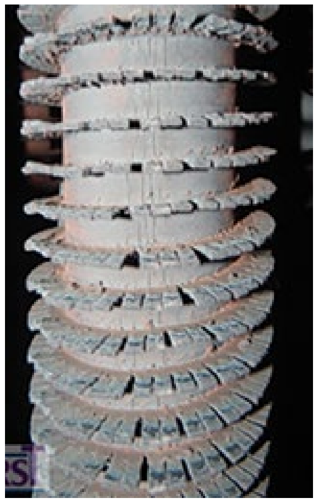
Here are two scenarios:

- *Uniform fuel-gas flow distribution, non-uniform exhaust-gas flow distribution.*

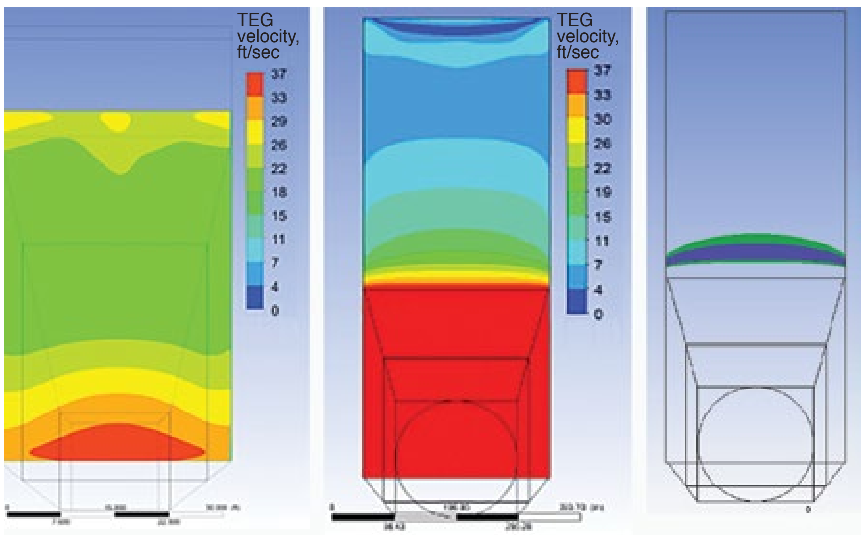
  Turbine exhaust gas (TEG) is the "air" source for an HRSG duct burner. If the fuel gas is distributed uniformly throughout the burner elements, but the exhaust gas flow is non-uniform, then the areas with higher-than-average exhaust-gas velocities will have a high air/fuel ratio, and areas with lower-than-average exhaust-gas velocities will



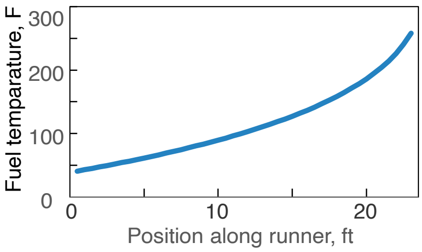
1. HRSG with a duct burner—a typical hot-end configuration for a large unit



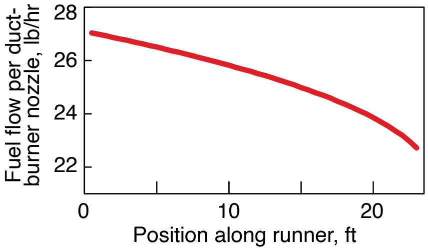
2. Reheater tube reveals long-term overheating damage



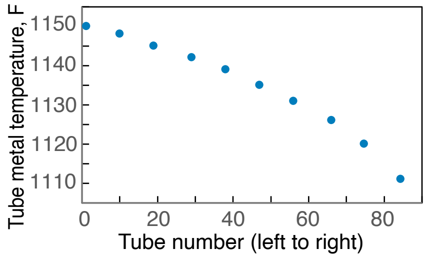
3-5. Turbine exhaust gas velocity profile at duct-burner inlet of a typical HRSG with a 60%-open perforated-plate flow distribution grid and eight rows of tubes upstream of the burner (left). In the middle is the TEG velocity profile of a unit with a short inlet duct, no flow distribution grid, and eight rows of tubes upstream of the burner. Sketch at right shows regions where the TEG velocity is within 15% of average (blue) and 25% (green) at the duct-burner plane for the middle case study with no flow distribution grid



6. Fuel enters the HRSG at a much lower temperature than the TEG at the duct-burner inlet

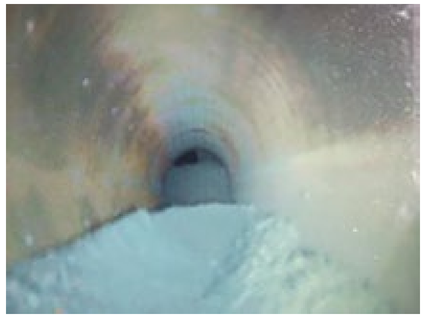


7. Fuel flow through burner nozzles likely will be higher at the inlet end of the runner because fuel is cooler there than at the far end



8. Downstream tube metal temperature is highest at the fuel-inlet end of the duct burner where fuel flow is greatest


9. Identical HRSGs, mirror images of each other, show overheating at the higher elevations and biased toward the fuel inlet to the duct burners (left side at left, right side at right)


10. Debris buildup inside duct-burner elements can be evaluated using a borescope

have a low air/fuel ratio. A low air/fuel ratio means fuel-rich. Thus, areas with lower-than-average TEG velocities will be fuel-rich and have longer-than-average flames.

- *Non-uniform fuel-gas distribution, uniform TEG flow distribution.*

This is straightforward. If there's uniform distribution of TEG flow to the duct burner, then the areas that receive higher-than-average fuel flow will be fuel rich, comparatively, and will have longer flames.

In reality, of course, neither the fuel flow nor the TEG flow to a duct burner is perfectly uniform. Still, it helps to think of the two effects separately.

TEG velocity profile. Turbine exhaust enters the HRSG at high velocity, at a low elevation. The momentum of TEG flow entering the HRSG causes its velocity to be higher at the bottom of the duct burner and lower at the top. This can be corrected by installing a flow-distribution device—such as a perforated plate.

If there are multiple rows of HP superheater and reheater tubes upstream of the duct burner, the flow resistance of these also can help to even out the TEG flow profile at the duct-burner plane. Even so, it typically is not perfectly uniform, as Fig 3 shows.

With this TEG flow profile, and assuming fuel flow is distributed equally to each duct-burner element and uniformly across the elements, you can expect a higher-than-average temperature and longer flames downstream of the HRSG at the top of the unit, and a lower-than-average downstream temperature at the bottom of the HRSG—based on the relative air/fuel ratios in the different zones.

Fig 4 presents the velocity profile for another HRSG, on the same scale as that described in Fig 3, but one with no flow distribution grid and a very short inlet duct. The TEG velocity at the bottom of the HRSG is much higher than average and the TEG velocity at the top of the unit is much lower than average. There is only a small zone with a TEG velocity close to the average value across the plane, as Fig 5 indicates.

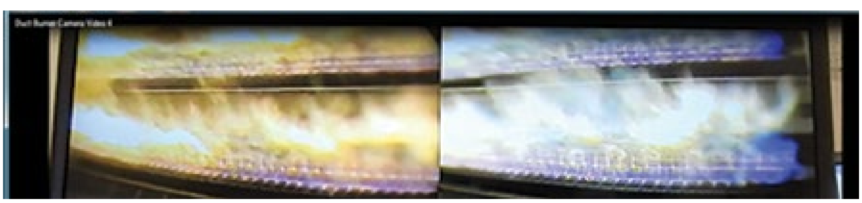
Fuel flow profile. Now, let's look at fuel flow. Fuel enters the HRSG at a much lower temperature (40F is typical) than the nominal 1000F TEG temperature at the duct-burner inlet. Thus, the fuel heats up as it flows along the duct-burner element. Heat-transfer calculations made by HRST engineers predict the fuel temperature curve in Fig 6 for a typical duct burner.

Most duct burners inspected by HRST personnel have uniformly distributed, equal-size openings (a/k/a nozzles) in the burner runners. With this design, a higher fuel flow per nozzle is expected at the inlet end of the runner where the fuel is cooler than it is at the far end. The duct-burner fuel-flow profile in Fig 7 is based on the fuel-temperature profile from Fig 6.

With this fuel profile, one would expect the downstream gas temperature to be higher, and flame length longer, on the fuel inlet side of the duct burner; and lower/shorter on the far side.

If you calculate the downstream tube-metal-temperature variation driven only by the effect of left-to-right fuel-flow distribution along the length of the duct-burner elements, the difference from the left side to the right side of the HRSG is nearly 40 deg F, as illustrated in Fig 8. This is substantial considering that a 15- to 20-deg-F difference in tube metal temperature can correlate to a factor of two in creep life!

Combined effects of fuel and exhaust-gas flow distribution. The photos in Fig 9 are from a plant with two identical HRSGs, except that


11. Duct-burner flame length can be monitored using a camera and control-room display

12. Gray zones in tubes downstream of the duct burner often correspond to long flames and possible overheating

they are mirrored. There are no flow-distribution grids in these units. The downstream tubes in both HRSGs show indications of overheating at the higher elevations, plus a bias toward the fuel-supply side.

It gets worse, in some cases. Duct-burner nozzles sometimes become plugged with debris (Fig 10). In HRST's experience, nozzle plugging is most prevalent at the far end of the burner elements (opposite the fuel supply).

Plugging can significantly exacerbate fuel-flow maldistribution, causing a far greater left/right temperature imbalance downstream of the burner than the fuel-temperature-driven imbalance described above. HRST engineers have seen instances of very large left/right fuel flow imbalances caused by nozzle plugging. Some of these have resulted in HP superheater tube failures immediately downstream of the duct burner.

Recommendation: Use existing view ports to visually observe the flames for length and shape when the HRSG is operating and the duct burners are at maximum fire. Flames should be independent and horizontal. A rule of thumb: Flame should extend only one-half to two-thirds of the way down the firing duct. If flames come within 3 to 4 ft of tubes, that's probably too close. Flames should never contact the tubes! If long flames occur, it is likely because of a problem with either exhaust-gas or fuel flow distribution—perhaps both.

A duct-burner camera is an alternative to using view ports to observe flame length during operation (Fig 11). One or more cameras can be installed inside the firing duct and provide a real-time view of the duct-burner flames to the control room operator.

During offline inspections, make note of, and photograph, any color variations in the tube bundle downstream of the duct burner. Gray zones in tubes downstream of the duct burner often correspond to long flames and possible overheating (Fig 12). CCJ

Desert Basin reports experience, success with first 501F FlameTOP7

The numbers are eye-opening: 20-MW gain in simple-cycle output, 3.8% heat-rate improvement in simple cycle, a stable GT turndown to 38%, and less than 9-ppm NO_x across the load range. That's what PSM and Salt River Project's (SRP) Desert Basin Generating Station reported at the 2021 501F Users Conference after upgrading a 2001 vintage Siemens 501FD2-powered combined cycle with PSM's FlameTOP7 technology, a first-of-a-kind for PSM on a 501F engine (figure).

Desert Basin has been a 501F fleet leader for two decades. This pioneering installation is no exception. But as Desert Basin's Moh Saleh and Jess Bills report, you can't avoid a few challenges along the way.

Design aspects of PSM's technology progression with GTOP6, GTOP7, FlameSheet™, and AutoTune have been explicated several times in the pages of CCJ (most recently, the last print issue, No. 65, 2021). FlameTOP7 essentially integrates the gas-turbine optimization aspects of GTOP7 with the output and efficiency improvements from the FlameSheet combustion system, with AutoTune thrown in for good measure. GTOP and FlameSheet are hardware upgrades, while AutoTune embodies advanced controls.

Here, the focus is on Desert Basin's install and initial operating experience, based on material presented with PSM at the conference, and a follow-up call with Bills and Saleh.

Changing needs, ageing units

SRP needs more flexibility and output from its GT fleet with the retirement of large coal-fired units in the state and growing customer load. It was also a natural point in the Desert Basin units' lifecycle to consider a major upgrade. Unit 1 had 12k EOH (equivalent operating hours) hardware in it, Unit 2 has 25k hardware. The plant wanted to use up the parts in inventory, so the remaining parts were installed in Unit 1. Generally, "the parts were on their last legs," noted Bills.

After evaluating advanced technology options and settling on FlameTOP7, the plant initiated a 10-month planning cycle, which of course was disrupted by Covid-19, and opted for a PSM total scope outage. It included scaffolding and installation requirements; and re-insulation (ARNOLD insulation) work for the walls, floor, and ceiling of the exhaust transition ducts.

Scope outside of PSM included internal repairs of exhaust transition ducts, HRSG repairs, relay upgrades, generator breaker replacement, new inlet air filters, upgrading of the exciter cooling system, and HRSG impacts evaluation.

Additional fretting of the rotor, initially observed seven years earlier, was discovered during the project. PSM worked with Sulzer to address it; this work did extend the outage.

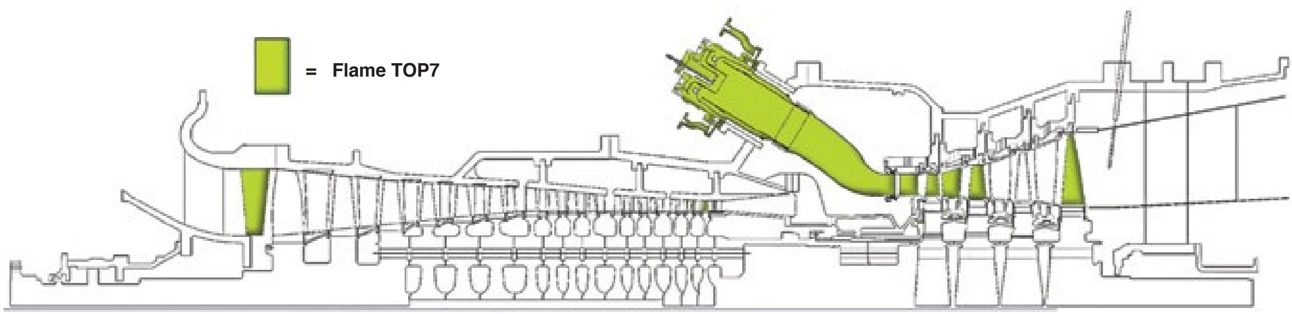
Planning included three site walk-downs, three joint PSM/SRP meetings ahead of the outage, review of logistics of PSM tooling and personnel onsite, and preparing for possible Covid-19 quarantine.

Bills and Saleh credit part of the project success to the decision to hire a third-party contractor for additional project oversight, "extra eyes on the work," as they put it in the presentation. Seth Conway, Somerset Engineering, had extensive experience doing contract work with PSM and with FlameSheet installations on 7FA machines.

Covid confounds

Once the pandemic settled in, the teams had to resort to virtual inspections of FlameSheet cans in the PSM shop and assembled parts ready for shipment, in addition to virtual training sessions. Plus, no one was able to walk down other sites which had installed GTOP or FlameSheet. Each contractor had its own workspace onsite to avoid cross-transmission.

All office space had to be arranged for social-distancing. Because these are



FlameTOP7 increases the simple-cycle output of a standard W501FD2 by 20 MW while reducing heat rate by 3.8% because of the improvements noted below the illustration. Unit turndown can extend below 40% of the full-load rating with FlameSheet™ and inlet bleed heat installed. NO_x emissions are less than 9 ppm across the load range

inside units, organizing work and tooling was especially important. Thankfully, no one became Covid positive while onsite.

Bills and Saleh laud tight and highly transparent communications during the entire Covid-impacted project. By the time of commissioning the new equipment, meetings were being held daily. They also credit early attention to logic and controls modifications (which had to be performed virtually) as a key factor in project success. "We were serial Number One," said Moh, "and we didn't want any impacts from something we might miss in the controls."

Taming NO_x emissions

Conversion from the original DLN (dry low NO_x) hardware to FlameSheet was "seamless," noted PSM and SRP, "the OEM's fuel manifold was adapted to the new combustor." However, when the units were first fired up with the new technology, the plant experienced some failed starts and incomplete ignitions. "GTs are very sensitive to fuel and air flows," Saleh reminded.

The more stubborn problem, though, was that NO_x emissions were initially much higher than expected at loads between 70% and 100%, higher than was demonstrated in PSM's lab. The original permit limit was 25 ppm, but the new guarantee point is 9 ppm.

PSM specialists Brian Micklos, senior manager of product management, and Brian Kalb, lead tech for combustion mechanical design, described "runback events triggered by elevated flashback," or in simpler terms, "the flame wasn't where it should have been." One liner experienced physical damage. The runback logic was revamped to prevent these problems, but the problem was that the combustor was running off of its design point.

PSM did some additional modeling and found unexpected air and fuel flows. Specialists added high-temperature thermocouples inside one combustor can, found some anomalies, and tweaked the FlameSheet liner with some expert welding. That helped, but a second "liner tune" was necessary. It involved "reworking the meter plate and flow sleeve" and additional welding modifications. The hardware tweaks were confirmed with CFD and air-flow testing.

Once the fuel/air ratios across the multiple fuel circuits were rebalanced, the units were able to achieve sub-9 ppm across the load range; reliability also greatly improved, as the combustion dynamics were much more stable after tuning. CO emissions were tuned to 7 ppm at 70 MW, and 10.5 ppm at 65 MW.

Safety minute: Crossed crane signals

Seasoned plant folks live by such mottos as "expect the unexpected" and "only the paranoid survive." Still, no mind or collective hive can be all-knowing. Here's an important safety minute that came from this project: Don't assume that the crane remote control is operating the crane you think it is.

Desert Basin has two bridge cranes: a 60-ton unit over the gas turbine, and a 70-ton unit over the steam turbine. Each has a 10-ton auxiliary hook. Hand-held radio controllers are used to move both. Rarely are both cranes used at the same time.

The plant wanted to add load cells so staff would know the weight of equipment being lifted, and an accompanying LED readout option to the joy-stick-equipped belly box for the 70-ton crane used by the operators. One was already installed on the 60-ton crane's controller.

The appropriate chip was pulled from the box and sent to the manufacturer so it could be re-programmed. After it was returned and re-installed, the SRP crane group tested it. All good. However, the 60-ton unit was not operating during the test.

When the 70-ton crane was next pressed into service, the 60-ton crane started moving! The operator quickly got off the joy stick, and supervisors declared a safety stand-down to figure out what happened. A root-cause analysis was initiated. "You try to do something to make life better (like add an LED readout) and something hiccups," Bills lamented. Thankfully, no one was injured. The local crane rep reviewed the chip programming and discovered that the signals were crossed at the factory.

Now the plant runs both cranes during tests to make sure there are no interactions between them.

Saleh and Bills added that replacing the problematic combustion dynamics monitoring system (CDMS), a fleet-wide issue with these machines, contributed to the improved reliability. "The original electric sensors would fail monthly, lead to runbacks, and other problems," they said. They were also difficult to access, because of the ¼-in. stainless-steel tubing attached over the combustor can. The new ones are mounted on the combustor "top hat," not directly on the combustor.

"We were limping along with the old ones for so long because they were costly and difficult to retrofit," Saleh noted. In any case, the old sensors were not compatible with AutoTune.

Lesson learned—permit details. Commissioning new technology takes time and patience, but as importantly accrues operating hours. Emissions compliance permits are usually very meticulous when it comes to startups and total emissions over a time period.

Desert Basin by no means is the first to drop this into the lessons-learned box, but it's an important one. "You need to ensure that the owner/operator and the technology vendor are fully aligned on permitting," stressed Saleh, "and that you know the details of the permit inside and out." Bottom line: Make sure you manage expectations on how many additional starts, stops, and operating hours could be necessary to fully commission the new technology.

Can the HRSG take it?

Impact on the HRSG was another challenge and lesson learned. "If there was one thing we could have done better, we would have worked out the full impact of the GT upgrade on the HRSG," Bills said. The first contractor they hired to assess the impact gave them modeling, but "what we needed was a practical approach." So a second contractor was engaged to more fully understand design aspects.

This part of the project is still being investigated. While the GT can now operate at 38% turndown, the plant is limiting it to 45% pending a better understanding of HRSG stresses. In the meantime, they are running field trials to see how the HRSG reacts at lower GT loads.

Balance-of-plant impacts

Another important area of BOP impact was the generator. The generator itself had ample design margin, but ancillaries needed attention. "We were fortunate that Desert Basin typically runs low VARs, so we don't stress the excitation system," said Bills. However, plant staff observed that the exciter was running hot the previous summer and, with the GT upgrade, was now bumping up against its temperature limit.

"Our exciter bridges are obsolete, but we devised a home-grown cooling system for them," Saleh beamed. He credits one of the plant machinists with a penchant for race cars and a crack electrician for the creative solution.

Beyond the generator, Bills and Saleh add, be sure to review transmission capabilities, previous studies, and the owner/operator's transmission agreements. CCJ

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A Better Way to Clean HRSGs

What makes EPIC off-line HRSG cleaning unique? The EPIC (Extraction Pressure Impulse Cleaner) system produces a rapid succession of controlled combustion events within its own patented combustion tube (not in the open HRSG environment) that permeates deep into each tube module with 120 or more repetitive, focused shockwave impulses from each side at every cleaning shroud position, for a cumulative total of 240 reverberating impulses. This alone is a major differentiator vs virtually any other method.

The rapid shockwave impulses progressively dislodge and effectively purge deposits from tightly spaced finned surfaces without spreading tubes or risking excessive open blast pressure on your HRSG structure, observed by the owner in real time from 8 camera views. The loosened deposits are further motivated to the lower header area with the assistance of low intensity vibrators.

Case study: Effective HRSG Cleaning with Off-line EPIC Shockwave Technology at a Florida Combined Cycle Plant

Problem: A large combined cycle plant needed to remove surface and embedded oxidation and operational deposits from a Nooter/Eriksen HRSG unit. They were experiencing restricted CT backpressure and insulated crucial heat transfer surfaces, affecting their overall efficiency and performance.

Solution: Using the proprietary EPIC™ cleaning system expertly executed by Thompson, the method utilizes shockwave displacement energy generated from the patented IMPULSE® cleaner to safely and effectively concentrate a repeated series of dynamic high-pressure cleaning pulses *directly and deeply into the tube module* via a remote-controlled navigation system with all personnel located safely outside of the HRSG.

The automated cleaning system is extremely safe for personnel as well as the entire HRSG structure with numerous fail-safe features fully integrated into the overall process. The EPIC system is the most effective and efficient method to deep-clean fouled tubes and decrease combustion turbine back-pressure restoring your HRSG to its optimum operation.

Results: The EPIC™ cleaning system effectively dislodged and removed the deep and heavily impacted deposits that had accumulated on and within the finned tube surfaces. The post-cleaning visual inspection throughout the HRSG, complimented by penetrating in-depth videoing into multiple harp panels by borescope, combined to provide clear evidence of the EPIC cleaning effectiveness. The operating performance was later evaluated by plant engineering and management personnel resulting in comments such as one from the Operations Manager being "thrilled" with the results and the Plant Manager enthusiastically stating "EPIC is the way to go to clean our HRSGs and we'll use it again in the spring for our next one."

Based on 6-month comparative operating data that was voluntarily shared with Thompson, it was determined that the **combustion turbine backpressure was reduced by 4 in. H_2O, resulting in a heat rate decrease by roughly 0.5 MMBtu/MWh. This was computed to yield an equivalent payback in 1,018 hours (41 days) due to reduced fuel costs, based on a 100% production (MW) load.**

The negative effects are undeniable: Fouling on the gas-side of HRSG tubes compromises plant performance, but it can be restored through innovative HRSG cleaning that reduces back-pressure on the CT, increasing net power output. Furthermore, when it comes to safety considerations of various HRSG cleaning techniques, the automated EPIC off-line pulse-detonation cleaning technology reduces hazard exposure, cleaning time and outage duration.

For more information, contact Carl Wise at 910-612-5468, 800-849-8040, or cwise@thompsonind.com. Or visit ThompsonIndustrialServices.com/EPIC.

Benefit from current experience with film-forming substances

The Fourth International Conference on Film Forming Substances, held virtually March 23 and 25, addressed a narrow, but important, topic in cycle chemistry control for powerplants and steam-generating facilities. The 2021 meeting, chaired by Barry Dooley of Structural Integrity Associates, was supported by the International Association for the Properties of Water and Steam (IAPWS, www.iapws.org) and organized by PPChem AG, publisher of *PowerPlant Chemistry Journal*. The event attracted a record 130 participants from 28 countries, about one-third of whom are affiliated with powerplant owner/operators.

Recall that film-forming substances consist of two main categories of chemicals: amine-based (FFA, Film Forming Amine, and FFAP, Film Forming Amine Product), and non-amine-based (FFP, Film Forming Products) which are proprietary compositions. For a backgrounder on the subject, see CCJ No. 60 (2019), p 12, "A wakeup call on film-forming substances," by Consulting Editor Steven C Stultz.

The meeting provided a forum for the presentation of new information and technology related to FFS, new research results, and case studies of fossil, combined cycle/HRSG, nuclear, geothermal, and industrial plant applications. Discussions took place among plant users, equipment and chemical suppliers, researchers, and industry consultants. The open format allowed users to engage productively with the industry's international experts and researchers.

Conference highlights included the following:

- Presentations by owner/operators confirmed that the use of FFS contributed to reductions in the measurements of feedwater total iron and copper corrosion products.
- There was general observation of hydrophobic films in the water-touched areas of feedwater and condensate systems. Film formation is still questionable in dry steam areas. Suggestions were made to improve the verification process using tube samples and corrosion-product monitoring during startups.
- Most user participants had appreciation of, and had applied, the IAPWS Technical Guidance Documents (TGD) for conventional fossil and industrial plants. Especially significant: More consideration was being given to pre-application review of the plant and chemistry as recommended in Sections 8 and 9 of TGE8-16(2019), "Application of Film Forming Substances in Fossil, Combined Cycle, and Biomass Power Plants." New information provided on "boiling out" with FFS provides an opportunity for updating IAPWS guidance.
- One of the continuing conclusions from previous FFS conferences was the important requirement to first optimize the current chemistry in a plant with verification through baseline monitoring before application of

any FFS. It was again emphasized at the 2021 conference that FFS should be regarded as an extension of optimized cycle-chemistry control.

- Problems still are occurring in a few plants worldwide following application of an FFS where there were no pre-application chemistry reviews of corrosion-product transport and deposition in HRSG HP evaporators. Some examples of problems presented: increased levels of internal deposits, tube failures (especially those associated with under-deposit corrosion), and formation of "gunk" (gel-like deposits) on heat-transfer surfaces and in steam turbines. These problems need further definition.
- Future planned research for nuclear plants was discussed. One topic cited that may be of interest to combined-cycle users: The effect of FFS on degradation of gaskets and elastomers.
- Research was presented on electrochemical impedance spectroscopy (EIS) studies of FFA on the corrosion protection of bare carbon-steel surfaces. This research showed how EIS can be used in the laboratory to evaluate in-situ film formation, thickness, and porosity, and thus the effectiveness of a protective film. These techniques must be developed further for plant applications.
- The conference included presentations of online instrumentation, analytical procedures for measurement and quantification for both FFA and FFP, and on surface-wipe techniques to supplement visual observations.
- There was new and important research reported on decomposition/breakdown products of FFA, thermolysis and distribution of FFA, and adsorption kinetics of film formation.
- The important effects of FFA on single- and two-phase flow-accelerated corrosion were reported and discussed. The latest laboratory results reverified the previously recorded reduction in single-phase FAC. However, there still is variability between laboratory results and field observations of two-phase FAC—for example, the benefits of FFS application in air-cooled condensers. This FAC investigative work should be extended to a wider range of FFA and FFP.
- As a direct follow-on from the IAPWS 2018 and 2019 FFS conferences, no new work was presented to better understand the mechanism of the interaction of FFS with surface oxides, and how an FFS film might change the growth mechanism and morphology of the oxides and result in the reduced levels of iron and copper corrosion-product transfer that are reported in all FFS plant applications. Future work was encouraged on the interaction of FFS films with existing oxide/deposit surfaces of Fe_3O_4, Fe_2O_3, FeOOH, CuO, and CuO_2 in condensate/feedwater and boiler/evaporator water environments.
- There was discussion on the lack of understanding on the effect of FFS on the oxides which grow in steam circuits, and on the chromia oxides which form in the phase transition zone (PTZ) of the steam turbine. The need for more observations during future plant applications was stressed.

Wrap-up. Overall, it was clear that the understanding of FFS application is improving worldwide but that there is still much to learn and a lot of fundamental work that must be done to understand the mechanisms at play. This includes film-formation kinetics, equilibrium and stability, film structure (for example, thickness or number of layers) and porosity, how adsorption is affected by other amines, and the correspondence to the reduction in corrosion rate through understanding of the interactions with oxides and deposits. Another remaining open question is whether an FFS improves heat transfer. CCJ

Stellite delamination is preventable, but owner/operators must 'enforce' the solution

Liberation of cobalt-based hardfacing (oft-used Stellite™ being one of these materials) from large Grade 91 valves installed in combined-cycle main and hot-reheat (HRH) steam systems, and in steam turbines, was a hot topic in the industry about a decade ago. With the need for an evidence-based solution, the Electric Power Research Institute (EPRI) assembled a committee consisting of owner/operators and stakeholders in the valve manufacturing supply chain to collaborate on the development of guidelines to mitigate the issue.

Three reports on that effort were released by EPRI in 2015 (sidebar) and the solution identified has prevented disbonding of the hardfacing where employed—at least CCJ has not identified any cases where the solution has not met expectations. Although there are only five or six years of field experience to validate the successful approach at this time, that's a big improvement for some plants where delamination had occurred in as little as 12,000 hours of operation.

With a solution available, why is CCJ covering this topic again? The answer in brief: Not everyone who should know about this relatively recent development is aware of it. Proof of the knowledge gap came by way of a phone call from Aaron Florek of Millennium Power Services, a major player in the valve repair business, who told the editors that his firm recently had repaired valves suffering disbonding at three plants in a three-month period.

Needing confirmation that the old news (delamination) is new again, the editors contacted two technical experts with deep experience on the subject—Kim Bezzant of Utah-based Wasatch Welding Engineering Services and John Siefert, manager of EPRI's Materials and Repair Program—as well as current users, and power-industry veteran Joe Miller, now industry director for power at ValvTechnologies Inc (VTI), which offers an alternative to Stellite hardfacing on the disks, seats, and stems of new steam valves.

All agreed that Stellite disbonding continues to haunt the industry—in large measure because owner/operators generally haven't been diligent in upgrading their specifications both for new valves and valve repairs to reflect recent experience. It is not sufficient to simply specify that valves be manufactured, or repaired, to meet the requirements of the ASME Boiler and Pressure Vessel Code (for valves within the Code boundary) and ANSI/ASME B31.1 (for valves included with boiler external piping). Recall that these documents prescribe *minimum* requirements and were developed to ensure that the equipment they address is *safe*.

They certainly do not protect against the financial fallout from a delamination event that forces your plant offline or prolongs a scheduled outage. With all the changes to grid contractual agreements over the last few years, it is worth reviewing the exposure your plant could have to a valve failure and how much it's prudent to spend on original equipment and repairs to insure against one.

Remember, too, it's not enough to simply upgrade valve specifications, you have to monitor the manufacturing and repair practices of the selected solutions providers to ensure they are doing what you have carefully specified in the contract. This can be challenging where offshore vendors are involved. Boiler manufacturers and EPC firms tend to buy foreign, in particular from Korea and India, to reduce their costs and they may be reluctant to monitor contract performance in-person. Such details must be agreed to and understood before work begins.

Many boiler and turbine valves have performed admirably over the years with cobalt-based hardfacing, as well as with other hardfacing materials. But the change to Grade 91 valve bodies and the demanding operating conditions for heat-recovery steam generators (HRSGs) in combined-cycle service have pushed to the limit the technology traditionally used to bond cobalt-based hardfacing to C12A or F91 valve trim. Today's high steam temperatures required a different methodology for attaching the two materials.

In simple terms, here's what EPRI's materials experts learned: Addition of a "buttering" layer of nickel-based alloy—such as Inconel™—separated Stellite and F91 material and prevented formation of an undesirable metallurgical condition in the weld zone between the two metals which is conducive to disbonding.

Plant experience

Florek told CCJ many plants in the country are addressing Stellite delamination issues and there are many more not yet aware of the problem they probably have. The three plants located in the Northeast that Millennium Power provided outage services for in the three-month period (2020) mentioned above illustrate findings typically identified at other facilities. Here are some of the details from those projects:

The first plant, a 2 × 1 H-class combined cycle began operating in 2017. Delamination was observed on six valves associated with the boilers and steam system at that facility—HP HRSG isolation, HP header isolation (a/k/a blending valve), and HRH (hot reheat) header isolation (for isolating one boiler from the other when necessary). The first type

1. Removal of damaged seats and reinstallation of new ones is a job for experts capable of quality work in uncomfortable positions **(A).** Examples of seat **(B)** and disk **(C)** delamination illustrate typical damage to these critical valve parts. Stellite overlay has been welded on new disc **(D)** with an Inconel butter layer between the F91 base material and hardfacing. Final machining of the stellite overlay on valve seat is in progress in **(E)**, finished product in **(F)**. New seat was installed in valve body **(G)** using a robotic welder to make the critical weld behind the seat. With both seats installed **(H)**, the valve is ready for reassembly

was in the European boiler manufacturer's scope of supply and sourced from Korea, the mixing valves in the EPC firm's scope came from another manufacturer.

The 14-in., F91 HP boiler valves were specified for service at 2420 psig/1065F. The type of Stellite hardfacing was not specified. What is known is that no buttering layer was used and that the Plasma Transferred Arc Welding (PTAW) process likely was employed for Stellite attachment. The HP isolation and blending valves are of the parallel-slide gate type and suffered Stellite liberation from both the seat rings and discs.

Note that these valves were manufactured *before* the EPRI guidelines (sidebar) were published. The EPRI findings identified disbonding concerns beginning at steam temperatures of about 975F, possibly even lower, with shorter expected life as the operating temperature increased.

When restarting the plant after the 2020 spring outage, an HP bypass valve on one of the HRSGs stuck open at 80% of full travel. This particular valve had just been retrofitted with a new magnetite strainer modification and reassembled. Inspection revealed hardened material in the valve, begging the question: Where's this coming from?

Repair of two valves on the boiler (the stuck-open valve and one additional HP valve), plus inspection and removal of debris from the steam system, were priorities. Some of the liberated material had traveled downstream to the steam turbine. It had piled up against the unit's protective steam strainers and was removed later, in fall 2020. During both outages, a borescope equipped with a magnet was run up through the steam lines to collect any remaining loose debris.

A specialty engineering firm was engaged to analyze the scrap and make recommendations. There were no unexpected findings. That company also confirmed the importance of a buttering layer. Bezzant recommends a buffer layer of ERNiCr-3 (Inconel Filler Metal 82), or an equivalent PTAW powder, to prevent carbon migration into the Stellite.

The affected valves were disassembled and discs and seat rings cut out. Millennium provided new seat rings and hardfacing for the discs consistent with EPRI recommendations and the company's experience.

Plant personnel continue to analyze the delamination issue and how to prevent it, with assistance from one of the valve manufacturers. One of the questions they are trying to answer: Is there a temperature at which hardfacing of the type currently used and applied becomes impractical? Another: Is the ramp rate or steam temperature the cause of disbonding?

Steps already taken by the plant include modification of its cold-start procedure (more time) and greater emphasis on the use of sparging steam from an auxiliary boiler to keep the unit warm when offline.

Regular inspections of valves are important to assess their true condition. The plant manager suggested that absent leak-by, your valves likely are fine. But it's probably a good idea to still select one or two valves at random for a thorough NDE inspection during each hot-gas-path outage. Why only one or two valves? Every time you open a healthy valve you run the risk of compromising its integrity.

If your inspection indicates leak-by, immediate action to correct is recommended.

Millennium Power refurbished four HP valves (isolation and blending) on the affected boilers to return the combined cycle to full power as quickly as possible. Work on the valves was completed in-situ a day ahead of the eight-day schedule. Plant's plan is to address damage to other valves suffering delamination, as necessary, during future scheduled outages.

In preparation for the fall 2020 outage, Millennium got the repair effort on the two HRH blending valves moving before the outage began by making new seat rings in its shop, Florek touting the company's ability to reverse engineer and typically make any manufacturer's valve parts in less time than it would take the vendor of record to supply them.

2. Strange things can happen to equipment in severe service. Welds joining the valve seats to their bodies were found broken and one of the seats badly deformed

The first step in the repair process was to remove damaged parts and prep the valves for new parts and hardfacing—something Florek says the company has done at least a couple of dozen times to date. Follow key steps in the montage of photos incorporated into Fig 1. He added that sometimes just the hardfacing is damaged, not the basic part. In such cases it's sometimes possible to remove the coating and reapply Stellite with the requisite butter layer.

Millennium Power's field service personnel moved in short order from this project to another in the region where two 24-in. parallel-slide gate valves were refurbished within two weeks. Old seats were removed, new seats manufactured with Stellite overlay and Inconel butter layer, and the valves rebuilt, including new actuators. Original seat welds were found broken; one of the seats was severely deformed (Fig 2).

At the third plant in the Northeast that Millennium serviced within the three-month period noted above, a 24-in. wedge gate valve in the HRH system was scheduled for a stem replacement to mitigate packing wear. A new stem was manufactured in the company's shop and shipped to the site for installation.

When technicians disassembled the valve, Stellite disbonding was found on the wedge and both seats. The owner approved corrective action the next day and Millennium's field machining crew arrived onsite four days later to remove both seats while concurrently refurbishing the existing wedge in accordance with EPRI recommendations. Seats were replaced, wedge refurbished, and valve reassembled all within 16 days of project start.

Steam turbine

A case study of damage suffered by a 262-MW D11 steam turbine because of Stellite delamination associated with HRSG steam valves was presented at the 2019 meeting of the Steam Turbine Users Group. The clue that something was amiss: Following a routine valve test, operators recognized that throttle pressure had to be increased by 70 to 80 psig above "normal" to maintain desired output—symptoms consistent with possible steam-path fouling or damage.

After weeks of data monitoring and analysis involving personnel from the owner/operator and OEM, a two-week outage was taken. Delamination of Stellite from the seats of HRSG steam valves was confirmed by investigators and a borescope inspection of the turbine HP inlet revealed significant damage to the first-stage nozzle block and buckets.

Three run-versus-repair options were considered for the steamer: repair now (reliability outage); run at reduced load with no cycling permitted, and repair when new buckets arrive; and run until the major maintenance outage planned for some months ahead.

The OEM's recommendation was to run the turbine until the planned major and order new buckets and diaphragms for the first four stages of the 262-MW unit; plus, monitor the machine for noticeable changes in operation that would indicate additional damage. Also recommended was that the owner implement a program to inspect and replace similar Stellite-hardfaced valve parts exhibiting delamination.

Be aware that Stellite also has disbonded from the seats of steam-turbine valves; guidelines for their inspection are presented in GE's TIL-1629R1, "Combined Stop and Control Valve Seat Stellite Liberation," Dec 31, 2010. Thus, the information provided in this document predates the extensive work done by EPRI, and summarized in the sidebar, by five years.

Inspection

Industry experience suggests inspection of large steam valves for delamination and other possible issues during the next hot-gas-path (HGP) or major inspection—especially if this has not been done previously. Wasatch Welding Engineering Services' Bezzant explains that visual inspection will confirm Stellite liberation, dye penetrant testing will reveal cracking not visible with the naked eye, and a *straight-beam* ultrasonic examination is necessary to identify disbonding that may be occurring but not found by visual or dye-penetrant examination.

But before opening your valves, he suggests you have a game plan for repair or replacement in case you find damage. Failure to plan ahead could significantly add to your outage schedule. Here are your options if damage is found, according to Bezzant:

- Replace the existing valve with a new one.
- Cut the valve out of the line and send it to the manufacturer or a qualified third-party shop for repair.

EPRI reports: A short course on delamination of hardfacing and how to avoid it

EPRI led a research effort from 2013 to 2015 to identify contributing factors to the large number of hardfacing failures—a/k/a delamination or disbonding events—experienced industry-wide. The project purposely engaged stakeholders in the valve supply chain with both users and valve manufacturers sponsoring the effort. Content summaries of the three technical update documents issued in 2015 as a consequence of this effort are below. They are available at no charge to select EPRI members and for a fee to others. To purchase, contact the EPRI Order Center at 650-855-2121 or orders@epri.com.

Investigated failures occurred primarily in valve components (disc, seat, and/or stem) fabricated from CrMo Grade 91 or 400-series stainless where a cobalt-based hardfacing material (Stellite) was directly clad on the base metal. Failures were observed in components where the stated operating temperature was a nominal 975F or higher.

EPRI continues to investigate and update its guidance on the subject. The latest iteration of this ongoing research effort is being led by Dan Purdy (dpurdy@epri.com), a senior technical leader in the organization's Materials and Repair Program. Purdy now is in the early stages of integrating the first report in the three-part series into a more encompassing large-bore valve-body specification.

"Guidelines and Specifications for High-Reliability Fossil Power Plants: Recommendations for the Application of Hardfacing Alloys for Elevated-Temperature Service," EPRI product 3002004990, 30 pages.

Cobalt-based hardfacing alloys are used to protect sealing surfaces in high-temperature valve components primarily because of their resistance to wear. Inspection of ex-service valve components has revealed early cracking and disbonding of the hardfacing from the substrate material. Analysis identified the formation of undesirable hard, brittle intermetallic phases in an intermixed zone typically between the substrate and the hardfacing layer.

Although the degree of this first weld pass dilution can affect the extent and kinetics of embrittlement, it is desirable to remove the possibility of the undesirable phase formation entirely through the application of nickel-based-alloy butter layers that do not show the tendency of phase transformation at any level of dilution with the substrate or cobalt-based hardfacing

Report's objective is to provide scientifically based guidance in the engineering, quality control, and inspection of welded joints between ferritic valve components and cobalt-based hardfacing to avoid delamination in service.

"Experiences in Valve Hardfacing Disbonding," EPRI product 3002004991, 96 pages.

Evaluations of service history and failed ex-service components have led to an understanding that metallurgical changes within the microstructure during welding and high-temperature service exposure contribute to disbonding. Cracking has been shown to prefer bands of unexpectedly hard layers in the weld deposit, and there is evidence of the formation of the brittle intermetallic Sigma phase in those regions. The solution appears to be not one of process—that is, dilution—control, but rather identification of the alloy combinations that remove the possibility deleterious phases will form.

The report discusses the history of hardfacing disbonding as it applies to the power-generation sector of the industry. Included in the timeline are the advances in the state-of-the-art in fabrication, the potential consequences of those changes in processing, a variety of notable failures, and a thorough look at the thermally driven stresses in valve components. Metallurgical analyses of failed components covering a range of material combinations and applications are presented. Many material combinations have been used to varying degrees of success; the report describes the causes of the issues.

"Proposed Solutions for Hardfacing Disbonding in High-Temperature Valves," EPRI product 3002004992, 66 pages.

This third report elaborates on an exhaustive thermodynamics methodology to predict the formation of deleterious intermetallic phases over a range of alloy combinations, and the degrees of mixing among them. The thermodynamic predictions uncovered a wide range of problematic material combinations, as well as several key parameters that lead to metallurgically stable combinations—regardless of the degree of mixing among the constituents. Stitching together these safe combinations creates a layered hardfacing welding procedure that removes the possibility of harmful phases affecting the matrix and leading to disbonding.

These alternative weld solutions were validated through laboratory trials and extended ageing to demonstrate their long-term stability. Laboratory welds that recreated the problematic combinations were observed to begin their transformation, while alloy combinations that were expected to be free of that risk did not harden.

- Repair the valve inline.

Owner/operators who have already faced repair/replace decisions suggest that you factor the following facts into your decision:

- The lead time for new valves may extend beyond a year.
- Shops capable of doing quality valve work and welding generally have a backlog.
- Quality repairs are difficult to make inline because of preheat and access requirements.
- Field-service organizations with the requisite in-situ valve repair experience are extremely busy.
- There is no industry standard for applying hardfacing, although EPRI's recommendations for this are supported by those contacted by CCJ. Manufacturers and repair firms may have other procedures but they should be qualified metallurgically before work begins on your valves. Plus, owner/operators are advised to carefully monitor repair work to the qualified written procedure.

The editors contacted California-based Bay Valve at the suggestion of a user to get an idea of what's involved in conducting a valve inspection. In two words: A lot. Bay said the company's standard procedure is to have highly experienced personnel perform visual and dye-penetrant inspections and if cracking or other problem is identified it is referred to plant management, which might decide to expand the scope of the examination.

Preparation for inspecting a 12- to 14-in. HP or 20- to 24-in. HRH valve can take upwards of two days, one of the field supervisors told CCJ. Actual time depends on the size of the valve, manufacturer, plant constraints, etc. He walked the editors through the rigging and safety measures required to remove a 1-ton handwheel as evidence of the difficulties sometimes encountered. Budget another five days to complete the inspection and return the valve to operational condition.

Stellite-free valves

Hardfacing options other than Stellite are used in the industry. They too may have technical challenges and owner/operators should investigate their service histories thoroughly before deciding on what hardfacing material to specify.

ValvTechnologies' Miller, contacted at the suggestion of an owner/operator with several VTI Stellite-free valves at its plants that have been problem-free for several years save one stem packing leak, discussed the highlights of his company's IsoTech® design for high-pressure applications.

VTI's parallel-slide gate valves for demanding combined-cycle service rely on the manufacturer's proprietary RiTech® 31 (80% chromium carbide and 20% nickel/chrome by weight) coating, which is much harder than Stellite 6 (68.5 Rockwell C versus 30 for Alloy 6 at 1000F, a difference that increases with temperature). The coating is applied to critical parts—discs, seats, and guides—in HVOF (high-velocity oxygen fuel) spray booths using a compressive spray technique to achieve high bond strength.

The hard coating on the web guide ensures the discs are kept parallel through the entire valve stroke. As the valve is cycled under differential pressure, the hard surfaces reportedly burnish and polish each other, avoiding the scratching and galling cited by some users not using RiTech 31.

Miller said the company's new IsoTech hybrid design has a cast A217 C12A short pattern body with welded-on forged end rings (pup pieces) which can be either A182 F91 or F92 to match the piping-system material. The length of the end rings also can be customized to meet either ASME B16.10 end-to-end dimensions, or be provided longer to allow removal of heat-affected-zone material on valve replacement projects. Expected time for customization to your specific requirements is four weeks or less.

The new valve, characterized by a very low pressure drop, according to Miller, accommodates 12, 14, and 16 in. requirements with the same cast body. CCJ

Diaphragm repair strategies

By **Moe Fournier** and **Bryan Grant,** Advanced Turbine Support LLC

Diaphragms are a hot topic at most conferences where owner/operators gather to discuss issues with their steam turbines, such as the Steam Turbine and Combined Cycle User Groups operating under the Power Users Group umbrella. To get the most from these meetings, it's important to know the basics of steam-turbine design, the differences among machines offered by the leading manufacturers, and typical challenges faced by O&M personnel.

The intent of this article is to provide users a backgrounder on the different types of steam-turbine diaphragms and their associated repair challenges. Recall that the purpose of the stationary blades in a diaphragm—a/k/a nozzles—is to redirect steam from the exit of one rotating stage of blades into the entrance of the next rotating stage. The design intent of the nozzle is to optimize both the angle of steam flow and its velocity into the downstream stage of rotating blades to maximize energy conversion.

Diaphragms are a two-piece assembly consisting of upper and lower halves that are installed in the upper and lower halves of the steam-turbine casing, respectively (Fig 1).

Recall that impulse turbines (Fig 2) typically have far fewer stages than an equivalent reaction turbine. Thus, the energy transfer across each stage of an impulse turbine is much greater than it is in a reaction turbine.

Almost all of the stage-to-stage pressure drop in an impulse turbine occurs across the stationary blades, virtually none across the rotating blades. This means stresses on an impulse blade holder (diaphragm) are significantly higher than they are for a reaction blade holder—dictating that impulse stationary-blade holders be axially larger and more robust than reaction ones. Most are of welded construction to tie all parts together rigidly.

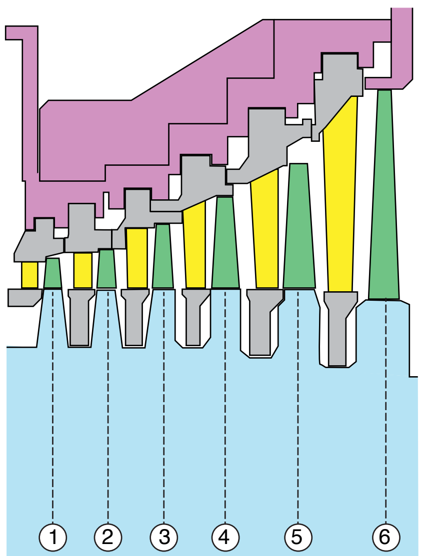
Because they are stationary components, diaphragms often do not receive the same level of attention as rotating blades/buckets. However, improper maintenance and/or repair of diaphragms can have a negative impact on steam-turbine thermodynamic performance. Plus, the mechanical failure of a diaphragm can cause significant turbine damage. Damaged diaphragms also can act as a stimulus on downstream buckets leading to their premature failure and consequential damage to the turbine.

1. Upper-half casing of an impulse steam turbine, flipped over, shows the top halves of diaphragms fully assembled in their proper locations

Diaphragm designs

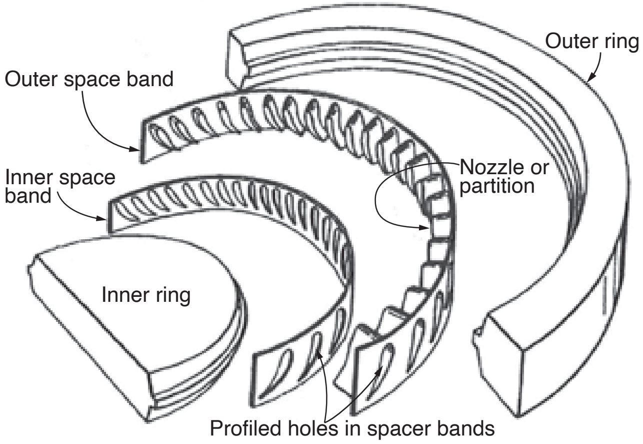
Spacer-band construction (Fig 3), the most common style of impulse diaphragm for many years, remains the industry's most prevalent design. It is characterized by individual nozzles without sidewalls, typically made of stainless steel, that are inserted into profiled holes in thin stainless-steel spacer bands that form the inner and outer flow paths for the steam.

The spacer band and nozzle subassembly are structurally welded to the inner and outer rings, normally in four places (inner and outer ring, inlet and exit sides) to form the diaphragm. The weld process typically used is MIG or submerged arc; stick and electron beam welding are less common.

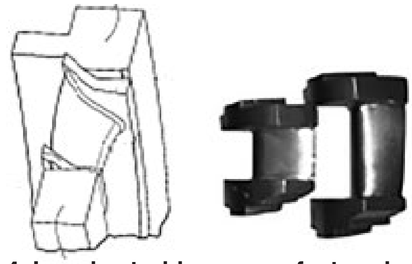


2. Individual diaphragms serve as stationary blade holders for each stage of this impulse steam turbine. The nozzles are highlighted in yellow

Integral sidewall construction (GE singlet, Alstom platform, etc)

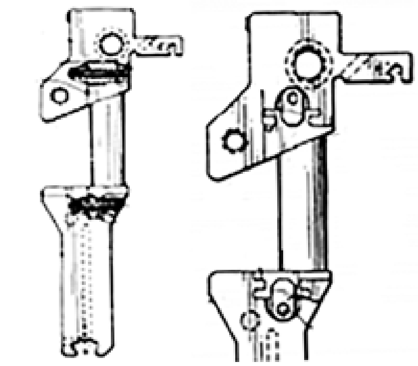


3. Impulse diaphragm of the spacer-band type, the industry's most common design, has been challenged by alternative arrangements over the last 25 years



4. Impulse turbines manufactured since the late 1990s often have diaphragms consisting of individual nozzles with integral sidewalls

5. Full-perimeter fillet weld ties each blade into the inner and outer rings



6. The mechanical-assembly alternative for diaphragms eliminates distortion from welding and is designed to permit replacement of individual components

generally is found in impulse turbines installed since the late 1990s (Fig 4). It consists of individual nozzles with integral sidewalls, typically of stainless steel. The nozzles are structurally welded to the rings, normally in four places (inner and outer ring, inlet and exit sides). Weld process used usually is MIG or submerged arc; stuck and electron beam welding are less common.

Fillet fabrication construction (Fig 5) is very common on the last few stages of LP steam turbines. It consists of individual nozzles, usually of stainless steel, welded directly to the inner and outer rings using full-perimeter fillet welds. A TIG weld, using an Inconel or stainless filler wire, is typical. The nozzles can be solid or hollow and may incorporate moisture-removal features.

Mechanical assemblies are less common but are being offered by some OEMs because they are said to eliminate distortion from welding. In theory, they allow you to replace individual components in the diaphragm. Fig 6 shows two patented concepts.

Failure modes

Steam-path distortion and or blade/nozzle mechanical damage (including foreign-object damage, solid-particle erosion, cracking, and moisture erosion) are the most common failure modes for diaphragms.

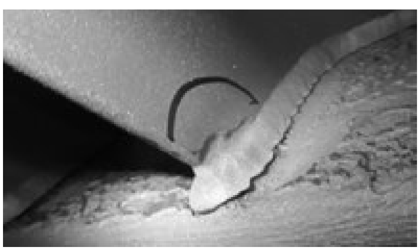
Nozzle mechanical damage and blade flow-path distortion can contribute to three significant failure modes for the steam turbine. They are:

- Distortion at the nozzle opening adversely affects turbine thermodynamic performance and efficiency because it suboptimizes flow from the nozzle to the downstream rotating bucket.
- For long blades, changes in nozzle exit openings are conducive to variations in the impulse on the downstream bucket and can lead to bucket resonance/vibration and premature failure of the rotating blades.
- Nozzle damage can lead to stress risers and mechanical failure of the nozzles themselves, which, in turn, can cause severe or catastrophic downstream damage to rotating buckets.

Structural weld failure. When the structural welds that tie the nozzles to the inner and outer rings fail, the diaphragm is likely to collapse and move into the downstream rotating buckets. This can cause significant damage to steam-path internals, up to and including catastrophic failure of the turbine. Failures often can be attributed to inadequate weld tie-in, improper weld application, and undercut erosion (Fig 7).

Nozzle failures. Although not a common cause of failure, a temperature difference between the diaphragm's upper- and lower-half components can create forces strong enough to crack and liberate nozzle partitions. Condensate introduction typically is the cause of a thermal mismatch (Fig 8).

Dishing (creep). Diaphragms designed and manufactured with less-than-desirable materials or inadequate structural-weld depths, can, over time, and at elevated temperatures, distort (creep) in the direction of stress. Eventually, this causes the diaphragm to rub



7. Undercut moisture erosion is one cause of structural weld failure

8. A thermal mismatch across the upper and lower halves of a diaphragm can create bending forces strong enough to crack (left) and liberate (right) nozzles against the downstream rotating bucket stage, often resulting in significant damage to steam-path internals, and possibly catastrophic turbine failure.

Seal degradation. Diaphragms typically incorporate seals to prevent performance-robbing steam leakage around bucket tips and along the rotor shaft. When seals are damaged—especially seal tips—their effectiveness at keeping steam in the as-designed pathway is greatly diminished and efficiency suffers. Worse still, if the seals rub against mating components, they can cause surface cracking on the bucket covers and/or rotor shaft. Such cracks can propagate and lead to bucket or shaft failures.

Most diaphragm designs incorporate replaceable seal strips, which should be inspected, straightened and sharpened, and/or replaced at major-inspection intervals. Proper planning is required to ensure the correct spares are on hand to support component replacement.

Repair challenges, risks

Steam-path sections of all diaphragm types. The goals for repairing nozzles and sidewalls of a diaphragm are the following:

- Remove stress risers in the steam path that could lead to mechanical failure of the diaphragm.
- Restore the flow path (nozzle opening) to reduce opening-to-opening variations that can cause undue stresses on downstream buckets and premature failure.
- Ensure diaphragm steam flow into downstream buckets is optimized for thermodynamic performance.

The repair challenges are to understand and apply the correct repair techniques and to preserve flow-path integrity with respect to the three goals above. When the repair involves welding, selection of weld process, weld materials, and proper application of post-weld heat treatment (PWHT) is critical to a successful and lasting repair.

Structural repairs to welded diaphragms. Repairs involving the structural weld require a finite determination of the construction type and the axial depth of the OEM's structural weld, as well as a basic understanding of the stress fields in the diaphragm.

Additionally, for structural repairs to rings and/or sidewalls, welding must account for the very thin nature of the space band (or hollow ring) and its tendency to distort. Keeping the sidewall in the correct radial location is critical to unit performance; minimizing distortion of the steam path is critical to unit performance and the diaphragm's fit into the turbine.

Weld repairs also require knowledge of the material types for each component. Material verification testing is recommended before any welding is performed. PWHT must be evaluated based on material types and weld repairs.

Repair of mechanically assembled diaphragms. For blade and steam-path repairs, the challenges noted above apply. For structural repairs to any diaphragm components (rings, etc), knowledge of the component material is necessary. Material verification testing is recommended before any welding is performed. PWHT must be evaluated based on material types and weld repairs. One more concern: Make sure the proposed repair does not negatively impact the mechanical joining feature at the ring-to-nozzle interface.

Best practice: Review proposed repairs on a case-by-case basis with a full understanding of the mechanical stress transfer mechanism of the diaphragm assembly.

Seal repair/replacement. While some refurbishment of seals is possible, replacement typically is the best solution. Depending on the type of seals, challenges can range from procurement cycles to installation techniques; knowledge of the seal design is critical. CCJ

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Lessons learned from an HRSG over-pressure event

Powerplant work can be a humbling experience. It seems that once you begin feeling overly comfortable about how well your facility is running, something unexpected occurs and snaps you back to reality. You can blame the "bad luck" on the gremlins, but more likely the cause was human error.

Consider the following experience at a 1 × 1 combined cycle assembled in 2001 from a W501F gas turbine, a 114-MW steam turbine from a retired 1958-vintage coal-fired plant, and a triple-pressure Nooter/Eriksen HRSG designed for operation at a main-steam pressure of 1750 psig:

A maintenance technician working in a control/breaker cabinet accidentally tripped two breakers. He responded immediately, returning them to the "on" position. However, re-energization caused the flow-proportioning/temperature control valve TCV 12 (Figs 1 and 2) to fully close.

With turbine exhaust gas still flowing through the HRSG, water trapped in Economizer 2 by the closed valve flashed to steam. Pressure increased to the 5000 psig or so engineers believed it took to burst the joint between one of the 6-in. riser pipes and the SA 106B 8-in. manifold shown in Figs 3 and 4. The good news: No one was hurt.

This accident happened because there was no way to safely relieve a pressure excursion in the feedwater system between the HP feedwater inlet to the two-stage economizer and the steam drum. This was not a design oversight. Rather, a mechanical stop installed in TCV 12 to prevent it from full closure had been removed, unbeknownst to anyone on the current staff.

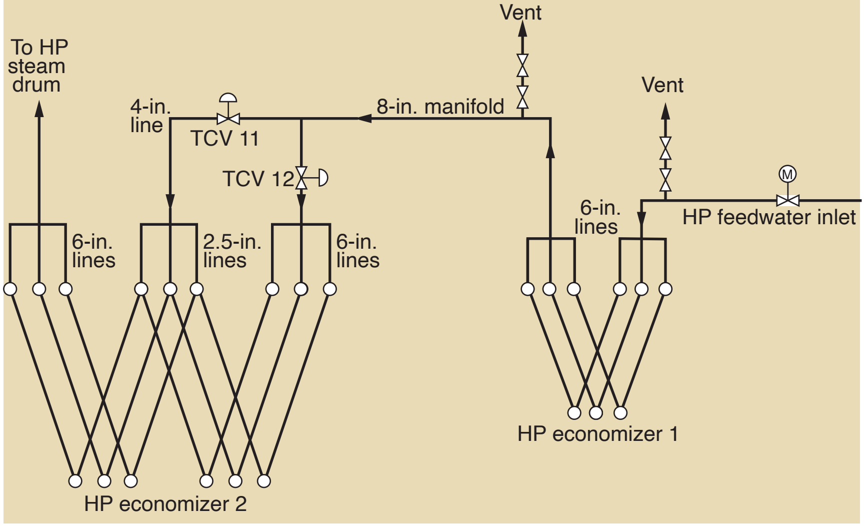
The generating unit had been sold by its utility owner to an independent power producer about six years prior to the incident and there had been personnel changes. As many have learned, some of the historical information important to O&M operations does not transfer well—or not at all.

There are alternatives to the mechanical stop to protect against the inadvertent full closure of control valves in this type of service: Relief valves could be installed in the feedwater lines to the economizer (ahead of HP economizers 1 and 2 in this case) or an unrestricted bypass could be routed around the control valves. All of these methods are acceptable to the ASME Boiler and Pressure Vessel Code.

HRST Inc, Eden Prairie, Minn, was dispatched to the site immediately after the over-pressure event. Results of the company's inspection—including no flow-accelerated corrosion indications, no bulging or cracking of piping or tubes elsewhere in either section of the economizer—were discussed with plant staff and incorporated into the RCA (root-cause analysis) investigation conducted by NAES, the plant operator. Advanced NDE techniques and hydrostatic testing were used to evaluate system health.

Finite-element analysis revealed high bending stresses at the joint where the failure occurred. Fatigue stress caused by many expansion/contraction cycles over time may have been a factor in the failure.

During the investigation and repair stages of the project, the valve-close event was replicated multiple times with the same result: Power failure resulted in the same valve closing. There was no explanation as to why a power-loss event signals TCV 12 to close. At least some of the members of the accident investigation team hypothesized that the Siemens TXP control system might be somehow involved. Most O&M personnel consider that system obsolete and not user



1. No relief valves were installed in the feedwater lines serving HP economizers 1 and 2, as is common in some piping layouts to protect against the possibility of an over-pressure event

2. TCV 12 was installed with a mechanical stop to prevent full closure. That safety feature was removed at some point and never noted on plant drawings friendly. Few in the industry are said to have the knowhow to troubleshoot TXP successfully.

An unvalved, ¾-in. bypass line was routed around TCV 12 to protect the system going forward. TCV 11 had an intact mechanical stop and did not require a bypass.

3. The 8-in. manifold distributing feedwater to the three sections of HP economizer 2 is peeled back at the weld connection to one of the 6-in. risers (above)

4. Here's a side view of the 6-in. riser connection to the 8-in. manifold. Note the deformation of the riser caused by the overpressure event (left)

Damage was local to the failure location. However, the repairs required were extensive, spanning 2½ months and totaling about 10,000 man-hours. In addition to the obvious pipe replacement activity, significant quantities of cabling and cable trays, insulation and cladding, and heat tracing were replaced. Plus, building repairs were necessary. As many as eight contractors and 30 craft personnel were onsite at one time.

Recommendations to others based on lessons learned:

- Check your economizers for valves that can block feedwater flow to the steam drum.
- Review original P&IDs and compare them to the system as it exists today. If valve changes have been made over the years that could bottle-up the economizer, correct any deficiencies in timely fashion.
- If your system does not have a relief valve between the boiler-feed pump and the last valve before the steam drum, investigate why there is none. If there is a relief valve, is it being tested and serviced at the proper intervals?
- If your system is protected from over-pressure by a mechanical stop, turn off the air to the control valve to be sure it doesn't go to 100% closed. CCJ

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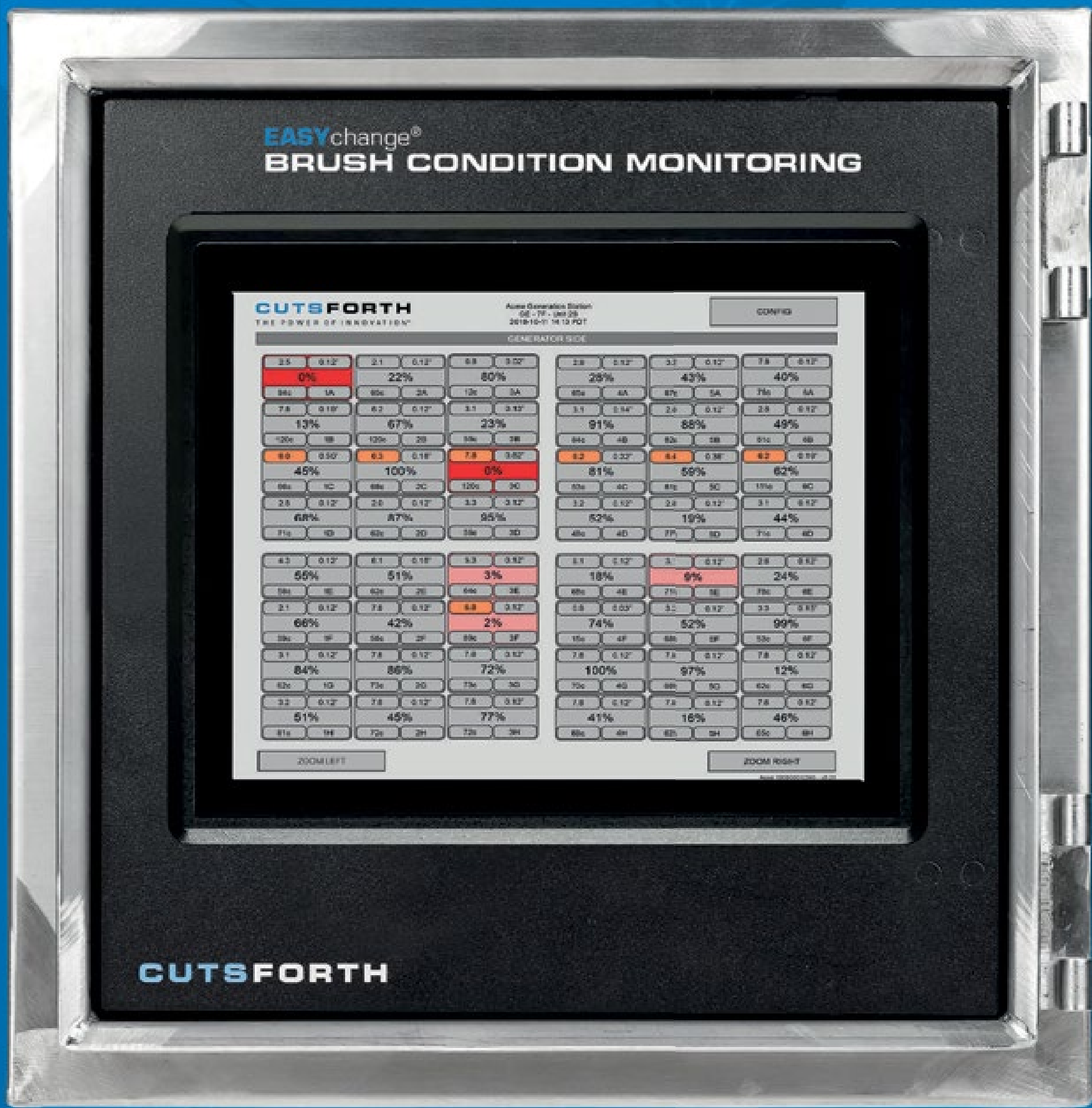

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STEAM TURBINE USERS GROUP

STUG2020

The annual conference of the Steam Turbine Users Group was conducted online for the first time in 2020. The meeting, exclusive to owner/operators, ran four days, spread over a period of four weeks. The 2021 meeting will be an in-person event at the Marriott St. Louis Grand, August 23-27, and co-located with annual conferences for the 7F, 7EA, and Power Plant Controls user organizations—all organized and managed under the Power Users umbrella. Stay tuned to www.powerusers.org for current conference information.

Program for the first day of last year's STUG meeting, November 11, focused on user experiences and vendor products and services. Highlights are compiled in the Week One section below. Vendor presentations were limited to 30 minutes each and conducted in two half-hour sessions. While attendees could not participate in more than two vendor presentations during the live Week One program, all presentations—both user and vendor—are available to registered owner/operators on the Power Users website at www.powerusers.org. Several are recordings of the actual presentations, others are PowerPoint slide decks.

November 18 (Week Two) was GE Day and featured technical presentations, Q&A, and open discussion on topics of interest to the user community. These presentations can be accessed through the OEM's MyDashboard website at https://mydashboard.gepower.com.

Week Three's agenda, December 2, featured presentations by three owner/operators, MD&A, and Shell Lubricant Solutions, plus an HP/IP roundtable discussion.

STUG2020 concluded December 9 (Week Four) with presentations by three owner/operators, ARNOLD Group, and EthosEnergy Group, plus a roundtable discussion on valves.

Week One

User presentations

D11 last-stage bucket inspections and findings

Input from five plants suggests that leading- and trailing-edge erosion of L-0 blades is driven by operating hours and exhaust temperature versus starts. More specifically: The fewer the hours and the higher the temperature the less erosion. Inspections indicate that Stellite shielding noticeably reduces the erosion rate, moisture-removal troughs in the last-stage diaphragm do as well.

Other findings are the following:

- Erosion rate for combined-cycle turbines is higher than for steamers at coal-fired plants, in most cases. Plus, trailing-edge erosion is more prevalent in the combined-cycle fleet.
- Erosion proceeds quickly after COD, then slows. Thus, if you blend out surface irregularities, the airfoils actually erode faster than they would have had you left them alone.
- The highest level of erosion typically occurs from the top of the blade to 3 in. below it.
- Blade damage is related to the moisture content of the steam more so than water chemistry.

One Experience with 40-in. titanium L-0 blades—Case History

Owner/operators of Toshiba steam turbine/generators received an alert in fall 2018 regarding the failure of 40-in. titanium L-0 blades at a Japanese powerplant. The OEM recommended inspections every 24k operating hours or 600 starts.

Personnel from a US combined-cycle plant with two steam turbine/generators affected by the notification shared with STUG2020 attendees their inspection and repair experiences from spring 2018 through spring 2020. The two steam turbines (called ST10 and ST20) typically were starting 125 to 225 times annually prior to the alert.

Readers are reminded that the PowerPoint for this presentation is posted on the Power Users website and accessible only by approved owner/operators. With two steamers and two OEMs involved (GE, the gas-turbine supplier, provided some ST outage support), a review of the author's slides may facilitate your understanding of this ongoing project.

A spring 2018 L-0 inspection done before the alert was issued revealed no crack indications. However, some trailing-edge wear was in evidence near the dovetails, as was some so-called "wormholing."

A follow-up inspection of ST10 was conducted the following spring when the unit was out of service to correct diaphragm dishing. Results were dramatically different than those recorded a year earlier. This time, every L-0 blade had cracks emanating from wormholes—from two to three indications per blade to between 20 and 30. Plus, one airfoil had a 0.75-in.-long through-crack.

The titanium blades on the generator end of the machine were removed and were replaced with a pressure plate because a replacement row of blades was not immediately available. The trailing edges of the L-0 blades at the opposite end of the cylinder were checked by fluorescent penetration inspection (FPI), blended, and reinstalled. The emergency pressure-plate repair was effective with no vibration or thrust issues after restart. However, the loss of output was significant at about 17 MW.

Another advisory was released by Toshiba in mid-June 2019. It reported that low-load operation of the turbine increased the rate of trailing-edge erosion because of flow reversal. It also indicated the lower portion of the trailing edge, extending from the platform to about one-quarter of the way up the blade, was most susceptible to damage. Cracks initiated by fretting of the midspan snubber sleeve were identified as well. The fix there would be upgraded material.

The pressure plate was removed from ST10 in fall 2019, replaced with non-OEM refurbished L-0 blades except for one new GE L-0 blade. The unit achieved full capacity on its return to service following a low-speed balance.

Both turbines passed their trailing-edge FPI inspections in spring 2020, leading personnel to assume it would be smooth sailing until the major. But that did not happen as stress corrosion cracking of dovetails was found in ST20. Temporary pressure plates replaced ST20's L-0 rows and the unit was returned to service with a reduction in output of about 40 MW.

ST10 was restarted with new L-1 blades, upgraded materials, and new locking hardware.

Attend STUG2021 in St. Louis to get an update on this project and others as well.

Experience with 40-in. titanium L-0 blades—Case History Two

Another combined cycle equipped with a Toshiba steam turbine then shared its experience with 40-in. titanium last-stage blades in a double-flow low-pressure section. This plant, which began commercial operation in 2005, was designed as a 2 × 1 facility but constructed as a 1 × 1, reducing the output of the 330-MW steamer to about 100 MW.

The owner/operator making the presentation bought this combined cycle in 2016 with 20k to 25k service hours and lots of time on turning gear. There was no record of the plant having had an inspection to that point. The new owner inspected the ST's last-stage blades in-situ during a valve outage shortly after purchase.

A major inspection was conducted in fall 2017. Plan was to visually check the last-stage blades, but during the outage the OEM recommended adding an eddy-current inspection. This was the owner's first and last experience (to date) with 40-in. titanium blades. It sold the facility in 2019.

Most blades had worse-than-expected erosion of their trailing edges. The distressed area extended from the platform upwards about 20 in. and from the tailing edge inwards about ¼ in. Some blades also had leading-edge erosion to the same degree. Plus, one airfoil was found with a 150-mil-deep indication about 4 in. up from the platform.

Plant personnel attributed the erosion to multiple years of low-load operation—that is, low steam flow. What happens, the speaker said, is that the root section of the L-0 blades acts like a pump, pulling droplets of moisture back into the trailing edges of the airfoils. This phenomenon is described in the article referenced previously.

New titanium blades, including supporting hardware, were ordered for both rows of last-stage blades. Today there's a two-year delivery time for these parts.

The following points were mentioned during the presentation (recorded) and follow-on discussion:

- Data provided by pressure transducers installed in the condenser hotwell, said one user, shows promise in helping to determine the degree of wear suffered by last-stage blades.
- The general feeling of the group was that the leading edges of L-0 blades should not be blended to address erosion. Thinking on whether to blend the trailing edges, or not, was split 50/50.
- Stress corrosion cracking is a concern and water chemists should be involved in decisions concerning the low-pressure section.
- Do crawl-throughs and borescope inspections of the LP section at every opportunity.
- Decisions on the lowering of backpressure during winter should be made carefully. Low pressure can exacerbate moisture formation and erosion. As one user noted, it's a tradeoff between maintenance and additional power.

The speaker ended his presentation by noting that his company sold

1. ARNOLD advanced single-layer turbine warming system

the plant a year after the major so he did not know when the blades would be inspected again and if they would be replaced with the ones on order.

Vendor breakout presentations

ARNOLD Group

Advanced single-layer turbine warming system

Pierre Ansmann and Norm Gagnon covered the basics of steam-turbine warming for increased startup flexibility in their breakout presentation, which began by answering the question, "Why install a turbine warming system?" Highlights of their PowerPoint, available on the Power Users website, include the following:

- Maintenance and operational benefits.
- Differences in warming-system arrangements.
- System durability and reliability.
- Importance of proper insulation for a warming system.
- Controls.
- Cost and schedule of the initial installation.
- Periodic maintenance plan.

In their review of alternative warming-system arrangements, the duo rejected those integrating heating circuits in insulation blankets, installing the heater on a thin mattress below the blanket, and using glass-fiber-insulated heating cable. The optimal system for the upper casing, they said, is a heater on a metal-mesh baffle; for the lower casing, permanent mounting of heating cable below the split line.

Ansmann and Gagnon explained that the ARNOLD system features interlocking high-performance blankets which conform perfectly to the turbine surface (Fig 1). High-quality materials and manufacturing, and long-term high-temperature resistance, allow the company to guarantee reuse of its insulation system for 15 outages without a decrease in efficiency.

More than five-dozen thermocouples, strategically located on the turbine, ensure proper heating. Each of the 18 or so heating zones has t/cs installed on the heating wires to double check if the zone is responding correctly and at the specified temperature. Below every heating zone, multiple t/cs are mounted on the casing to confirm even heating of the turbine.

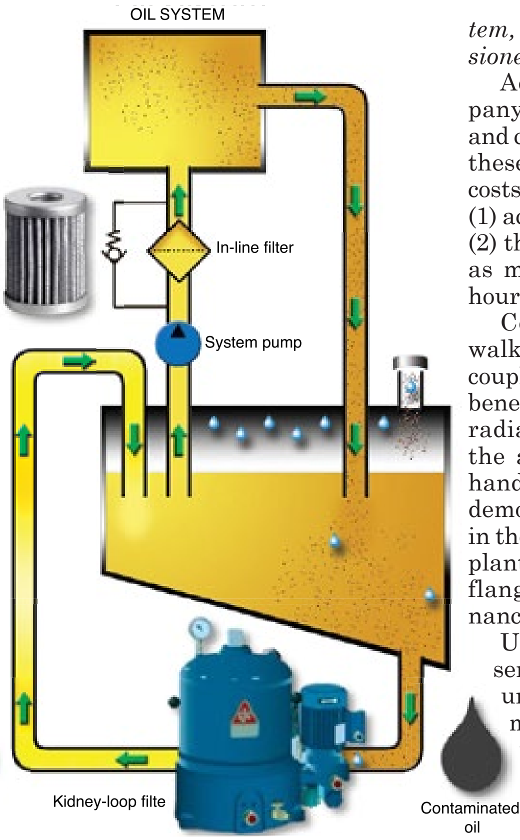
The speakers said the ARNOLD warming system can maintain your turbine in a hot-start condition for at least four or five days after shutdown. No preheating of the turbine is required prior to a restart within this time period, reducing startup fuel consumption and auxiliary power.

C C Jensen, Oil Maintenance

Remote monitoring of lube oil and diesel conditioning

Oil conditioners/kidney-loop filters are known for their ability to keep oil, and the machines relying on it, clean and healthy (Fig 2). In his presentation, Axel Wegner shows you how to keep lube and diesel oils in top condition; plus, how to receive alerts as soon as anything oil-related drifts out of spec—such as cooling-water temperature, excessive wear of machine parts, ISO particle count, etc.

Wegner's recorded message is clear: The optimal condition-monitoring and filtration system for any machine and oil type allows you to identify problems remotely and to take action before they get out of control. This presentation is one you might want to consider sharing with your plant's O&M staff during a lunch-and-learn session.



2. C C Jensen collects data from kidney-loop filter, which is integrated with an online condition monitor to alert when oil-quality parameters are drifting from their optimal values

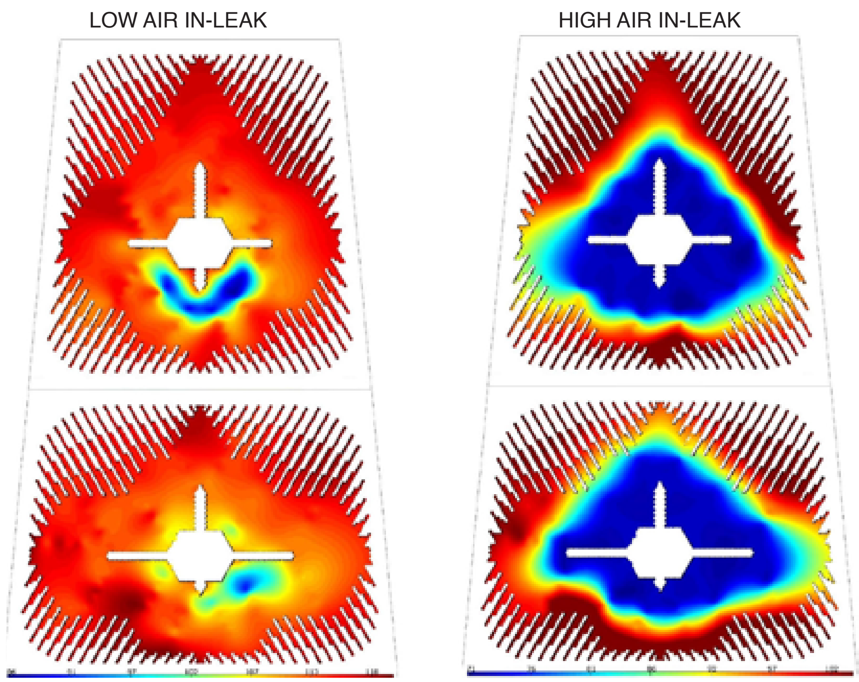
Intek Inc

Essential monitoring for quickly identifying and repairing air in-leak sources

The recording of Collin Eckel's presentation focuses on presentations of case studies highlighting a new process that combines repair of air in-leaks—identified through a condenser helium leak audit—and condenser vent-line air in-leakage measurements using the company's Multi-Sensor Probe (Fig 3).

Recall that the presence of helium at the condenser exhausters indicates a leak. Intek's MSP, installed in the vent line between the condenser and exhauster, measures and continuously calculates the condenser's total air in-leakage rate.

Data from the MSP allows users to narrow the search areas for potential leaks, thereby increasing the success rate for finding and repairing them, and reducing the time for doing so. As air in-leaks are repaired, the MSP's air in-leak value indicates the size of the leak eliminated by subtracting the new value from the total air in-leakage rate recorded before the repair was made.



3. Intek Inc's RheoVac multi-sensor probes measure air in-leakage, which adversely affects condenser performance

Nord-Lock Group

Solutions for the D11 closure system, coupling bolts, and casing tensioners

Adrian Price discussed the company's Boltight D11 closure system and casing tensioners, focusing on how these products can cut maintenance costs by reducing the time required for (1) accurate, damage-free bolting, and (2) the tops-on/tops-off process—from as much as several days to several hours.

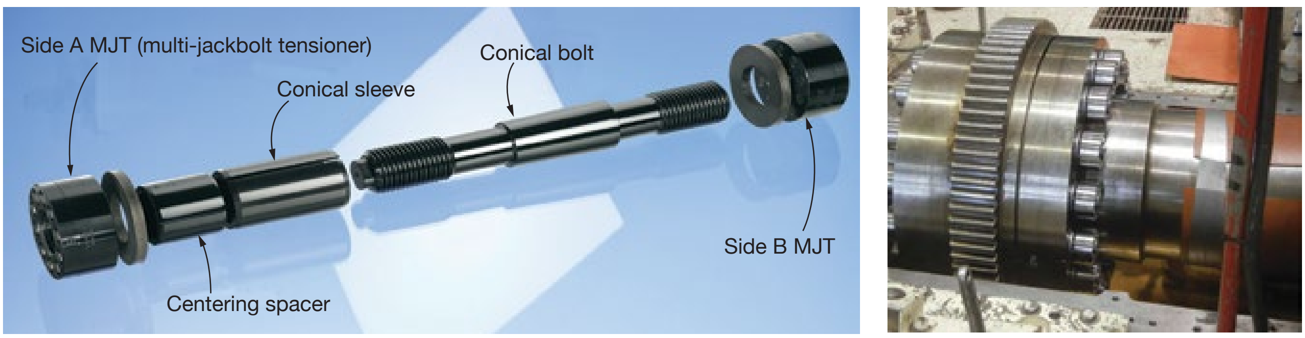
Co-presenter Steve Busalacchi walked attendees through the EzFit coupling-bolt solution (Fig 4) and its benefits: reduced downtime, accurate radial force, safer installation, and the ability to achieve preload with hand tools. He profiled recent cases demonstrating the technology's value in the field; plus, the preemptive steps plant personnel can take to minimize flange-bolt faults in future maintenance situations.

Users reviewing Busalacchi's presentation will benefit from a better understanding of the principles of mechanical expansion bolts—what they are, how they work, and how they mitigate the problems associated with fitted bolts.

Parker Motion & Flow Control Products Inc

Legacy Denison EHC hydraulic pumps and steam turbine applications/support

Steve Westmoreland, a senior design engineer at MFCP, had good news for users trying to get by with their Denison EHC pumps, typically used to provide the hydraulic power for

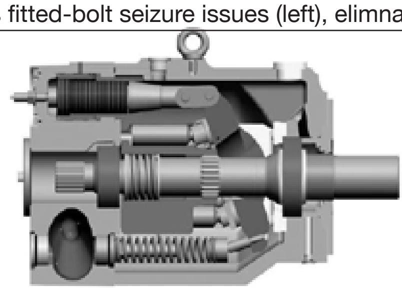


4. Nord-Lock EzFit coupling bolt avoids fitted-bolt seizure issues (left), elimnates slippage during operation (right)

opening/closing valves on steam turbines. The workhorse Denison PV-09, which dates back 70 years, is no longer offered. The pump is obsolete and parts are not available from Parker, which bought Denison in 2004. Plus, it is becoming increasingly difficult to rework existing parts.

Westmoreland's recorded message introduced attendees to the Parker PV+ variable-volume piston pump, available in horizontal and vertical arrangements, as a replacement for the PV-09. The following benefits of the PV+ over the PV-09 were highlighted:

- The pump/motor interface is a simple bolt-together process; no laser alignment necessary.
- Response time has been halved.
- Higher efficiency (volumetric and mechanical).



5. MFCP's Parker PV+ variable-volume piston pump replaces the superannuated Denison PV-09 for providing the hydraulic power to open and close turbine steam valves and for other uses

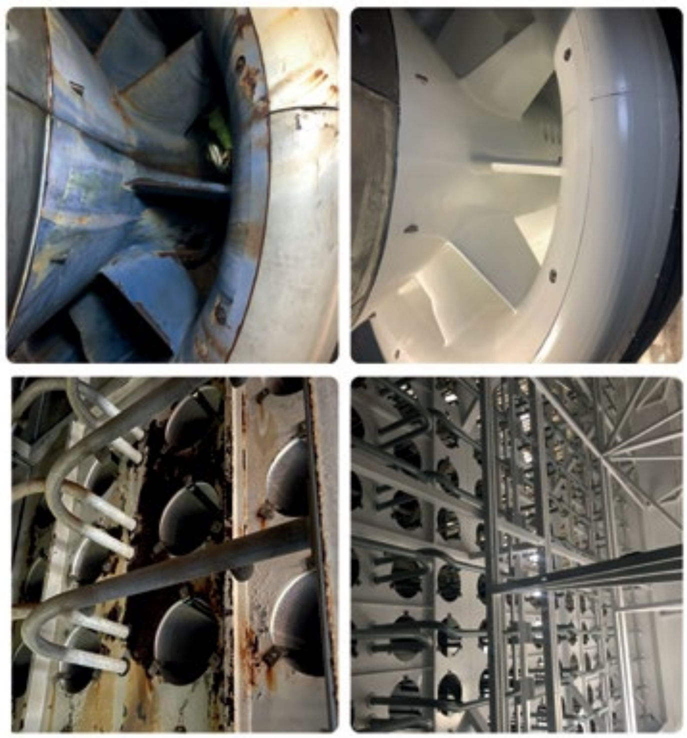
- A hydrostatic saddle bearing/swash-plate replaces wear-prone rollers and bearings.
- Improved suction characteristics—especially important to units operating at high altitude.
- Separate cooling/filtered-oil loop to cool shaft bearings and seal, and the hydrostatic bearings.

Siemens Energy

Advanced crack detection in free-standing steam-turbine blades

The risk of steam-turbine blade flutter increases at low loads and vibration monitoring can detect this condition, thereby allowing owner/operators to take corrective action with the goal of maximizing fatigue life. Think of this presentation as a primer on how blade vibration monitoring is implemented. It also discusses a proven technique developed by Siemens to detect cracks in free-standing blades.

Lifecycle maintenance planning and



execution for reliability and cost control

The second presentation made in the Siemens breakout explained the company's bid strategy and outage planning. The key message here was to begin planning as early as possible and engage the OEM's experts, and others, to assist in decision-making.

Neither of the Siemens presentations is available on the PowerUsers website. Siemens owner/operators should contact the service representative for their plants regarding information on how to obtain a copy.

Week Two

Matt Foreman, platform leader, Combined-Cycle Steam-Turbine Services, opened the GE Day program for the Steam Turbine Users Group (STUG) with an overview of the topics to be discussed, including: fleet updates, valve and turbine-casing cracking, valve upgrade experience, D11 rotor bow, assessments to improve operability and reduce O&M spend, and performance improvement. Highlights of the presentations follow.

TIL, GEK, and fleet updates

Mike Jones, service manager for ST products, and Jamie Anderson, ST system integration leader, stressed the importance of these two Technical Information Letters:

- TIL-2010 recommends endoscopic inspection and NDE of the radial inlet vane at the next scheduled outage to identify possible deformation and/or cracking, which can be caused by a clearance reduction attributed to scale buildup. A borescope inspection ahead of the outage was suggested.
- TIL-1886-R1 requires removal and NDE of finger-dovetail L-1 buckets after 30 years of service to inspect for stress corrosion cracking in the dovetail area.

Recent D11 shell and valve casing findings

Dave Welch, consulting principal engineer for ST product service, shared recent HP/IP shell casing findings and experience in mitigating horizontal-joint leakage, plus N2 packing-head experience and valve-casing findings.

He stressed the cleaning, inspection, maintenance, and repair of casing cracks as essential outage activities to prolong the life of HP and IP shells. Photos of casing findings and typical locations of occurrence provide valuable user perspective. TILs 1748 and 1749 suggest machining actions to address casing stress issues, which are impacted by creep and low-cycle fatigue.

Horizontal joint leaks are not a major fleet concern, noted Welch. They are caused, he said, by creep relaxation of joint studs and nuts and by localized casing distortion from thermal- and pressure-induced stresses. Repair options are presented.

N2 packing-head (PH) replacement benefits and experience were summarized for attendees. Users were referred to TILs 1627, 1748, and 1749 regarding shell and N2 PH fit modifications released about 10 years ago. Welch said GE has successfully implemented about 50 modified packings within the D11 fleet. He added that the OEM's reconfigured N2 packing head has reduced premature failures of the shell and the PH throughout the fleet.

Casing cracking on old-style main stop and control valves (MSCV) has occurred before 15 years of service, Welch continued, recommending blast-cleaning and inspection for indications at every minor outage. Grind and blend, or machine-out, small cracks once they are found to minimize the need for a weld repair later.

GE's Next-Gen ST valve experience

Welch opened his second presentation by explaining that Next-Gen is a name change for the "digital-valve" moniker used previously. Reason: The improved offering goes beyond digital with robust hardware material and geometry improvements. The enhanced hardware can enable minor-outage interval extensions from three to six factored years.

There are two standard product offerings for MSCVs and combined reheat valves (CRVs):

- Package 1 targets 7.5-, 9.25-, and 11-in. valves with modern actuators and no casing cracks, primarily addressing issues related to the internals—such as stem sticking and solid-particle erosion (SPE). Installations, which can be done during a minor outage, thus far reveal no SPE of valve stems. Return-to-service issues—wiring and erratic behavior—on two valves—were resolved quickly. In both cases, the actuators had not been replaced. Eight units now have Package 1 installed with the first unit accumulating hours since 2017.

- Package 3 addresses issues related to valve casing cracks and includes a new actuator. Target is 9.25-in. lower-chamber valves and CRV links and lever hydraulics. Valves for the first replacement project in October 2019 were installed in less than a month.

Rotor-bow detection and corrections

John Sassatelli, consulting engineer, repair development, opened his presentation with a survey, to help focus his presentation on user needs. The question: Where is your plant regarding ST rotor bowing? There were four possible answers: I don't think my rotor is bowing; I think my rotor is bowing and I'm monitoring it; I have taken some action to address rotor bow, and it's working; and I have taken some action; however, it looks like the bow is returning. Nearly 60% of the respondents did not think their rotors were bowing.

Sassatelli then outlined his highly informative and practical presentation, one that all users with rotor involvement likely would benefit from (access it at GE's MyDashboard.com). He covered rotor-bow *detection* (What is it? What to trend?), *causes* (Why does it happen? And system effects), and *management* (Managing the factors contributing to rotor bowing, plus issue remediation and intervention.).

Runouts taken with the unit out of service are critical to understanding what's causing the bow, the consulting engineer said. He then put up a slide of a D11 rotor with three typical curves developed from runout data—one showing a bow centered at the HP-steam inlet, one with a "kink" at the reheat-steam inlet, and one illustrating a bow distributed along the length of the rotor (parabolic shape).

If you suspect your rotor may have a bow, Sassatelli said you want to know if the bow is temporary or permanent and if the vibration response is trending up or down over the unit's service history. He suggested reviewing the first-critical-speed response over the time horizon for which data are available. You also want to see if the shutdown critical normalizes the thermal effects of startup.

Three well-illustrated case histories were presented to facilitate understanding the vibration signatures of bows. But wait! Things other than a bow can produce similar signatures (misalignment, oil/steam whirl, mass loss, rotor crack, for example) and you should rule them out before pursuing a bow solution. Suggested reading: GEK 89610.

Sassatelli then asked the group which came first on their units: rubbing or bowing? More than two-thirds of the respondents said "rubbing." He then offered several charts to help owner/operators answer the question: Does rubbing cause bowing or vice versa? Vibration plots of cold and warm starts show the latter is less likely than the former to produce vibrations of sufficient magnitude to initiate a turbine trip.

Although a warm start does not give the same high vibration numbers as a cold start, Sassatelli continued, it does seem to correlate with accumulated damage. The riskiest timeframe for light rubbing, he said, is a warm start 24 to 48 hours after shutdown.

The impact of insulation condition was factored into the speaker's comments on rubbing. The increasing temperature deviation between the upper and lower casings over time in the area of the HP and RH steam inlets, he said, generally can be attributed to insulation deterioration. The delta T contributes to casing distortion conducive to rubbing.

The pros and cons of various rotor and system interventions closed out Sassatelli's presentation. They provide of checklist of options for owner/operators to consider for mitigating bowing concerns.

Analyzing the data from your combined cycle

Principal Engineer Peter J Eisenzopf's goal was to share methods for turning operating data into information that can be used to make better O&M decisions. He, like the previous speaker, began with a short survey question to help focus his remarks on user needs. The question: Which steam-turbine components/systems drive the most emergent work? The four choices: Turbine valves, rotors, casings, and accessories and balance-of-plant equipment. If "turbine valves" is your answer, you're among the majority. Two-thirds of the respondents, in round numbers, agreed with you.

Eisenzopf then provided a useful checklist of items the OEM uses to gather information of value so you can better manage your unit and outages. The variables discussed and illustrated in the presentation included the following:

- Lifetime mission mix. The chart provided for one D11 plots the HP bowl metal temperature at the time of turbine roll for all lifetime starts, allowing plant staff to identify easily changes in mission over the years. Examples: When the plant was in peaking service, when warm starts predominated, etc.
- Lifetime shutdown hours preceding an ST roll (an alternative to HP bowl temperature to define the type of start). Fleet data indicate the most common starts, in decreasing order, occur at eight, 32, and 56 hours, and in 24-hr increments beyond that. The message: When specifying guarantees for new units, owners should consider asking the OEM for the start times associated with these specific shutdown durations, plus dead cold. Traditionally, start-time guarantees for new units most often have been specified at eight, 48, and 72 hours.
- Percent cyclic tracking. GE invented the parameter "percent cyclic" because simply tracking the number of starts does not include sufficient information for lifetime evaluations. Eisenzopf said units with similar percent-cyclic missions may also have similarity in the features which require maintenance. Understanding this with GE's help could be valuable in both outage planning and in designing an operational profile to maximize asset value.
- Lifetime operating hours are tracked by virtually all plants because of its value in inspection and maintenance planning. But the speaker said tracking factored hours is more valuable because it is condition-based.
- Transient ST load profiles. Eisenzopf explained GE's transient-data-viewer tool which enables you to chart important turbine operating parameters—such as start time, which can help operators reduce start times and lower startup cost.
- ST rotor cyclic life per start/shutdown cycle helps in reducing start times. It is particularly valuable for quickly assessing the impact of changes to startup logic/procedures on rotor life consumption.
- Cooldown upper-to-lower shell metal temperature-difference tracking allows operators to assess the relative quality of their insulation, the OEM having fleet-wide data for comparison. Eisenzopf stressed the importance of insulation quality in minimizing casing distortion. The methodology discussed can be used by plant staff for evaluating the work of contractors in replacing insulation after an outage.

- Startup transient efficiency tracking. GE invented the "transient efficiency" metric to measure/quantify startup quality. In the example provided by the speaker, plant was able reduce the start time by more than an hour with life consumption equal to or lower than the baseline number.

Several more parameters—such as steam-to-metal temperature matching at ST roll—also are discussed in Eisenzopf's presentation available at MyDashboard.com. While they all enable better decision-making, their measurement and tracking may require instrumentation and data collection capability not currently available at your plant. Performance improvement, like most everything else, has a cost, but it typically is a relatively small percentage of the financial gain.

One way to launch a performance improvement initiative at your facility might be to review the presentation, determine what variables you are not now tracking and begin doing so, identify other parameters you believe have value in tracking, and determine what equipment and controls changes are necessary to make this happen. Then do it. Your GE rep can help, of course.

Combined-cycle steam-turbine performance improvement strategy and tradeoffs

Jim Stagnitti, leader, application and requisition engineering, began by reviewing the reasons owner/operators pursue performance-improvement initiatives—extend maintenance intervals, improve reliability and/or flexibility, for example—and the considerations involved in decision-making—including cost, desired remaining unit life, and operating profile.

He then explained the value of a so-called "opening assessment" to make recommendations for repairs during an upcoming outage, both structural (impacts reliability) and thermal (impacts performance). A closing assessment also is necessary, the group was told, to verify the as-left condition of the unit.

A highlight of the presentation was an overview of what's involved in upgrading your ST with a new rotor. Simply put, a typical scope is full steam-path replacement—that is, bucketed rotor, diaphragms, packing heads, and seals. This likely would be done to accommodate an increase in steam flow attributed to a gas-turbine uprate, increase in duct-burner capacity, and/or HRSG upgrade. The benefits of this approach include the following:

- Avoid emergent work and the risk of outage extensions.
- Restart the maintenance clock with new and clean replacement parts.
- Improve heat rate.

An economic analysis presented supports the value of rotor replacement. The case study showed steam-path replacement value is positive within three years and increasing over time.

Weeks Three and Four

User and consultant presentations

Alstom MI with IP blade replacement and L-0 replacement

Details a full-train major inspection (HP/IP, LP, generator). This includes HP and IP stop/control valve inspections, replacement of Radax blade row, seal replacements (rotor and casing), plus replacement of rotating blade rows in the first two stages of the IP turbine; replacement of L-0 blading, refurbishment of LP gland housing; controls upgrade.

GE D11 casing cracks and repairs, 2013-2020

Valuable insights for anyone challenged by casing cracking. Provides photos and details of casing cracks found during unit's first major inspec-

tion in 2013 (2002 COD) after nearly 1700 starts. Outage planned for 49 days, ran 95. Discusses PAC recommendations and aftermath of the weld repair process, plus corrective action. Findings during the second major in 2020 also presented. Baseload operation during the seven-year interval mitigated cracking.

GE HP/IP rotor indication recovery
Turbine experience is for a 1973-vintage gas-fired steam plant (523 MW at 2285 psig/950F/950F) recently relegated to peaking service. Issue was vibration identified in 2019—especially on IP T1 and T2 bearings when coasting down. The unit was last opened in 2007. A full-circumference crack was found on the discharge side of the first-stage wheel transition area. Crack was excavated (8 in. deep) and the rotor repaired. A major cause of failure was rapid ramping with temperature differentials of about 500 deg F.

D11 stop-valve maintenance and lessons learned
Fleet-wide perspective on valve maintenance based on operating-hour intervals. Findings focused on are solid-particle erosion of valve stems and seat erosion. Shearing of main stop/control valve strainer anti-rotation pin, LVDT nut looseness, and implementation of GE's "Digital Valve" upgrade are other discussion points.

GE D11valve upgrades
Presentation highlights valve findings and repairs, presents a historical perspective on valve indications, offers the owner's perceived value of the OEM's "Digital Valve" over in-kind replacements of damaged valves, identifies valve-replacement risks, how to plan for valve replacement, lessons learned, and operating experience to date with the "Digital Valve."

Steam turbine and auxiliaries valve O&M considerations
Eric Prescott, EPRI's program manager for valves, discusses maintenance strategies for valves—including condition-, fleet-, value-, and time-based programs. Coverage includes solid-particle erosion, fasteners and sealing elements, the spindle-guide bushing interface, Stellite hardfacing, monitoring of valve castings, and evaluation of casting fitness for service.

Special technical presentations

Using turbine performance to improve your maintenance strategy, James Miller, PE, MD&A
The four basic tasks of a performance review are pre-test planning, test execution, data reduction and analysis, and reporting.
Miller's presentation covers performance testing, steam-path audit, case studies, and performance and overhaul planning. Equations and data provided will assist in your analyses.

Choosing and maintaining lubricants, Chelsea Bukowski, Shell Lubricant Solutions
Most everything you wanted to know about turbine lubricants jam-packed into one presentation that includes base-stock evolution, varnish fundamentals, mitigation methods for varnish, lube-oil testing and characteristics, etc.

Advanced steam turbine warming for increased startup flexibility, Pierre Ansmann and Norman Gagnon, ARNOLD Group
Turn to page 12 for a summary of this presentation, users can get the details at www.powerusers.org.

Multiple upgrades improve reliability of a D11, Charles Kaslow, EthosEnergy Group
Get the details on the repair of 40-in. titanium L-0 blades, Smart Seal upgrade, N2 packing box upgrade, and outage planning and execution.

GENERATOR USERS GROUP™

GUG2020

The annual conference of the Generator Users Group was conducted online for the first time in 2020. The event, exclusive to owner/operators, ran four days, spread over a period of four weeks. The 2021 meeting will be virtual as well and have a program format similar to last year's. Dates are July 15, 22 (GE Day), and 29, and August 5, from 11 a.m. to 3:30 p.m. Eastern. Stay tuned to www.powerusers.org for conference updates.

Program for the first day of last year's meeting, November 12, focused on user experiences and vendor products and services. Highlights are compiled in the Week One section below. Vendor presentations were limited to 30 minutes each and conducted in two half-hour sessions. While attendees could not participate in more than two vendor presentations during the live Week One program, all presentations—both user and vendor—are available to registered owner/operators on the Power Users website at www.powerusers.org. Many of these are recordings of the actual presentation, others are PowerPoint slide decks.

November 19 (Week Two) was GE Day and featured technical presentations, Q&A, and open discussion on topics of interest to the user community. These presentations can be accessed through the OEM's MyDashboard website at https://mydashboard.gepower.com.

Week Three's agenda, December 3, featured presentations by three owner/operators, an independent consultant, and one each by National Electric Coil and MD&A.

GUG2020 concluded December 10 (Week Four) with four user presentations and one each by AGT Services and Siemens Energy.

Week One

User presentations

Subharmonic stator ground-fault protection

This is an important presentation for generator owner/operators because the failure to protect adequately against ground faults could lead to a hugely expensive outage in terms of equipment damage and prolonged loss of generation. Unfortunately, to fully understand the protection schemes available to prevent such damage it helps to be an electrical engineer with power experience—a rare species in an industry dominated by mechanical engineers.

Perhaps no one knows this better than Clyde V Maughan, who has degrees in both mechanical and electrical engineering, and was the muscle behind the founding of the Generator Users Group in 2015. He "blew the whistle" on the shortcomings of IEEE standards in adequately protecting against grounding issues in stator windings back in mid-2013 with his CCJ article, "Generator Protection: IEEE standards may not sufficiently address grounding issues in rotor, stator windings," 2Q/2013, p 7.

The GUG2020 speaker reviewed some material covered in the Maughan article and provided details on a ground-fault experience that involved two unit trips several months apart. The second fault occurred because analysis of the first trip proved incomplete. This was a real "whodunit" in a sense because questions remain; however, the generating unit has been back in service for more than a year with no issues reported.

The presenter reminded attendees that large generators have high-impendence grounding (neutral) connections to limit ground-fault current (read "damage"). Other generator ground-fault protection methodologies require the unit to be online. The two methods typically used are the following:

- 59N—Generator Neutral Over-voltage Protection, which detects faults in the top 95% (approximately) of the generator up to the generator transformer.
- 27TN—Third-Harmonic Neutral Under-voltage Protection, which detects faults on the neutral side of the generator.

Together 59N and 27TN can provide full protection for the generator but many units still are protected only by the 59N relay—the 95% solution—and are at risk. Consider, too, that some generator designs may not produce sufficient third-harmonic voltages to allow reliable ground-fault protection schemes based on third-harmonic signals.

Given these concerns, voltage-injection relay systems (64S) have gained favor—especially where there are concerns regarding stator-winding condition and/or when the unit is deemed critical by the owner. A big advantage of the 64S is that it provides its own excitation source and assures the entire generator ground-fault protection when it is shutdown (at standstill or on turning gear), during startup, and at-speed offline or online.

Concerns regarding 64S are cost, more complicated analysis of issues, and more equipment to go wrong.

Remote technical support during generator maintenance

The second presentation at the conference, was insightful given the dearth of generator engineering talent in the electric power industry today (see previous article), and travel and other restrictions that have become the norm during the global pandemic. It was developed by Clyde V Maughan and would have been the 94-year-old's first formal virtual presentation had a schedule conflict not interfered. Jim Timperley, well respected by generator users worldwide, made the presentation.

Maughan began by illustrating the need for, and drivers of, remote technical support, complete with examples. Next, he covered the advantages of working remotely—saves a lot of money and time. And the disadvantages: It's difficult to see and hear about everything you might want to know without the close personal connections typically developed during a site visit. Regarding the last point, Maughan acknowledged this will be less of a concern in the future because of the rapid advancements in digital technologies and communications.

But wait, there's more. With retirements, cutbacks in plant staffing, and the absence of traditional face-to-face conferences, Maughan thought it necessary to have a consultant register as a means for introducing generator-owner/operator personnel to candidate experts capable of fulfilling their needs.

So, he worked with General Manager Scott Schwieger to develop the Generator Consultant Skill Register, posted on CCJ's website at www.ccj-online.com/generator-experts, where you can search for an expert with the specific skills required for your assignment. If you're a generator expert who wants to be included in the register, present your qualifications for vetting at www.ccj-online.com/generator-expert-skill-register.

When a new stator requires a rewind: Vendor oversight lessons learned

This is a case history that every user should read through. It tracks oversights/errors compounded over a period of six months and offers lessons for all plant personnel that don't just apply to generators.

The "adventure" begins during initial startup testing: Generator vibration increased and the turbine tripped. Generator fans had been installed on incorrect ends of the machine and a blade liberated. There was no alert from the M&D center because it did not monitor units in commissioning. Damage to the machine was minimal, essentially limited to deposits of foreign material sprinkled throughout the generator. The unit was cleaned and the unit restarted relatively quickly after appropriate inspection and testing.

Likely, those involved breathed a sigh of relief at that point thinking they had dodged a bullet. Well, about a month after the first blade failure there was another, but this one was more severe, with over 500 damage locations on the endwinding. An engineering assessment based on bar voltage and damage location and depth revealed 14 bars at high risk, 10 medium risk, and three low risk.

The root-cause analysis of this failure revealed the blades that had been installed incorrectly on the turbine end of the generator before the first failure had been reused on the collector end. New blades were installed only on the turbine end after the first event. Engineers found that because the reused blades had operated backwards, they were prone to cracking from high-cycle fatigue. No NDE had been performed on the blades prior to their reuse.

The plant owner decided on bar repair to fix the damage done. Following lab testing of the proposed repair method, it was implemented on the affected generator. A follow-up ac hi-pot test failed on two phases, but neither failure occurred at a repair. Lab analysis determined the failures were caused by subsurface cracks attributed to debris impact. No visible surface damage was in evidence at these locations.

Next, a decision was made to proceed only with the replacement of the two failed top bars. But during this activity, six bottom bars were damaged by metal wedges. A full rewind was ordered.

Now four months into the project, during assembly of the stator bars, misalignment between the top and bottom bars was discovered. The bars originally were manufactured on the wrong bar form for the stator frame. When the top-bar replacements were planned, as-built dimensions were used instead of the design values.

You can only imagine what went on from that point until the generator was cleared for full-load operation about two months later. Get the details in the presentation, available to registered users only at www.powerusers.org.

Lessons learned were plentiful on this project, including these:

- Written communication between owner engineering and vendor field services is necessary for important recommendations and decisions. Too much can be lost or forgotten in verbal communication. Had this been done for the fan-blade replacement activity after the first blade failure, the second failure might not have happened.

- Owner oversight of critical activities is very important. It's highly unlikely that an experienced owner's eyes would have missed use of the destructive wedges during top-bar removal.
- Carefully vet the vendor's human performance program regarding adherence to procedures, validation of assumptions, staff communication, and training. Don't expect that the vendor's human performance program is as rigorous as yours. Certain things were assumed during the manufacturing phase of this project that should have been verified before moving forward.
- Request shop quality exceptions. Recall that incorrectly manufactured bars were discovered during the rewind. There was no notification from the vendor during original manufacturing of the generator. The owner was told later such notifications had to be requested. Important to note here that the owner was not "allowed" to have a witness monitoring critical shop operations.
- Document and maintain vendor quality performance records. Don't expect the vendor to do this for you.
- Be sure you have the "right" (read, most capable) people in the field to monitor contractor activities. It's important that your team relentlessly follow up on QA/QC activities and collect and maintain meaningful data. Dotting eyes and crossing tees is vital to project success.

Effects of flexible operation on generators—stator winding.

Bill Moore, PE, EPRI's technical executive for generators, began his presentation by reminding owner/operators that while the effects of stop/start operation on rotors are discussed relatively frequently, the impacts of flexible operation on stator windings have not been. He referred attendees to EPRI Report 1008351, publicly available at www.epri.com, which says the forced-outage rate of generators increased by 246% because of speed (stop/start) cycling.

In simple terms, Moore told the group that as a generator changes load its temperature changes. Given that endwinding materials (copper, blocking, insulation) have different coefficients of expansion, epoxy bonds break, blocks move and shift, dusting and greasing occurs and insulation can crack. Endwindings loosen as well.

The core of Moore's presentation was an analysis by Siemens Energy which provides a calculated approach to accounting for stator-winding degradation in various types of generators for various load-cycling scenarios. Get the details in the presentation available to users at www.powerusers.org.

Moore shared the following conclusions/recommendations:

- Repeated major load swings cause a significantly higher degradation of the stator winding than smaller load swings.
- Areas of high degradation typically are inboard, towards the core, rather than outboard at the series connections.
- A typical indirect air-cooled generator is likely to suffer a higher rate of degradation from load cycling than a GVPI air-cooled generator.
- Temperature control could be used to reduce temperature change during load swings and can provide the opportunity to reduce degradation.

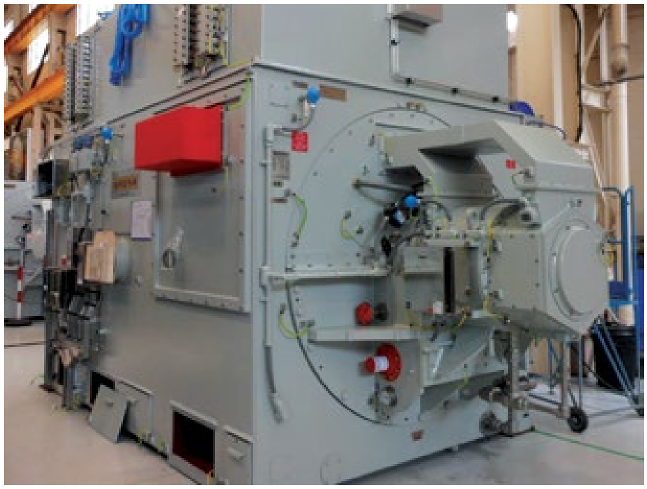
Vendor breakout presentations

Nel Hydrogen

Advanced onsite hydrogen generation solutions for power plants

Dave Wolf told attendees that onsite hydrogen production is a safer, more economical alternative to delivered hydrogen for generator cooling. He explained, with an assist from system drawings, how ultra-pure, pressurized, dry hydrogen gas is produced onsite

1. Nel Hydrogen's onsite hydrogen production system requires little space to serve a 500-MW plant



2. Brush 2-pole, 13.8-kV generator is designed for operation in hazardous areas

from electricity and water using the company's Proton Exchange Membrane electrolyser (Fig 1). The compact system is easy to install and available in capacities to provide scavenge hydrogen for plants of any size.

Wolf went on to say that the required hydrogen storage capacity for delivered gas typically ranges from 60k to 100k scf at combined cycles maintaining inventory for both scavenge and regas use. Plants opting for a Nel Hydrogen system can either produce and store regas or size the system for scavenge gas only and have regas delivered as necessary.

BPhase Inc

Monitoring the generator with a fiber-based thermal/strain monitoring system

Derek Hooper walked attendees through the operating principles of a fiberoptic monitoring system for providing online analysis of core temperature and coil motion in electric generators. The system, which provides a way to assess coil tightness, is a work in progress with early results described by the speaker showing promise.

Sensors, installed before wedging, provide wavelength amplitude measurements which are used to determine the temperature and motion of components. Measurements were taken in several slots during starts and full-load operation at both the turbine and exciter ends of the unit. One of the graphs presented indicated that coil displacement at the end of the core was, perhaps, as much as four times that about 30 in. from the end of the core.

Brush Group

Design and manufacture of non-sparking 13.8-kV 2-pole generators for operation in hazardous areas

Roy Beardshaw told owner/operators Brush has supplied about three-dozen (in round numbers) of its DAX 2-pole generators for operation in areas where ignitable concentrations of flammable gases, vapors, or liquids are of concern but not likely to exist under normal operating conditions. Most installations are in Brazil, Nigeria, North Sea, and Asia.

3. Electric Machinery's rice-like CO_2 pellets (bottom) were effective in cleaning insulation (top). Tight process control is necessary to prevent unintended damage to insulation

The most popular drivers have been LM2500 and SGT A35 RB; the generator model supplied for these prime movers typically is the BDAX 71-193 ERH with brushless excitation and rated for 25 to 40 MW depending on site conditions (Fig 2). End-frame stator design allows for quick installation and ease of access for maintenance.

Beardshaw reviewed design requirements for the machine and its safety features. The latter includes the method used to control and monitor the release of purge air into the machine prior to startup and the continual monitoring of enclosure pressure to ensure it remains ambient. If pressure drops, risking the ingress of a hazardous atmosphere, an alarm will sound and/or the machine will be shut down.

Details on testing and "explosion-proof" certification are provided in the presentation on the Power Users website.

Electric Machinery

CO_2 cleaning of high-voltage windings—a cautionary tale

Sean Orchuk, Electric Machinery's field service manager, reminded GUG attendees that the use of CO_2 pellets as a generator cleaning tool is well-documented, but long-term insulation loss must be weighed against the potential benefits of dry-ice blasting.

Generators are expected to function for decades with minimal intervention, he said, and between maintenance cycles the stator windings may be exposed to oil and other sticky substances. There is a strong motivation to remove surface films because they attract contaminants, thereby reducing insulation resistance, increasing the propagation of corona, and ultimately causing winding failure.

CO_2 pellets, Orchuk continued, offer the promise of a cleaning medium without the challenges associated with chemical cleaning and are proven to remove dust, carbon, oil, etc, from windings and other irregular surfaces (Fig 3). The high velocities used in CO_2 cleaning processes create a risk of damage to the insulation systems of generator windings. When improperly used or misapplied, dry-ice particles can damage brittle mica and other materials used in winding tapes—an unintended consequence of the maintenance process.

In addition, the cleaning medium

is limited by the line of sight from the nozzle, and significant areas of the generator winding may not receive direct benefit from this method. Case studies provided in the PowerPoint on the Power Users website review cleaning methods for typical insulation systems, as well as typical typical contaminants and the range of velocities recommended for their removal with minimal or no insulation damage.

Electrical Builders Inc

Anti-condensation measures for metal-enclosed bus—what you need to know

Steve Powell, EBI's subject matter expert on bus duct, addressed the concerns of owner/operators regarding condensation in metal-enclosed bus and suggested methods for its control. His slides, available on the Power Users website, provide insights on the following topics:

- Causes of condensation in busduct—design flaws (such as no drains in outdoor installations), poor maintenance, faulty heaters, poor installation.
- Types of bus designs associated with condensation issues—outdoor installations without pressurized hot air for condensation control (Fig 4).
- When to be concerned about condensation.
- Solutions for controlling condensation, including the purpose of each and the type of bus where used.
- Maintenance concerns.

Nord-Lock Inc

Exciter coupling bolts and solutions for vibration-induced bolt loosening

Julie Pereyra introduced owner/operators to Nord-Lock's wedge-locking washers that prevent bolts from loosening because of vibration (Fig 5). They are said to reduce maintenance costs and increase worker safety. Steve Busalacchi followed with presentation on the company's EzFit expansion bolts, which promote safe and easy making and breaking of turbine couplings as summarized in the STUG2020 report elsewhere in this issue.

Week Two

RyaneClair, generator product-line manager, Gas Power Services, opened the GE Day program for the Generator Users Group (GUG) with an overview of the topics to be discussed, including: negative-sequence-current impacts and causes, fleet updates and new observations, 7FH2/family and 2020 stator update, amortisseur spring axial migration cases and retention solutions, hi-pot testing, and third-harmonic stator ground. Highlights of the presentations made November 19 during the second week of the 2020 virtual meeting follow. To dig deeper, access the presentations on GE's MyDashboard.website at https://mydashboard.gepower.com.

Negative-sequence-current impacts and causes

Janusz Bialik, principal engineer, and Ben Mancuso, generator design technical leader, Product Service, began by outlining their presentation: Current induction theory, overview of damper systems, case studies, and recommendations.

Negative sequence currents are a common and destructive phenomenon in generators—generally preventable by good design and operation, and the use of monitoring equipment. They can be caused by unbalanced three-phase currents, unbalanced loads, system faults, open phases, asynchronous operation, etc.

Recall that the phase currents and voltages in a three-phase power system can be represented by three single-phase components: Positive-, negative-, and zero-sequence. The first has the same rotation as the power system and represents balanced load. The second has a rotation opposite that of the power system; the zero-sequence component represents an unbalance that causes current flow in the neutral.

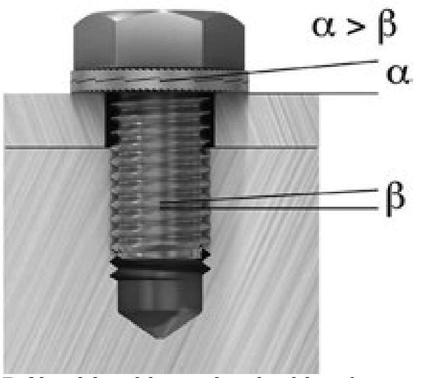
The negative-sequence current component circulating in the stator windings creates a magnetic flux in the air gap of the machine. This flux rotates at synchronous speed, but because its direction is opposite to the normal flux, eddy currents are induced in the rotor body. They tend to flow mainly in the outer regions of the rotor, because of the "skin effect," which was explained by Bialik.

If large enough, the induced currents will spark and arc between wedges, wedges and forging, wedges and retaining rings, forging and retaining rings, and any component on the periphery of the rotor. Such sparking/arching can cause hardening of the metal in critical areas, followed by cracking.

Thus, negative-sequence currents have the potential to cause rapid heating and significant damage to the generator, dictating the need to protect against them.oss of mechanical integrity or insulation failure can occur quickly.

Generator designers include many features to mitigate the effects of negative-sequence currents, Bialik told attendees. Examples include assuring good electrical contact between rotor structures to prevent arcing, a damper system (a/k/a amortisseur windings) in the rotor slots to form low-resistance paths across the rotor surface, aluminum slot wedges, etc. Use of a damper bar in the pole zone of the machine and a low-resistance endwinding design are illustrated in the presentation.

4. Electrical Builders' forced-air system cools busduct conductors and controls condensation



5. Nord-Lock's wedge-locking feature positively locks fastener in the joint, preventing it from rotating loose. Wedge effect is created by having the cam angle α larger than the thread pitch angle β

Generator fleet updates and new observations

Ross Sacharow, generator product service manager, began with an overview of what he considers one of the OEM's most important—possibly the most important—maintenance document, GEK103566 Rev M. It includes a new section dedicated to brushless-exciter maintenance. This just-released guide is a complete update of Rev L, combining input from both the GE and Alstom fleets.

A particularly valuable slide for users, the fourth in the presentation, details the terminology changes important to owner/operators and defines first, borescope, and rotor-in robotic inspections. Access the presentation on GE's MyDashboard website.

Sacharow told attendees that where inspections with robots are possible (air gap large enough to accommodate the robot), a rotor generally should be removed only for repairs and upgrades. He cited the following among the maintenance/repair activities that would require rotor removal:

- Rotor tooth and wedge inspection and repair to remove hardened material.
- Rings-off cleaning up to field rewind.
- Partial or full stator re-wedge.
- Core or wedge repair.
- Partial or full stator rewind.
- Retaining-rings-off inspection.

Another slide summarizes inspections and maintenance intervals as specified in Rev M alongside those published in Rev L with updates highlighted—a handy guide for maintenance managers.

GE polled the group to learn how users view the ability of robotic rotor-in versus rotor-out inspections to find a problem—assuming no known components to repair. Here's what they said:

- Very comparable, 13%.
- Similar, 25%.
- If it were up to me, I would always pull a rotor for a major inspection, 42%.
- If it were up to me, I would always use a robot for a major inspection, 20%.

Recent findings regarding collector flashovers was Sacharow's next topic. He said reducing selectivity—the unwillingness of brushes arranged in parallel to share current equally—was critical to reducing such incidents. Much has been published on the subject, yet flashovers still occur—typically a dozen incidents worldwide annually.or those requiring a refresher, the presentation has a slide dedicated to collector-system maintenance activities (daily, weekly, monthly, during an outage). This might be a good topic for a lunch-and-learn in the plant break room.

Next topic: Recent 7FH2 core-damage findings. At least six examples of turbine-end core damage at the step iron have been reported—five in the last year. All were found on generators made by a third-party. In each case, there was evidence of core ID looseness at the teeth. Risk is not clearly tied directly to operating hours or starts. Preliminary findings point to manufacturing practices as the cause of the looseness.

With the root-cause investigation ongoing, the following recommendation was made for units in this fleet not planning a generator outage in 2021: Perform a borescope inspection—as early as possible in the year—focusing on visual evidence of turbine-end step-iron core damage or greasing/red dusting.

For units planning a generator outage in 2021, suggestion is to follow the standard inspection procedures presented in GEK103566 and use the outage to thoroughly inspect for evidence of core looseness or lamination damage. The recommended inspections (a list is included in the presentation) require removal of end shields, gas baffles, and at least one cooler. Questions? Contact your GE service rep.

7FH2/family, 2020 stator update

Eric Buskirk, generator systems integration leader, responsible for guiding new unit and technology development, covered the rotor/stator configurations and manufacturing variables associated with this fleet, plus stator features, generator efficiency, fleet-wide issues and updates, and cyclic duty.

Presentation began with clarification of product nomenclature important to owner/operators. 7FH2 generators, made from about 1994 to 2015, dominate the fleet with about 850 units in service—the overwhelming majority coupled to 7F gas turbines. This product, renamed H33, has been phased out. Replacement is the 7FH2B, recently renamed H35, which has been manufactured since 2004. There are 75+ units in this fleet segment.

Users should be aware that during the gas-turbine bubble (1999 to 2005), GE expanded its generator manufacturing capability through partnerships with Doosan, Alstom, Melco, Toshiba, and Hitachi. While all insulation systems and generator processes were qualified by GE, there are minor manufacturing differences among the machines produced under license; some parts are interchangeable, some not—stator cores, for example. Valuable detail is provided in the presentation available on GE's MyDashboard website.

Buskirk mentioned the availability of exchange fields for the H33 and H35, which could yield a small capacity uprate, noting that the stator may be limiting and auxiliaries may have to be upgraded in order to capture the full-capacity uprate entitlement. Generator details (leads up versus leads down, coolers and their arrangement, bushing design, connection-ring configuration, loop blocking, etc) are explained in a series of slides easily understandable by O&M personnel.

Generators usually are very efficient, the speaker reminded, but there are opportunities for small, but meaningful, performance improvements under certain conditions. Example: Cooling may be improved by raising hydrogen pressure, but at the expense of increased windage/fan losses. If a machine is running cold or not operating near nameplate, perhaps a reduction in gas pressure would be beneficial.or an H35, going from 45 to 30 psig saves about 75 kW. Raising hydrogen purity (by reducing seal-oil flow and making other adjustments, for example) can save up to another 100 kW or so. Several more possible improvements were explained as well.

Gemerator field amortisseur spring axial migration cases and retention solutions

Ben Mancuso, generator design engineering technical leader, opened his presentation reminding attendees that the purpose of the amortisseur winding is to divert the negative-sequence current (see first presentation summary above) from flowing in the rotor forging and causing arcing and/or overheating damage during normal operation. Be aware that some abnormal events can exceed amortisseur capability.

Mancuso provided valuable graphics and summary statements to explain the various slot amortisseur windings (Gen 1, 2, and 3, plus non-static start) found in the fleet and how they work. Plus, he addressed excessive axial misalignment—when a wedge vent hole exceeds 30% or more blockage—and its causes. Should wedge hole blockage exceed 50%—not typical—it's possible to cause a hot spot in the winding, possibly leading to an electrical fault.

Finally, the speaker presented solutions to address component migration—including an amortisseur/spring axial retention modification package available from the OEM to lock the various components together.

Over-potential insulation dielectric testing (hi-pot)

Michael Villani, product and factory support, Generator Services, explained that periodic maintenance over-potential testing of generator stator windings is a generally accepted industry practice. He said that when this test is performed on healthy insulation and according to the OEM's instructions, the insulation will not be damaged. Not everyone in the industry would agree with this. However, if the insulation's integrity has been degraded prior to the test—such as from stator-bar abrasion, girth cracks, etc—the test will accentuate that damage.

Later, Villani noted that the final hi-pot test during generator manufacture is considered the most reliable factory test to determine the quality of the insulation system at the time of shipment. Thus, he concludes, continued periodic hi-pot testing in the field is the most reliable test to determine the suitability of an insulation system to perform its intended functions reliably. The customer ultimately decides what voltage it is most comfortable with for conducting the hi-pot.

Villani also reviewed the pros and cons of ac and dc hi-pot testing, noting that all new stator bars and stator windings are tested with ac hi-pot. With the ac test set large and requiring trucking and cranes to transport and move around onsite, and a significant power source, its cost is higher than for the dc test, which is selected in most instances.

Final topic in Villani's presentation: Should hi-pot testing be closed or open? GE generally recommends hi-pot testing be performed with the unit degassed and opened up, so both ends of the generator are visible to the operator/second watch person and others observing the test. The benefit of this approach is that if a failure occurs it may be possible to see its location, thereby helping to quickly identify the failed winding.

Third-harmonic stator ground

Dhruv Bhatnagar's (generator application engineering) presentation was the second on this topic at GUG2020, the first one delivered by an owner/operator during the Week One generator session (see previous section).

Content of both presentations is similar and those with interest in the subject matter should review both—the user's on the Power Users website at www.powerusers.org and Bhatnagar's, which provides GE's recommendation for stator-ground protection, on MyDashboard. An important point: GE recommends simple and low-cost testing to ensure that the 27TN trip settings are properly configured. If the are not properly configured, significant generator damage can occur, as the examples provided in the presentation revealed.

Weeks Three and Four

User and consultant presentations

Use of a Fluke ultrasonic device for locating hydrogen leaks

Origins of EMI: History and New Research Users Group

GVPI stator-bar failure root cause

Nonmagnetic retaining ring in-service inspection drivers in 2020 and beyond

GE 7FH2 extreme vibration during LCI operation

SFRA study on generator stator rewedging

AeroPac brushless-exciter flashover

7FH2 collector flashover event

Special technical presentations

(1) Corona in HV stator coils: Theory, causes, repair, and lab progress.
(2) HV stator ground insulation repairs, Howard Moudy, National Electric Coil

(1) Generator findings and case studies.
(2) Preparing generator rotors for cyclic duty, James Joyce, MD&A

GE GT- and ST-driven generator field repair needs, Jamie Clark, AGT Services Inc

(1) Case studies: Cycling impacts on generators.
(2) Third-harmonic stator ground protection.
(3) Hi-pot testing approach, Alejandro Felix, Tony Camarano, and Jim Lau

All of the above presentations, except those from Siemens, are available to users registered on the Power Users website at www.powerusers.org. For access to the Siemens presentations, contact your plant's service representative.

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Connect with us on the User Forum to access to the following discussions:

- Frame 5 Combustion Turbines
- Frame 6B Combustion Turbines
- 7EA Combustion Turbines
- 7F Combustion Turbines
- 7HA Combustion Turbines
- Combined-Cycle Users
- Generators
- Heat-Recovery Steam Generators
  (moderated by Bob Anderson)
- Power Plant Controls
- Steam Turbines

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The road to 100% reliability in liquid-fuel starts, transfers on dual-fuel engines

The spate of lawsuits filed in the aftermath of the 2021 winter storm that left millions in Texas without power for days and sent natural-gas prices soaring to their highest levels in years—up nearly 17,000% in some cases, according to a *Wall Street Journal* report—testify to the value of having dual-fuel gas turbines as part of the generation mix.

The well-recognized ability of gas turbines to generate power at high efficiency and with minimal emissions is only one important attribute of these flexible machines. In emergencies, they can start within minutes and when equipped for black-start service can be a major factor in grid restoration as they first did immediately after the Great Northeast Blackout of 1965.

The most-recent Texas experience suggests a re-examination of the financial logic associated with buying gas-only engines may be in order.

In many instances, gas-only is an appropriate choice: Capital cost is lower than for a dual-fuel machine; no backup liquid-fuel system is required; environmental and safety requirements are reduced; overhauls are less time-consuming and costly; training of plant personnel is simplified. In some cases, the presumed advantages of gas-only operation convinced owners to *remove* liquid-fuel hardware from their engines and abandon in place or remove their oil-storage and fuel-transfer infrastructure.

However, business conditions in the electric-power industry are always in a state of flux. Today, with renewables in regulatory favor, it can be difficult to extract a profit from fuel-fired assets in some areas of the country if they are not equipped to start and run reliably on oil when gas is not available.

Reliable operation demands attention to detail in fuel-system design and equipment selection, which are impacted by such variables as the time allowed for startup on oil or for transfer from gas to oil, the financial penalty of a failure to start on oil, reliability/availability requirements of the off-taker, etc. But be confident that there are commercially available dual-fuel solutions to meet your needs. Success depends in large part on your ability to achieve the following:

- Assure reliable hot-gas-path (HGP) hardware is installed in your engine.
- Design a fuel system capable of providing the level of reliability on liquid-fuel starts and transfers needed to meet contractual requirements.
- Maintain backup liquid fuel in top condition.

HGP hardware. This probably is the easiest box to check. All turbine OEMs, as well as many third-party service providers, can evaluate the ability of your HGP components to perform reliably in dual-fuel operation. Lifetimes of airfoils and other critical parts are less when oil is burned instead of gas, but the number of oil-fired hours experienced by the typical dual-fuel engine will have minimal to no impact on parts life.

An informal survey by the editors indicates that more than a few dual-fuel engines have not operated on distillate oil for periods as long as years—other than to periodically test the ability of their turbines to run on liquid fuel.

1. Standard liquid-fuel check valve failed to transfer from gas to oil because its operation was prevented by the buildup of coke (pile below valve), removed during disassembly

Fuel system challenges. Oil temperature is, perhaps, the variable of greatest importance in the design of standby fuel systems. Reason is that distillate remaining in check valves and piping after firing on oil oxidizes at about 250F—or less. The resulting coke coats check-valve internal surfaces (and fuel lines as well) and restricts the movement of valve parts. Once this occurs, a check valve may not open and close properly until it is overhauled.

The most common trip during fuel transfer is believed to be on high exhaust-spread temperature—caused almost exclusively by check valves hung-up on coked fuel.

Engine compartments with GE frame turbines typically reach temperatures in the 250F to 300F range, according to a few users contacted by the editors. This puts uncooled fuel-system components at an elevated risk of coking.

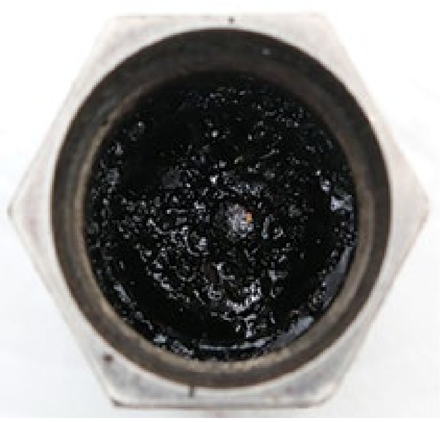
Given that liquid fuel lines are secured in close proximity to the turbine casing, sections of which can hit 500F, you can have oil baking at a temperature well above the coking point in some locations.

There are steps engineers can take at the design stage to mitigate the risk of coking in standard fuel-system components. For example, install a recirculating liquid system, move fuel lines away from the casing to reduce their exposure to very high temperatures, gravity-drain oil lines after use, etc. Regarding the last, one thing to remember is that oil does not drain completely and coke builds up in thin layers over time.

However, this buildup isn't the biggest problem. When layers of coke break loose, the cause may be a event which impacts multiple fuel lines simultaneously. Examples include liquid-fuel check-valve chatter and rapid expansion or contraction of fuel lines, both of which can dislodge mate-

Water-cooled liquid-fuel system

2. Hydrolazing liquid-fuel lines to remove coke is no small task; flatbed holds all the equipment required



3. Effectiveness of water cooling is illustrated by photos comparing the discharge side of an uncooled check valve (left) to that of a water-cooled valve after five years of operation and 60 consecutive monthly transfers

rial instantly. Rectifying the problem may require removal of fuel nozzles to address high exhaust-temperature spreads and related trips.

Depending on contractual requirements, another possible downside to the draining of fuel lines is that the system has to be primed and purged of air prior to burning oil again or a false start is likely to occur. Priming, of course, takes time, which you may not have.

Another point to remember: If your fuel valves and lines get plugged, the coke must be removed or the affected components replaced. Fig 1 shows how much coke was removed from one standard liquid-fuel check valve during an overhaul. Fig 2 illustrates the considerable effort required to cut through and flush coke from fuel lines of a 7EA DLN-1 unit using the hydrolazing technique. It took about a week's effort to return the machine to service.

The gold standard for liquid-fuel systems in dual-fuel plants is water cooling, to prevent coke formation in fuel lines and valves while the engine operates on natural gas and oil is maintained up to the combustor, assuring a seamless transfer to distillate when required.

Liquid-fuel quality must be maintained at the highest level to prevent water and other contaminants from entering the fuel system. Recent experience reported by users on the effectiveness of storage-tank side-stream filtration systems, based on technology used to restore turbine hydraulic and lubricating oils to top condition, illustrate the importance of avoiding the "fill and forget" attitude that prevails at some plants.

The ability of these systems to remove water entrained in stored fuel is beneficial to the health of cast-iron flow dividers still metering fuel to combustors at some plants (sidebar).

Schuyler McElrath, the industry's most vocal proponent of water-cooled liquid fuel systems, assures owner/operators that JASC's® Gen3 system is capable of approaching 100% reliability during oil starts, and on transfers from gas to oil.

On a recent call with the editors, he ran through the company's nearly two decades of product improvements and the reasons for his enthusiasm. McElrath pointed to five consecutive years of service and 60 consecutive transfers for JASC's water-cooled liquid-fuel check valves before an unsuccessful attempt (Fig 3) and seven years of experience with water-cooled three-way purge valves without loss of system reliability.

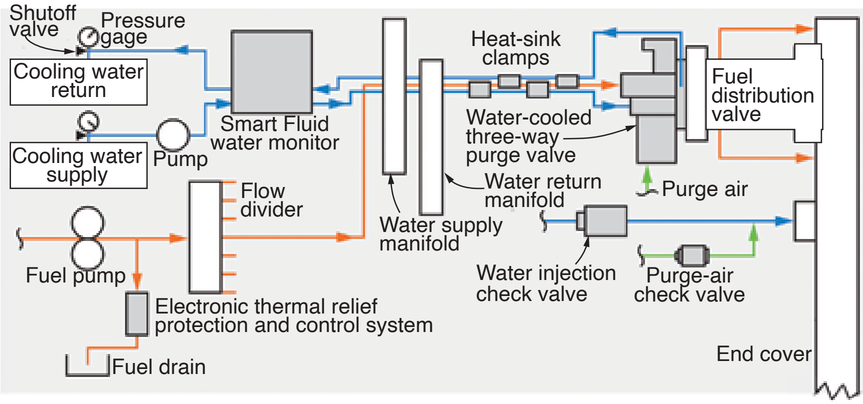
He began with a description of typical water-cooled systems for units with DLN combustion systems (Fig 4), highlighting the following components and their purpose:

The water-cooled three-way purge valve replaces the uncooled version of the valve, which could plug with coke formed by "cooking" of the liquid fuel when gas was burned. Perhaps the most significant Gen3 improvement on these valves was the elimination of heat-related O-ring failures on liquid-fuel and purge-air connections through the use of copper crush gaskets (Fig 5) in place of Viton.

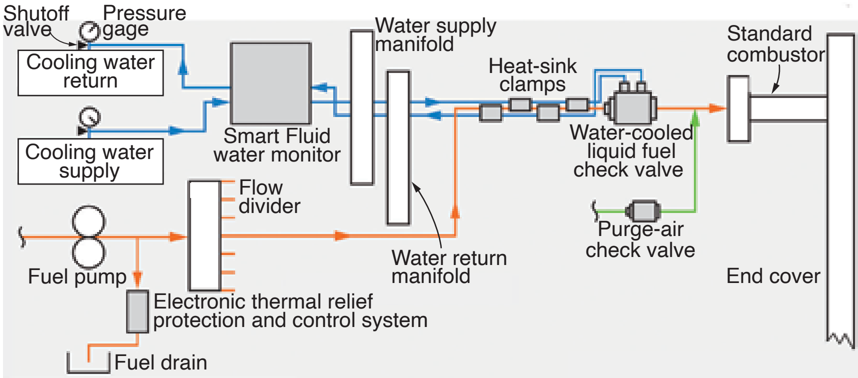
While Viton is designed for high-temperature applications, after long-term exposure to heat they lose elasticity, take a set, and crack. The typical result is leakage at joints because of metal expansion and contraction during operation.

JASC's experience is that copper crush gaskets will survive high-temperature exposure indefinitely with no change to sealing integrity, making them more compatible with today's extended maintenance intervals. Plus, these gaskets can be made, broken apart, and remade multiple times before requiring replacement.

So-called positional tees (Fig 6) are another Gen3 improvement associated with the three-way purge valve. They eliminate tees using Viton O-rings for the purge-air and liquid-fuel connections at the fuel nozzle, opting for copper crush gaskets instead. Positional tees get their name from the fact that they can be rotated and locked down at any point on their 360-deg circumference. The benefit: Three HGP cycles or 12 years of leak-free operation in both

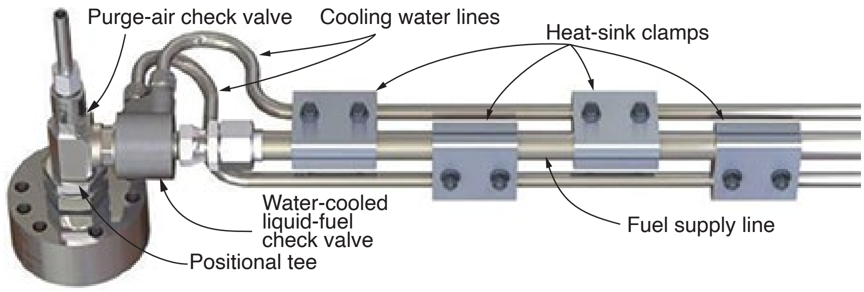


4. Water-cooled liquid fuel system, arranged for GE frame gas turbines, assures high starting and fuel-transfer reliability. Layout for DLN combustion systems is above, for standard combustors below



5. Copper crush gaskets provide more reliable long-term sealing than Viton O-rings in high-temperature applications. Photo shows these gaskets in a water-cooled three-way check valve that bolts to the fuel-nozzle distribution valve by way of an intermediate flange. Because check valves sometimes must be removed to facilitate maintenance, use of the multiple-use copper crush gasket speeds reinstallation, thereby enabling a quick return to service

6. Positional tee, which can be rotated and locked down at any point on its 360-deg circumference, eliminates tees using Viton O-rings for the purge-air and liquid-fuel connections at the fuel nozzle



7. Heat-sink clamps keep liquid fuel cool and protect against its degradation. Photo shows a check valve at the left, completing the integrated cooling circuit for valves and fuel lines

peaking and baseload applications.

Heat-sink clamps (Fig 7), located just upstream of the three-way purge valve in Fig 4, keeps the liquid fuel system primed from the stop valve to the fuel controls and ready for immediate dispatch. The clamps protect stagnant diesel fuel against viscosity changes which foul fuel control seats and can transition distillate oil to solid coke during extended periods of operation on natural gas.

Water-injection check-valve Gen3 improvements focus on metal-to-metal sealing, thereby eliminating the degradation of elastomeric materials formally used and preventing leakage while on standby during operation on natural gas. Eliminating water-system evacuation on standby avoids exhaust-temperature spreads/trips when water injection is reactivated for emissions control.

The smart fluid monitor shown in the system diagrams was redesigned for the Gen3 system to accomplish the following:

- Measure water supply and return flow discrepancies down to 0.1 gpm.
- Programmable shutoff range of 0.1 to 1 gpm.
- Ability to monitor up to four turbines remotely.
- Standalone control or output can be integrated into the turbine control system.
- Monitor and control cooling-water flow and temperature. A critical function of the smart fluid monitor is to protect the liquid-fuel system against low temperatures associated with paraffin dropout. Recall that wax can impede fluid flow and cause a failure to start.

Liquid-fuel quality

Contaminants introduced into your liquid fuel during transportation can require a substantial cleanup effort if foreign material remains in the oil for a prolonged storage period. Reason: Some contaminants will catalyze the fuel degradation process, compounding the problem.

Having a filter ahead of the storage tank capable of trapping large quantities of water (particularly saltwater, the largest single source of sodium

8. Filter elements capable of removing contaminants and water from distillate oil are being installed at left. Effectiveness of those filter elements in removing solid contaminants that could impede reliable operation of a standby fuel system is in evidence at right; water is removed in the second stage of the two-stage system. For the case illustrated, more than 340 lb of contaminants were removed by one set of depth-filter elements in four weeks

contamination so detrimental to HGP parts) and sediment before they enter the tank is important. Also critical to fuel quality is periodic—read weekly—bleeding of water from the bottom of the tank. This is especially true in warm, humid regions of the country. Remember that oil tanks are vented and they breathe.

Plants monitoring the condition of their backup fuel sometimes are surprised by the poor quality of oil at the bottom of their tanks—say the last 5 ft or so. This generally is not problematic given the floating suction systems typically in use today—that is, until you have to burn the dregs. It doesn't take much sludge-type material to cause a failure to start or to trip a high-performance gas turbine. The financial penalties could be significant.

C C Jensen Inc's Technical Manager Axel Wegner, expert in the cleanup of turbine lube and hydraulic oils, has been promoting at user-group meetings for several years the idea of using similar technology to maintain backup-oil quality with a slipstream treatment system on the storage tank. Results from the first two installations (one on a 1-million-gal tank, the other a 4-million-gal tank) at gas-turbine peaking and combined-cycle sites, just in, are encouraging (Fig 8).

Wegner told CCJ that, based on current experience, an appropriate cleanup system for a standby oil tank might turn over the inventory once a month to maintain the fuel quality desired. A plant burning only diesel (no gas) the system probably should be designed to process oil at 110% of the consumption rate, he added.

One user told the editors that he received only two responses to his RFQ for a diesel-fuel cleanup system, purchasing one each from C C Jensen and Hy-Pro Filtration. CCJ

What flow dividers do

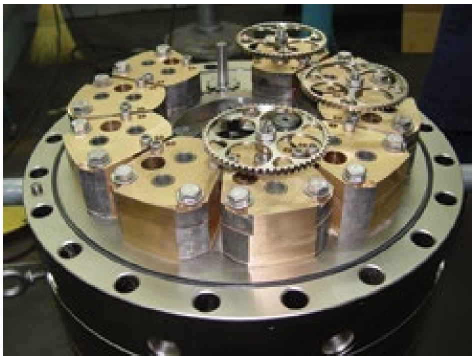
Flow dividers are used on gas turbines to maintain equal flows of liquid fuel to all combustors. They are passive devices that derive their motive power from the energy contained in the fuel delivered by the main fuel pump. Although designs and layouts vary, the fundamental principle of flow-divider operation is the same.

Flow dividers are little more than an array of virtually identical, high-precision, spur-gear hydraulic motors (think of them as flow elements) that are mechanically coupled to run at equal rotational speeds. When liquid fuel enters the flow divider, it simultaneously exerts a pressure on the inlet side of all these hydraulic motors, which causes them to rotate and meter oil at virtually identical discharge rates.

To maintain relatively equal discharge flows under varying pressure conditions, the running clearances inside each flow element must be extremely small. This characteristic also makes flow dividers very susceptible to fouling if particulate matter is allowed to enter the clearance areas. Particles larger than about 20 microns must be filtered out.

Certain non-particulate fuel impurities that cannot be filtered out are another potential source of problems. Liquid fuels may contain various corrosion-causing contaminants—water is most common—capable of attacking materials that many legacy flow dividers traditionally were made from—such as cast iron. Water corrodes the cast iron and the resulting iron oxides can quickly consume the small clearances between the gears and housings and prevent their rotation.

New flow dividers have for many years been made of aluminum bronze or a similar material to assure top performance and long life. At least one manufacturer supports a program aimed at improving the reliability of legacy equipment with corrosion-resistant replacement parts.



Flow divider made of cast iron (left) is susceptible to corrosion that can hamper or prevent operation. Upgraded materials (right) promote high reliability and long life

Power Plant Controls Users Group™

PPCUG2020

The annual conference of the Power Plant Controls Users Group was conducted online for the first time in 2020 and exclusive to owner/operators. The 2021 meeting will be held August 23-27, at the Marriott St. Louis Grand, co-located with annual conferences for the 7F, 7EA, and Steam Turbine user organizations—all organized and managed under the Power Users umbrella.

Presentations last year focusing on user experiences and vendor products and services (highlights below) were conducted November 10-12. The latter were limited to 30 minutes each and organized in two half-hour sessions. Each vendor was assigned a "breakout room" and users were connected to their presentations of choice. While attendees could not participate in more than two vendor presentations during the live program, all presentations—both user and vendor—are available to owner/operators registered on the Power Users website at www.powerusers.org.

GE Day, November 17, featured technical presentations, Q&A, and open discussion on topics of interest to the user community. Those presentations, also summarized below, can be accessed through the OEM's MyDashboard website at https://mydashboard.gepower.com. PPCUG2020 concluded after the GE program.

User presentations

User presenters wasted no time getting granular in reporting on their plant and portfolio level experiences with GT exhaust thermocouples (t/cs), corporate digital transformation programs, control system and logic mods to support deeper cycling automation, Mark VI control system upgrade, and steam turbine/generator hydrogen purge.

Exhaust thermocouples in 7F machines have been a source of operating issues and instrument failures for years. One combined cycle reported on multi-unit experience with a spring-loaded t/c replacement design. No failures were experienced for the first five years. After that, the plant experienced rapid failures on one unit, then another. You'll have to access the presentation on the Power Users website to get the details. The plant has not "given up on the design."

Digital transformation. Big owner/operators often implement portfolio-wide programs. A representative from one of America's largest electric utilities reported on progress with its digital transformation program. Truly massive in scale, it includes in-house built sub-programs for digitizing work optimization, work orders, lockout/tagout (LOTO), drone management, machine learning for critical assets, and a reporting, documentation, and comments platform organized to specific plant components and subsystems.

To head off heat-recovery steam generator damage from cycling, one plant reported on modifying the control elements and logic of its originally designed baseload combined-cycle unit to achieve greater automation and avoid the inconsistencies of manual operator intervention. Three focus areas are condensate removal through HRSG drains, attemperator sprays, and damage monitoring. Much of the work in the attemperator area was based on recommendations from an EPRI report.

In upgrading controls from a Mark V to a Mark VI to solve obsolescence issues, this combined-cycle plant, equipped with four gas turbines, also installed GE's digital platform. Goals were to use the same control system for all the turbines onsite; make the logic easier to read and consume; minimize HMI changes; share EGD (Ethernet Global Data) signals; monitor, track, and document relevant test data and results; and automate frequent testing procedures such as lift-oil and emergency lube-oil pumps.

The GT generator remote hydrogen auto-purge system at this plant never worked properly, and staff wanted to make it operate the way it was supposed to. Fortunately, engineers found a few unused contact outputs in the H_2 controls cabinet, upgraded the firmware, added sensors for other purge gases like CO_2, and integrated the purge sequence into a graphical interface. Once this was done, operators wanted a similar capability for the steam turbine/generator purge. The remote feature is especially needed in this location because of the frequency of severe weather events—such as hurricanes.

Some of the hair-raising in-field piping configurations, different from design, and discovered only when hardware mods were made, can only be appreciated from the presentation, available to users on the Power Users website. You probably guessed that when operators at other plants learned about the new ST/G remote auto purge system, they wanted one too, so engineers designed one for non-GE units.

Turbine Controls & Excitation Group Inc (TC&E), third-party experts on the upgrade of LCIs (load commutated inverters) with digital front ends, partners with Basler Electric and Emerson for full exciter replacements

Vendor presentations

Vendor presentations, available on the Power Users website, focused on flexibility strategies, small and large control system solutions for gas turbines, integrated control and monitoring solutions for older facilities, legacy controls support, and single-point-of-failure analyses.

PSM reviewed how the company's Autotune rack-mounted controls solution, now 10 years mature in Version 3, can satisfy small goals, like saving minutes on a simple-cycle unit startup, and large ones, like customizing a unit for greater fuel flexibility, capacity augmentation, and better turndown. Autotune is a machine-learning solution—it captures data from successful and unsuccessful starts/load change events. Need for tuning decreases as learning progresses.

MD&A's Michael Broggi, along with Craig Corzine, CSE Engineering Inc (MD&A purchased the rights to CSE's IBECS HMI platform), touted the ability of IBECS to integrate disparate control systems in older plants—such as turbine excitation, continuous emissions monitoring (CEMS), vibration monitoring, gas condition monitoring, generator relays, auxiliary PLCs, and balance of plant. Critical areas for success focused on by the presenters are time synchronization, sequence of events, high-speed data transmission versus historian-type data rates, data export, encryption, alarms, and reports.

TC&E's John Downing presented his firm's capabilities with digital front ends (DFE) for exciter controls. The company boasts over 200 Innovation Series load-commutated inverters (LCIs) with DFEs. TC&E has partnered with Basler Electric and Emerson for full exciter replacements (Fig 1). Some of the additional reliability scope can include water-cooled busbar and resistor components testing and replacement; check valves, 3-way pump valves, and other pump panel components, and Nato board replacement.

Gas Turbine Controls. Chief Engineer Abel Rochwarger addressed solutions for GE TIL-1524 (when one exhaust t/c fails high) and GE TIL-1275 (high P_2 pressure control), as well as for speed-pickup spikes, date cards from 1990 to 2001, and other cards in the Mark V and VI control systems (Fig 2).

Cemtek KVB-Enertec's Gary Cacciatore discussed the benefits of using the company's cross stack TDL/DOAS technology to measure O_2, CO, CH_4, NO_x, and NH_3 on gas-turbine inlet monitoring in pace of the typical extractive CEMS technology. Advantages include immediate response time, accuracy, and reduced CEMS maintenance and spare parts.

Gas Turbine Controls urges users to review for single points of failure in their control systems. Example given was a high differential among ambient-temperature thermocouples that was causing a "not ready to start" situation. It was traced to t/cs located too close to filter-house walls

Siemens Energy's Galen George addressed a round-robin of options for achieving flexibility when a combined-cycle plant's load curve shifts because of renewable energy coming online in the market or service territory. Siemens' Jim Badger supplemented the discussion by illustrating how battery energy storage systems can work with traditional GT plants. Note that this presentation was not submitted for viewing on the Power Users website.

GE Day

The first thing to note about the GE Day presentations is that you're probably going to want to listen to the recordings, provided you're approved to access them on the OEM's MyDashboard website at https://mydashboard.gepower.com. A blizzard of information swept through the virtual room, along with a virtual army of presenters and technical support folks at the ready. The overarching message was that if you're seeking to adapt your plant to changing market or operating circumstances, GE can help.

For the Power Plant Controls Users Group, the GE Day content was heavily oriented around elaborating on existing official documents—including numerous Technical Information Letters (TILs), GEH documents for Mark VI control systems, and maintenance documents for specific turbines and subsystems.

Will McEntaggart, a consulting engineer in the Product Services group, covered smarter pre-start checks to improve start reliability. Leveraging experience from the aviation industry, he said, "lots of tests can be automated." Generally, pre-start check philosophy has evolved to better reflect the service duty of the machine.

So, for example, automation start-ups can proceed with a failed test as long as it doesn't cause an unsafe condition or risk damage to equipment. Operators are instead given a warning and the system "facilitates testing between runs."

Included in his remarks were tests for power to dc lube-oil and seal-oil pump motors, manual tests for the large number of fuel and air valves for dual-fuel units (about 70 air/motor/hydraulic valves) and gas-only units (about 16 valves), leakage from small valves in the water-injection purge system, fan motors, and batteries.

Some tests are more critical, such as the gas-valve bottle test and the DLN valve tests. Regarding the latter, "all four valves have to be tested simultaneously, which is a pain in the butt," McEntaggart conceded.

Randy Ortiz, engineer, Product Services, covered common issues with static-starter systems, specifically switches. He mentioned that TIL-1755 Rev 3, is a "complicated but very important TIL." It addresses replacing nylon "T" connectors with stainless-steel flow restrictors in the source bridge. Other topics covered include confusion in troubleshooting exciter trip lockout events in the generator protection panel and generator dc ground faults while at speed.

Controls Manager Dave Boehmer, Product Services, focused on rationalizing turbine protection. He noted that new software is available for B- and E-class machines that reduce protective actions by 24%. Goal is to retain only those trips, runbacks, and permissives necessary for safe turbine operation, as well as single points of failure. One example given is a turbine trip on oil low pressure delays, which are not required on most new units.

Boehmer also covered stuck bleed-valve trips and wiring issues (such as limit switches which share a common wire and thus constitute a single point of failure) with compressor bleed valves, as well as overspeed testing executed by electrical overspeed protection circuits (in lieu of the mechanical bolt), which reduces subsequent stresses on the rotor from the test. CCJ

TURBINE TIPS, No. 9 in a series

What to do before relocating a gas turbine

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

Turbine Tip No. 9 from the PAL solutions library applies to General Electric package power plants (PPP), including the following: Model Series 5001P, 6001B, and 7001 B-EA.

Suppose your company has purchased a pre-owned PPP and must move it to a new location. Such resales have become more popular recently as the original purpose of this equipment (peaking and emergency power) has ended for many electric utilities. These plants can be relocated successfully, but it is important to engage a knowledgeable crew supervised by an experienced senior field engineer as technical director. This is no job for amateurs if you want to retain your asset's value.

Preparation work should reverse the OEM's original "as-installed" procedure from perhaps 40 or 50 years ago. Nobody working at your plant likely remembers that installation process. Plus, there may not be any GE installation records, field-engineer reports, or information available on how to move this unit to a new foundation.

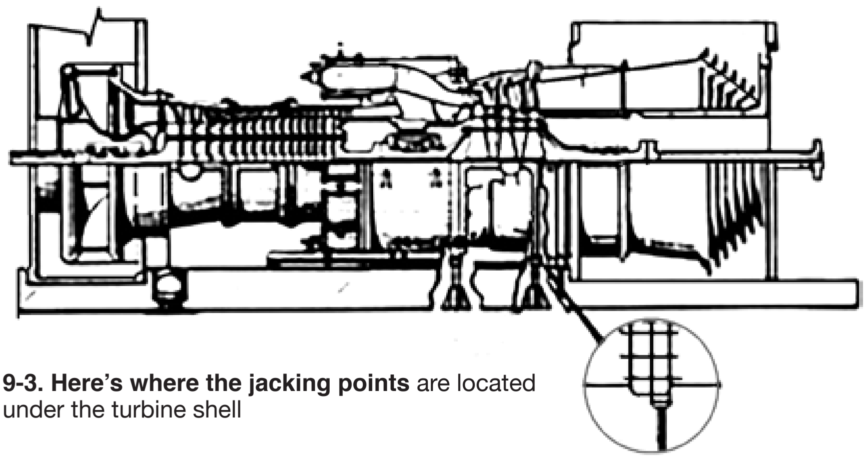
Bear in mind that to safely uproot and move a GE frame gas turbine, specific procedures must be followed. Among them are those described below:

- Remove the side panels adjacent to the turbine shell (Fig 9-1), taking note of the two shell supports, bolting, and dowels. Each support foot has four vertical bolts and one dowel (Fig 9-2).
- Loosen the bolts for the two support legs shown in Figs 9-3 and 9-4 and install mechanical jacks temporarily at each of the two vertical-joint locations. Next, jack up the shell about 15 mils so a shipping pin can be installed in the lower centerline gib key. Shell lifted, tap loose the shims under the support feet, which may be rusted in place.

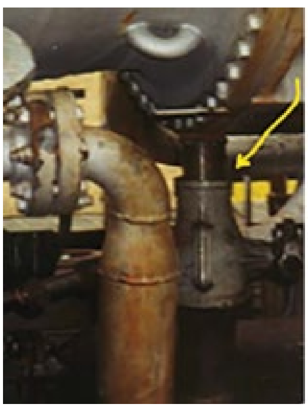
  Note that the turbine must "ride" on a shipping pin in case it is "humped" during transport. This can happen when the machine is lifted by crane or transported by truck or train. Damage could occur to the compressor blades and bearings if the unit is not prepared properly.

9-1. Turbine side panels are removed to access the shell

9-2. Vertical bolting and dowel hold the support leg in place



9-3. Here's where the jacking points are located under the turbine shell



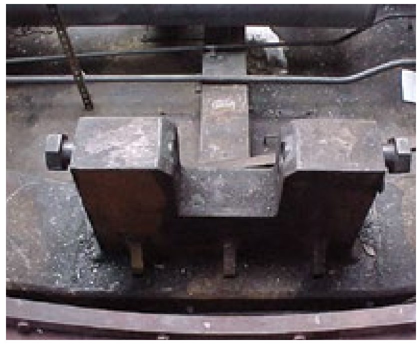
9-4. Temporary mechanical jack is shown in place

9-5. Bolts around the engine circumference hold exhaust seals in place

- Bolts for the exhaust seal should be loosened, otherwise they may "snap" when the shell is jacked up. The bolts may be rusted, so be prepared to replace them after tapping the holes (Fig 9-5).
- Notice the loosened fasteners and elevated dowel pin between the bolts at the left in Fig 9-6. The dowel remains in place, shims tapped loose, and support legs are not supporting any turbine weight. Fig 9-7

9-6. Loosened bolting and dowel pin at a support leg

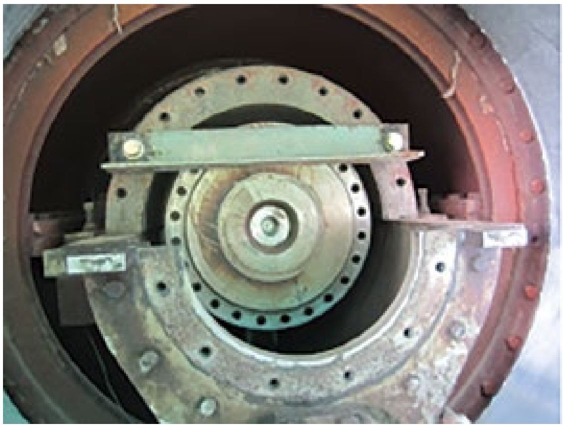
9-7. Red tag is on the shipping pin passing through the gib key



9-8. Gib-key block is welded to the engine base

shows the pin installed to support the turbine shell during shipping to prevent "humping" of the shell. Red tag is to remind personnel that the dowel should be removed after jacking at the new location. Then the legs can be bolted down to support the shell.

- The horizontal gib key bolts in Fig 9-8 can remain in place on each side as long as a 25-mil feeler gage can be slipped in to assure the shell (not shown) is not "pinched." This will maintain the horizontal centerline and shell position. Once they are installed, the mechanical jacks supporting the casing can be removed.
- Front flex-plate bolting need not be disturbed.
- The rotor must be pushed axially against the active thrust bearing (located internally on the opposite end at the No. 1 turbine bearing) to keep the rotor secure during shipment. The axial internal clearance between thrust bearings is about 16 to 19 mils. Use a dial indicator (not shown) to "thrust" the rotor backwards against the active thrust bearing (Fig 9-9).
- There's no need to disturb the front compressor flex support when preparing for the move (Fig 9-10).



9-9. Rotor locking plate prevents axial shift

9-10. No need to disturb front casing flex support when preparing for the move

TURBINE TIP 10

Replace your ageing CO_2 fire protection system

Turbine Tip No. 10 from the PAL solutions library applies to General Electric package power plants (PPP), including the following: Model Series 5001, 6001, and 7001.

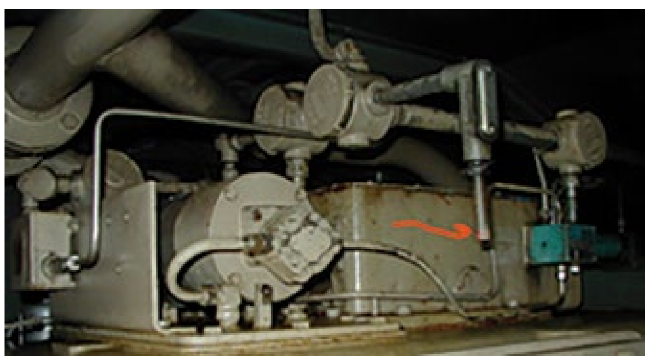
GE PPPs originally had Cardox CO_2 fire protection (Fig 10-1) with individual bottles of suppressant connected in two systems—initial burst and sustained delivery—to three compartments: accessory base, combustion, and load gear and exhaust area. Frame 5 and 6 engines with reduction gears had two overhead "trap doors" that closed when the discharge occurred, to mitigate CO_2 flow into the air-cooled generator from the load-gear compartment, thereby protecting the generator from contamination.

Each of the three compartments was equipped with color-coded temperature sensors indicating the ambient temperature allowed (Fig 10-2). If the temperature exceeded the setting in the tip sensor, the bottled suppressant would be discharged to extinguish the fire.

Location, location. Most GE gas turbines had fire protection systems installed inside their control cabs, taking valuable space away from plant operators. Owners typically didn't like having the bottles so close to person-

10-1. Cardox fire-protection system was used in GE's early package power plants (left)

10-2. Temperature sensor for CO_2 system activation is in accessory compartment here (right)



10-3. Modified CO_2 system was moved to an external building

10-4. Seals for package panels and doors (left) must be maintained in good condition to prevent leakage of CO_2. Seals at right should be replaced

nel, often moving them to an adjacent building (new or existing), thereby opening up space for a desk and chair. Fig 10-3 illustrates a system and batteries that were moved outside the control cab.

Enclosures for PPPs are supposed to be sealed to contain any fire that might occur. The goal is to entrap the fire and smother it with suppressant, extinguishing it as soon as possible. Thus, door and panel seals must be maintained in good condition (Fig 10-4). Insurance companies may require plant operators to "prove" the integrity of the sealing system.

Many insurance companies now are requesting that owners consider replacing antiquated fire protection systems. But before doing this, be aware of the following onsite considerations with the existing enclosures and fire sensing systems:

- Test the existing system for leaks—that is, deliberately discharge suppressant into the compartments to locate leaks, holes, rusted panels, etc. It is very likely that the door and panel seals have rotted, and the panels no longer fit properly to envelop and contain the compartment.
- Refer to the schematic piping diagrams for the tip ratings of compartment temperature sensors. Typical settings are as follows:
  - Accessory compartment, 45FA-1 and 45FA-2 (200F nominal).
  - Turbine combustion compartment, 45FT-1 and 45FT-2 (600F nominal).
  - Load gear (exhaust plenum) compartment, 45FT-3 and 45FT-4 (500F nominal).

Caution: The CO_2 fire protection system is passive. It remains in standby mode until a fire occurs in one of the compartments.

Personnel should "pin" the system whenever personnel are working in the area to prevent accidental discharge. If you think this can't happen consider the following experience: During cranking checks on MS5001L fuel-regulator controls, a flexible coolant line feeding the diesel cranking engine burst, igniting the ethylene glycol. A flame ball roared through the accessory compartment and the CO_2 system discharged to extinguish the fire. The technician was not injured seriously—thankfully—and no lost-time accident was recorded.

TURBINE TIP 11

Compartment heaters not for creature comfort

11-1. Space heaters are installed in the accessory and turbine compartments to promote reliable operation of critical fuel-system components

Turbine Tip No. 11 from the PAL solutions library applies to General Electric package power plants (PPP), including the following: Model Series 5001, 6001, and 7001.

GE installed heaters in the accessory and turbine compartments (combustion-chamber area) to maintain their space temperatures at levels that promoted good combustion on initial firing.

One experience to share: A client with two MS5001N gas turbines for emergency and peak-power generation called a couple of years ago to say both units were having difficulty starting and firing in the dead of winter (February, minus 18F—to be exact). Once

11-2. Operation of the fuel pump (left), flow divider (center), and combustion chamber (right) can be adversely impacted by cold weather, making heaters necessary

onsite I opened the accessory compartment on one unit and found wires hanging from a space heater. I was told that the heaters in the combustion compartment had failed because of the too-hot environment so all heaters were disconnected, staff believing they were "unnecessary."

Space heaters are not there for operator comfort, I reminded plant personnel: They are installed to assure that the on-base fuel and fuel-system components are kept relatively warm. Lines from the LP fuel filter, fuel stop valve, fuel pump, HP filter, and flow-divider elements must be warm to function as designers intended. Especially important is to keep warm the 10 small-diameter fuel lines running from the flow divider under the compressor inlet plenum to the combustors.

Why this is necessary: The first firing attempt involves approximately three gallons of fuel—oil already on the accessory base. If this first attempt fails, oil must come from the fuel forwarding skid, which is off-base and often in open air or an unheated enclosure. Most fuel systems have heat tracing for the buried fuel line to the gas-turbine base, but not all do.

Proper compartment sealing also is important, to retain heat produced by the space heaters. Doors and seals also should be kept in good condition to maintain effective fire protection (see Turbine Tip 10, above).

To sum up: Space heaters in the accessory and turbine compartments must be kept operational, particularly in northern US and Canadian locations. This way, when the ambient temperature drops below freezing, you can be confident that the fuel already on-base will be prepared to ignite on the first firing attempt.

TURBINE TIP 12

Are your compressor bleed valves open or closed?

Turbine Tip No. 12 from the PAL solutions library applies to General Electric package power plant (PPP) models MS5001D, L, and LA.

GE installed compressor bleed valves (a/k/a recirculation valves) on these legacy gas turbines. Axial-flow compressors for the earliest units—those with 15 or 16 stages—had valves to recirculate air from the 10th stage to the fourth, for "unloading" the machine during startup and shutdown to mitigate vibrations caused by the surge phenomenon. Two valves were installed for this purpose in the turbine compartment adjacent to the compressor casings (Fig 12-1).

Pond

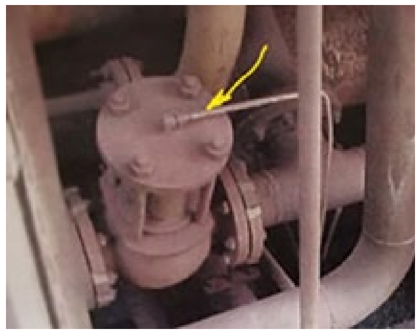
Later turbine models, those with 17- and 18-stage compressors, were equipped with valves to bleed air from the 11th stage to the turbine exhaust during startup and shutdown.

The recirculation valve shown in Fig 12-1 is open during startup and shutdown and later closed by compressor discharge pressure tapped from the 16th stage via the small line on top of the valve (arrow). Depending on spring strength, the valve is fully closed at a PCD of about 30 to 40 psig. Note that the acronym for compressor discharge pressure, PCD, as found in early instruction books, was changed to CDP in the mid-1980s.

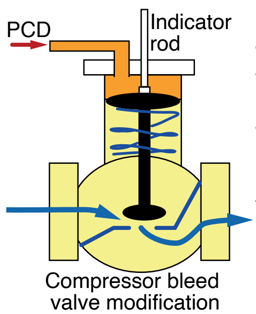
These recirculation valves do not have position "indicators." If either or both valves should remain hung-up in the open position during online operation, performance (turbine power output) would suffer, because air flow to the combustors would be lower. However, no damage to the compressor should be experienced even if not fully closed when the unit is online.

My late former partner, Charlie Pond devised a simple solution to assist operators in knowing whether the valve is open or closed:

- Remove the valve cover and drill a 9/16-in.-diam hole in the top beside the PCD tubing line.
- Relieve the hole opening to accommodate an O-ring.
- Determine the length of rod to be used as the indicator and mark it for the fully open and closed positions.



12-1. Compressor bleed valve recirculates some compressed air during startup and shutdown to mitigate vibrations caused by surge



12-2. Indicator rod retrofit tells operations personnel when the compressor bleed valve is open or closed

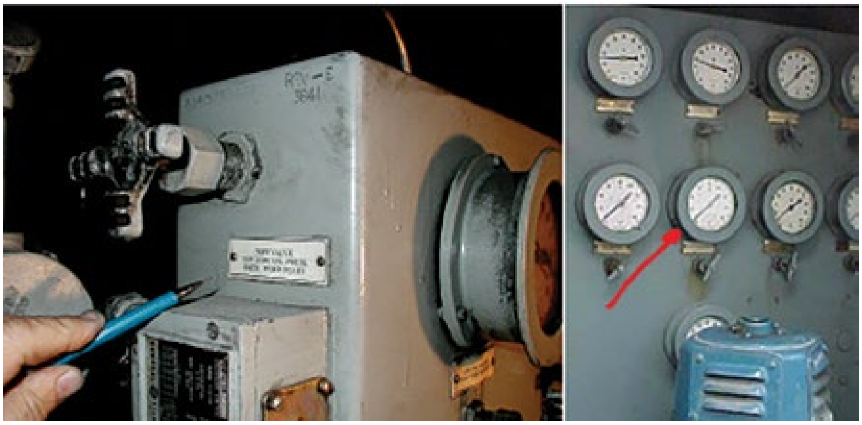
- Select an appropriate O-ring to help seal the rod from excessive air leakage.
- Grease the rod and O-ring, making sure the rod moves smoothly as the valve strokes from open to closed.
- Install a pressure gage in the PCD supply line.

Note that it's best to test the valve travel while the gas turbine is shutdown.

Endnote: As Pond would often remark, "Sometimes the simple solution to a problem is best."

13-1. Emergency lube-oil pump, located inside the oil tank, has both dc (green arrow) and ac (red arrow) motor drives arranged in piggyback fashion

13-2. Motor starter (dc) inside the motor control center shows details of the panel, nametag, sequence lights, and test switch



13-3. Hand test valve for the emergency lube-oil pump is at left, pump discharge pressure gage at right

TURBINE TIP 13

How to test your emergency lube-oil pump

Turbine Tip No. 13 from the PAL solutions library applies to General Electric package power plants (PPP), including the following: Model Series 5001P, 6001, and 7001.

GE gas turbines are equipped with dc emergency lube-oil pumps (GE designate 88QE). This device is controlled at the motor control center (MCC) with a three-step starter circuit. In many GE configurations, the 88QE is coupled to the ac lube-oil pump (88QC) in a piggyback configuration (Fig 13-1). The dc motor (green arrow) is atop the ac (red arrow) motor. Below, a centrifugal pump (not shown) has its suction inside the 1800-gal (nominal) lube-oil tank.

Note that while this design was typical in legacy units, some owner/operators preferred two separate motors and pumps, because the interconnecting coupling had been known to fail on occasion.

The dc motor starter is shown in Fig 13-2. Panel, nametag, sequence lights, and test switch are visible.

The system is designed to allow testing the 88QE motor starting sequence, which should be done regularly, whenever the gas turbine is operated at rated speed. It also can be tested when the generator is synchronized to the grid and under load.

For example, with a GE Frame 5 at 5100 rpm, a reliability test of the dc motor and pump can be conducted by two plant operators as outlined in the sidebar. One plant operator would be stationed inside the control cab observing the annunciator, MCC, and 88QE starter; the other outside, in the accessory compartment adjacent to the pressure-gage panel (Fig 13-3). They should have compatible communications devices.

Note that 88QE is expected to start during the turbine shutdown sequence. This is done automatically to assure when the rotor coasts down to a very low speed it is not bone dry. The gear-driven lube-oil pump inside the accessory gearbox delivers sufficient oil to do these two important jobs:

- Lubricate all the turbine, generator, and gear bearings as they coast down to a stop.
- Cool down the bearing babbitt material to prevent damage by wiping.
  - When the turbine goes on ratchet (or turning gear), oil flow and pressure are required.

Test procedure for the dc lube-oil pump (88QE)

Two operators are required to perform this test, both equipped with compatible communications devices. Operator 1 is in the accessory compartment facing the test valve and gage panel (Fig 13-3). Operator 2 is inside the control room facing the motor control center (Fig 13-2). The turbine is running at full-speed no load (5100 rpm); the generator can be synched to the grid and operating under load, or not.

- Step 1: Operator 1 slowly opens the hand bleed valve to drain oil under pressure past the adjacent inline orifice. Oil pressure *appears* to drop, although this action *fools* the system. The operator observes the dc oil pump turning and producing a pressure of about 25 psig.
- Step 2: Operator 2 confirms that the dc motor has started, not the ac motor. An alarm on the annunciator panel flashes, indicating that the dc pump is running.
- Step 3: Operator 1 puts his hand on the dc motor to see if it gets warm and is operating. He then closes the bleed valve, observing that the dc pump stops.
- Step 4: Operator 2 resets the alarm and clears the annunciator drop.

How to quickly inspect for cracking at tube-to-header welds

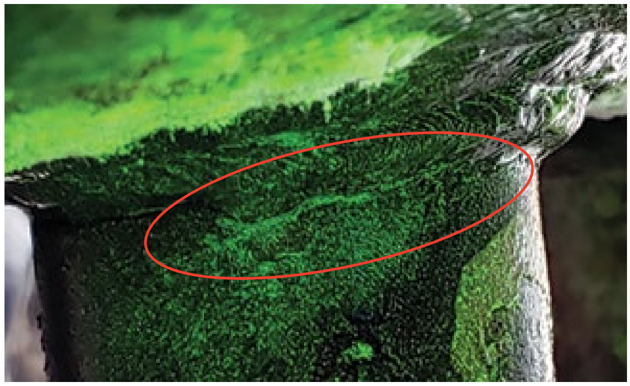
Finding and fixing HRSG tube leaks before they can grow to the point of requiring an unplanned outage to correct them is a priority of many maintenance managers during annual inspections. Tube-to-header welds are particularly susceptible to cracking and leakage given today's fast-start/fast-ramp operating practices.

There are several tools inspection personnel traditionally have used to inspect these welds for cracks—including visual, dye-penetrant, magnetic particle, and x-ray. One or more of them may require special certifications, surface preparation prior to use, and/or more working room than is available.

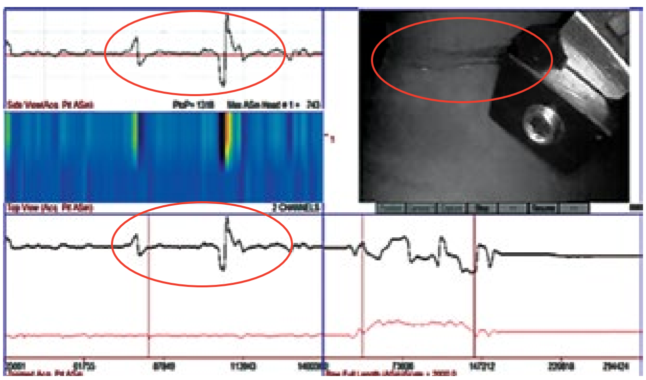
A relatively new tool for inspecting tube-to-header welds, "The Claw," developed by TesTex Inc, Pittsburgh, uses the Balanced Field Electromagnetic Technique (BFET) to detect cracking on the surface, and below it to depths of 0.250 in. (Figs 1 and 2). [https://www.ccj-online.com/new-tools-for-locating-pitting-wall-loss-corrosion-cracking-in-hrsg-headers-tubes-welds/] It was on display for viewing by owner/operators of heat-recovery steam generators at the 2019 meeting of the *HRSG Forum with Bob Anderson*.

Over the last couple of years, TesTex technicians have gained a great deal of experience with The Claw and are now able to examine up to about 200 tube-to-header welds in one shift. Fig 1 shows the BFET's two sensors spaced 180-deg apart and companion cameras traversing the full circumference of the weld. Important: No surface preparation is needed to perform the BFET inspection in HRSGs (Figs 3 and 4).

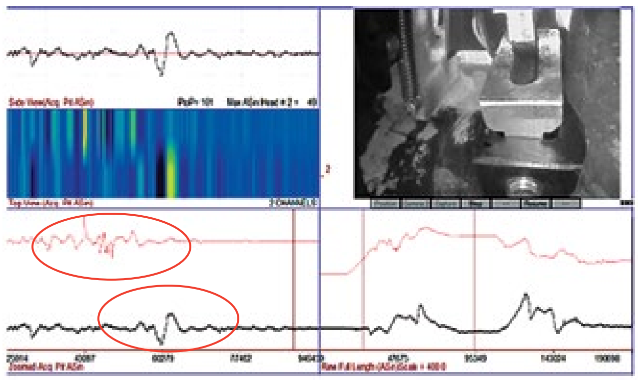
1. The Claw, clamped to a tube, traverses a tube-to-header weld looking for cracking



2. Surface-breaking crack, photographed during a magnetic particle test of the tube-to-header weld in Fig 4, is located at the tube-side toe of the weld



3. Waveform from a reheater tube-to-header weld shows crack taken by one of The Claw's cameras circled in red. This crack was located on the back side of the tube, preventing access for a magnetic-particle inspection prove-up



4. Waveform from a secondary-superheater tube-to-header weld shows a strong signal response on both channels of The Claw because the length of this indication covered approximately half the circumference of the tube

- 88QC may now be operating continuously with power. If not, the dc motor would be running. See the MCC to determine which motor is running.
- If the ratchet is on a three-minute stroking cycle (assuming ac power is not available), the dc motor and pump will turn on only when the ratchet is stroking.

Testing of the emergency lube-oil pump is a necessary action for gas-turbine plant operators (test success or failure should be noted in the logbook). It should be done monthly for baseload gas turbines, during the summer and winter runs for emergency and peaking-power units.

Plant operators likely failed to conduct this simple test on an MS5001P recently. The consequence of a "Failure to Start" of the dc oil pump was the wiping of bearings, causing rubs and blade damage in the 17-stage compressor. Testing of 88QE could have prevented this catastrophic outcome. CCJ

New Athens

Correcting ammonia permissive reduces emissions on startup

New Athens Generating Plant

Owned by Talen Energy

Operated by NAES Corp

1080-MW, gas-fired, three-unit, 1 × 1 combined cycle located in Athens, NY

Plant manager: Hank Tripp

Challenge. Several years ago, Athens Generating received a new air permit that placed strict limits on stack emissions during startups. The plant faced significant challenges maintaining the prescribed NO_x limits for cold and warm starts. Control logic at the plant dictated that the control valve for the SCR not inject ammonia until the heat-recovery steam generator (HRSG) temperature reaches 550F.

During cold and warm starts, the gas turbine (GT) typically held at around 20% load for several hours to warm up the HRSG and steam turbine (ST). The HRSG typically sat at temperatures of between 530F and 540F for hours during these starts, thereby preventing ammonia injection and keeping emissions elevated during startup.

Solution. Plant personnel reached out to the HRSG OEM and an independent contractor for input. Engineers determined the 550F permissive was based on firing the units on fuel oil. At this time, the plant only burns natural gas. Based on this information, the OEM determined the plant could safely lower the ammonia-injection permissive from 550F to 480F. The plant control logic was changed to reflect this.

Results. The lower ammonia permissive has been implemented on all three units and has been very successful in reducing NO_x emissions during startup. Table presents data for a dozen cold starts on Units 1 and 2—both before and after the reduced ammonia permissive was implemented.

For the selected cold starts shown in the table, NO_x emissions with the GT hovering at 20% load averaged 58.6 ppm before the change, 38.2 ppm after. This is nearly a 35% reduction in total NO_x emissions when the GT is held at 20% load.

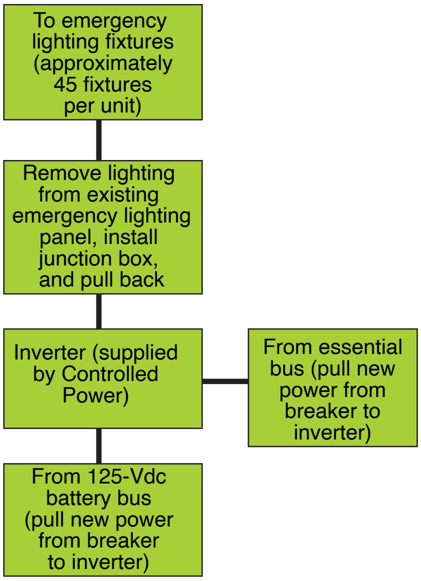
Project participants: Chris Mitchell, Todd Wolford, Bob Robinson, Hank Tripp

Emergency lighting switched from battery power to dc bus

Challenge. Emergency lighting was fed from an integral 110-V battery source. When the standard lighting loses power, emergency lighting from the 110-V battery turns on. During routine inspections of the emergency lighting system it was discovered that 10-15 light fixtures of the 80 installed were not powered. Years of heat and vibration in the turbine hall had reduced emergency-lighting battery power.

Solution. Existing fixtures were typical emergency-exit lighting with incandescent lamps. Most of these were replaced with high-efficiency LED lights. The units selected were not available with an integral battery backup. An existing system was deemed to have sufficient spare capacity to move the emergency-lighting load to the existing dc bus.

New inverters were manufactured and installed at the facility to pull



1. Plant staff worked with an outside engineering contractor to design and implement the new emergency lighting system which pulls power from the existing dc bus and routes it to the newly installed emergency lighting fixture

power from the existing bus and route it to the newly installed emergency lighting fixtures. Plant staff worked with a contractor to design and implement the new system (Fig 1).

Results. The new lighting system was successfully installed in the turbine hall for all three units. The scope of the project has expanded to include the air-cooled-condenser area serving all three units as well as the water treatment plant and the river-water pump house. This is in progress on Units 2 and 3. Because the inverters (Fig 2) power the new emergency lighting, they are always on, increasing visibility around the facility. Each inverter is designed to have a minimum 90 minutes of endurance.

Project participants: Kyle Kubler, Todd Wolford, Hank Tripp.

Ammonia injection at 480F when burning gas, instead of the 550F specified for fuel oil, reduces cold-start NO_x by one-third

Date	Unit	Time at 20% load, hr:min	NO_x at 20% load, ppm
Before permissive reduced			
5/15/18	2	3:30	60.1
8/27/18	2	3:34	55.0
2/28/19	1	3:11	57.5
5/5/19	2	2:45	65.6
5/23/19	1	3:45	56.8
5/29/19	1	2:05	56.6
After permissive reduced			
9/10/19	1	1:49	35.1
9/16/19	2	3:54	41.0
9/23/19	1	2:46	27.0
10/6/19	2	5:16	37.6
11/11/19	2	3:13	41.5
12/3/19	1	3:52	46.8

2. Inverters installed at Athens are designed to have 90 minutes (minimum) of endurance

Stack damper improvements

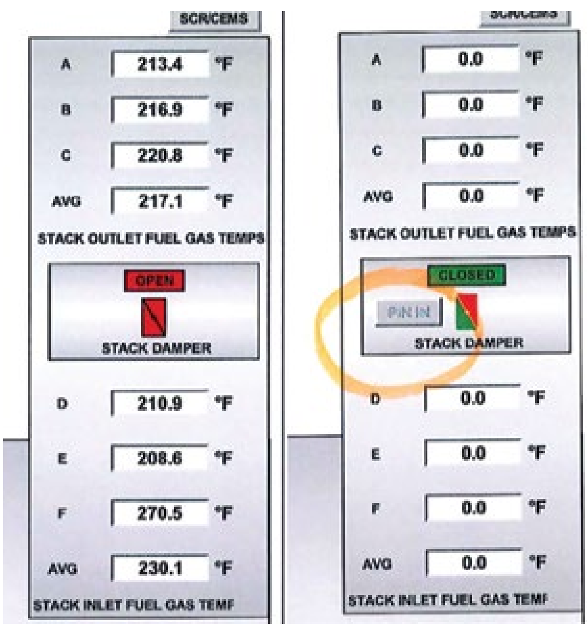
Challenge. The plant's stack damper is a fail-close design. The plant experienced several failures during gas-turbine operation, which resulted in forced outages and damage to the HRSG expansion joint. Issues related to the stack damper have caused four forced outages for the plant, with at least one being definitively linked to the stack damper closing during operation.

Solution. Plant staff researched several options. This included modification of the stack damper, replacing the stack damper, and removing the stack damper. Modifications and or replacement of the stack damper would have cost several hundred thousand dollars per unit.

The solution was to pin open the stack damper during operation. This was accomplished by adding fastening hardware to the actuating arm and linkage. When the stack damper must remain open during GT operation, the stack damper is opened and an operator inserts a pin into the slot added (Fig 3).

3. Stack damper is "pinned" open during gas-turbine operation

Logic was added to the control system so the control-room operator (CRO) can select a button to let him/her know that a pin is holding the stack damper open. Upon confirmation from the operator that the pin is in, the CRO selects the button to show "pin in." To close the stack damper, an operator must first remove the pin from the stack damper and the CRO will uncheck the "pin in" button in the control system.



4. Stack inlet and outlet fuel-gas temperatures with the damper pinned open (left) and closed (pin out, right)

Results. This simple and inexpensive solution has been implemented on all three units at the plant. To date, there have been no further issues of the stack damper closing during GT operation. The DCS screen as the CRO sees it is in Fig 4.

Project participants: Rob O'Connell, Chris Mitchell, Bob Robinson, Todd Wolford, Hank Tripp

New Harquahala

Taking confined-space identification to a higher level

New Harquahala Generating Co

Owned by Talen Energy

Operated by NAES Corp

1080-MW, gas-fired, three-unit, 1 × 1 combined cycle located in Tonopah, Ariz

Plant manager: Jeff Brady

Challenge. The confined spaces at New Harquahala Generating Station were identified and numbered a few years ago. It appeared that during the initial project, the numbering and identification were likely rushed, and the numbering system was labeled haphazardly from unit to unit. While there was the same number of entrances on the units, the numbers did not match up from one unit to the next.

Employees had to pay special attention to which unit's information was pulled to identify the space and the hazards associated with it. Employees tried to fix this over the years, but there was still much to be done. Three key issues were found in connection with the confined spaces.

First, it was brought to the safety committee's attention that employees believed some of the confined spaces had been misidentified and some completely missed. Also, numbering of the confined spaces did not match from unit to unit. The safety committee wanted the job done correctly and in a manner that would last a significant amount of time before needing much work again.

Second, the labels on the confined-space signs, along with a few missing signs, would fade and tear before they were even up for a year or two because of weather damage. The safety committee recognized that the current confined space signs, as they were, could not hold up to the elements of extreme heat conditions and the direct sunlight they were receiving. Something had to be done.

Third, the current computer program was not easy to change and/or add confined spaces to it. A list was compiled in Excel that identified the current confined spaces and the confined spaces that staff believed had been misidentified (multiple access points and/or levels) or missed entirely. The safety committee also wanted a new numbering system put in place for the confined spaces that included the missed spaces. They could then align the confined space IDs on the units so they matched.

Solution. It became evident that this project would be better served by seeking a contractor to fill the responsibility for completing it. The facility needed to be re-examined by someone to identify if any confined spaces were missed, if any should be divided into multiple confined spaces, and then the numbering system checked to make sure each unit matched the others. After the difficulty shown in completing the task in house, it was determined to bring in Michael Roberts with MRSafety LLC.

The task was developed in the following five phases:

Phase One was to finalize the outcomes and seek a common numbering system for everything in the plant.

Phase Two was a thorough and careful examination of the facility and each confined space already identified and then to identify any space missed. The locations were documented and numbers assigned to each confined space. Stainless-steel signs were specified for areas with high heat or sun exposure; hard plastic for areas better protected from the elements (Figs 1 and 2). The signs include a printed label with Quick Response (QR) codes.

Phase Three was to affix the signs around the facility and to provide a data sheet that could be entered into Tag Links. This would include a comprehensive notebook (electronic and paper copy) of all the confined spaces at the facility.

Phase Four was for Harquahala staff to pull all the existing photos of the confined spaces and available information into a usable product.

Phase Five was to provide new drawings identifying all confined spaces on unit and site drawings.

Results. Revamp of the confined-spaces portfolio created a better system, one much easier to identify the confined space and the associated hazards. The identification numbering system was redone so that each unit's identical confined spaces now match from unit to unit.

Signs were printed on the metal backing to ensure they would withstand the Arizona sun and heat through more than a year or two, making it easy for all to identify the confined space. Signs include the appropriate QR code, helping employees and entrants be better prepared for the hazards they might encounter upon entering the confined space.

The QR code was a major reason for using MRSafety's services. Instead of remembering which confined space is being used, then searching through the records to find the necessary information, and then printing that information, now, the information is provided quickly and efficiently using the QR Reader app.

Tag Links also was upgraded to TK Pro and each of the confined spaces was linked. Even better, the same message that appears on the QR Reader text has been linked to the confined space in TK Pro. When pulling up the confined space, the person in the control room now has access to the exact same information as the person in the field.

Project participants: Jeff Brady, Kim Steffen, Michael Roberts (MRSafety).

1. Old signage at New Harquahala might not last a year because of the harsh ambient environment (left)

2. New signage is made of durable stainless steel or hard plastic. QR code provides instant access to confined-space details (right)

Identifying design issues mitigates icing problems in the filter house

Challenge. To protect against ice formation on inlet guide vanes (IGVs) and Row 1 compressor blades during cold-weather operation, the plant was designed with inlet glycol heating and a compressor bleed air system (Fig 1).

Early in the plant's operation, staff observed that during low ambient temperatures and high humidity conditions, ice would form on the leading edge of the finned glycol heating coils. The gas-turbine control system limited the compressor bleed air system to operation at part load, thereby preventing the system from assisting with icing issues at base load. Even at part load, the nozzle distribution and resulting flow pattern were only able to prevent ice from forming in localized areas downstream of each nozzle.

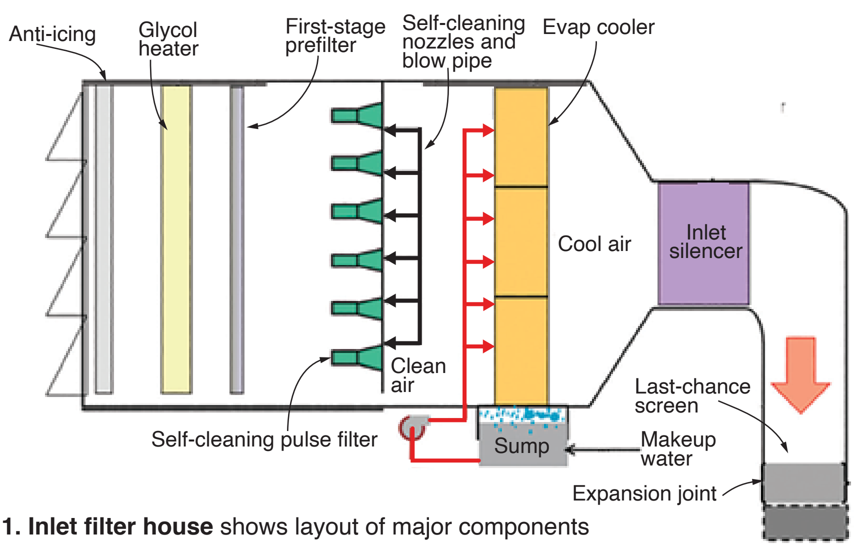
To prevent the ice from choking air flow to the gas turbine (Fig 2), the plant operations team scraped the face of the glycol heating coils. This had to be done continuously until the ambient conditions changed. Such events were experienced on a weekly basis over the course of the winter, with a typical event lasting between two and eight hours. In severe conditions, scraping was unable to mitigate the ice formation and the gas turbines would be derated.

Over the first three winters of operation, 6.3 GWh were lost because of derates, with an estimated 56 GWh of cumulative derates avoided by the scraping efforts of O&M personnel. Plus, to mitigate icing, the heating coils often were operated at full capacity which increased the gas-turbine inlet temperature by up to 22 deg F above ambient and significantly reduced gas-turbine output. And as these events were related to cold weather, they would coincide with high power prices, which magnified the impact to the plant.

Solution. To further understand the issue and begin working toward a resolution, the plant commissioned a study to assess design documentation, review historical operating data, conduct a site survey, collect field data, and perform CFD modeling (Fig 3). It found the root cause of the glycol coil icing to be the materials of construction. The original coils were made of stainless steel having a poor thermal conductivity. CFD modeling showed that the temperature of the leading edges of the fins were expected to increase by only about 4 deg F above that of the ambient air. Issue identified, multiple options were proposed for permanent resolution.

Option 1: Swap the glycol flow direction from counterflow to parallel flow.

Calculations proved this method to be ineffective. Limited by the thermal conductivity of the stainless steel, even providing hot glycol to the front face of the heating coil was predicted



1. Inlet filter house shows layout of major components

2. Ice buildup on the upstream face of the glycol heating coils impedes air flow

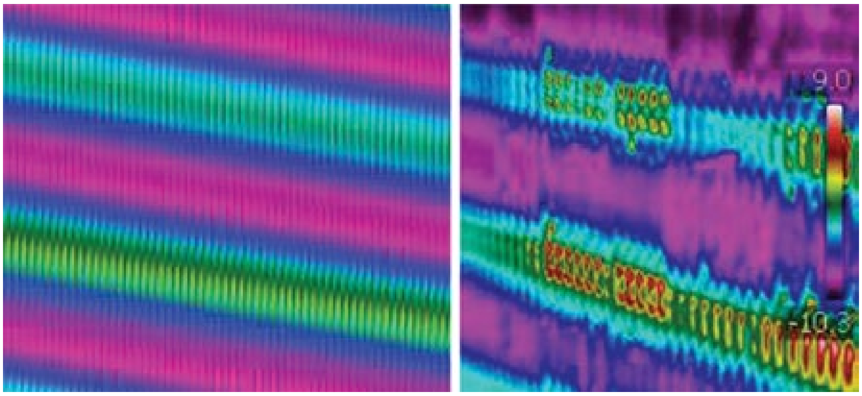
Shepard Energy Centre

Owned by Enmax and Capital Power

Operated by NAES Corp

860-MW, gas-fired, 2 × 1 combined cycle powered by M501G1 gas turbines and located in Calgary, Alta, Canada

Plant manager: Terence Dumonceau



3. CFD output (left) and thermal imaging (right) is for the heating-coil upstream face

4. Original heating coils on Unit 1 (left) and replacement coils on Unit 2 (right) during an icing event in December

to only result in a 7 deg F increase above ambient.

Option 2: Install an infrared heating system upstream of the glycol heating coils.

Although technically feasible, the high implementation cost and significant electrical load requirement of 600 kW per unit was difficult to justify.

Option 3: Revise control logic to enable use of compressor bleed air at base load.

Control logic changes were evaluated with the gas-turbine OEM. However, use of the bleed air system at base load was not desirable as the primary resolution because of its negative impact on output and heat rate. To properly mitigate the icing issue, the nozzle arrangement and resulting flow pattern would have to be addressed as well.

Option 4: Replace the existing heating coils with ones of copper/aluminum construction.

Despite the coils not being designed for replacement, a cost/benefit analysis supported this as the preferred option.

Implementation. A specification was developed for the replacement heating coils which included copper tubes and aluminum fins with a protective coating. The replacement coils were then procured though a public bid process.

In parallel, the plant team prepared for the complex task of swapping the heating coils through development of a detailed installation plan. This plan was executed during a scheduled gas-turbine outage, which included engineered scaffolding, mobile crane, jack-and-roll system, and over 2000 man-hours. All 12 coils (six left-hand and six right-hand) were safely replaced on schedule within a six-day window.

Results. The performance of the new coils has been validated during multiple icing events (Fig 4). The project has a forecasted payback period of less than five years. With the observed success, the plant is currently proceeding with plans to complete the heating coil replacement on its second gas turbine.

Project participants: Mike Sterling and Shane Bucar, with support from AAF and Camfil.

Middletown

Switch source of condenser vacuum-pump cooling water

Middletown Energy Center

Owned by NTE LLC

Operated by NAES Corp

475-MW, gas-fired, 1 × 1 M501GAC-powered combined cycle located in Middletown, Ohio

Plant manager: Dino Padilha

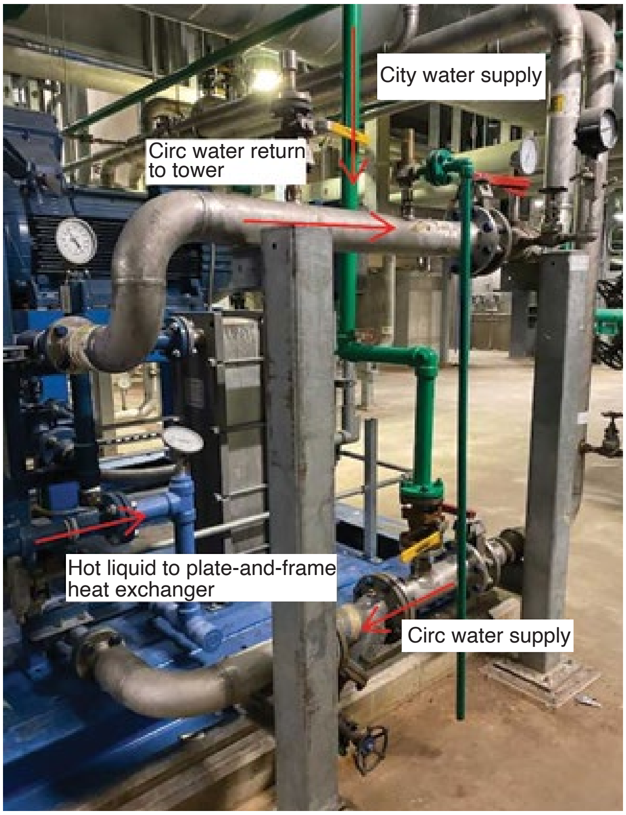
Challenge. Middletown Energy Center's (MEC) liquid-ring vacuum pumps were experiencing cavitation and a significant decrease in capacity because of high liquid temperature. There was also a constant need for filter cleaning given the high level of suspended solids in the pump's cooling water.

Staff responded by changing the cooling-water supply to the vacuum-pump skids—from circulating water to service (city) water. This modification did not increase water usage because the service water used on the vacuum skid was sent to the cooling tower as makeup.

Solution. To help alleviate the effects of pump cavitation and performance loss, and to minimize the need for personnel intervention, MEC piped service (city) water to the plate-and-frame heat exchangers on the vacuum skids. Using city water to cool the operating liquid stopped the cavitation and gained back some of the performance lost (photo). Circ-water temperature in summer is in the 90s; service (city) water is in the high 60s. Note that the circ-water line is still in place and can be used if needed.

Results. The plant estimates that an average of four man-hours per week is saved by using city water instead of circ water for pump cooling.

Project participants: Scott Ashley, Dan Truax, Dino Padilha



Middletown re-piped its cooling-water supply for the plant's liquid-ring vacuum pumps to allow a choice between circulating water and city water

Plant cold-weather operations

Challenge. Middletown Energy Center faced no operational challenges during its first six months in the PJM market, achieving high reliability during that period. However, it faced freeze-protection issues during the first winter and tripped several times—adversely impacting plant performance. It was imperative that the plant identify and correct the problems to assure reliable and safe operation in future winters.

Looking into the issues that affected the plant during its first winter, staff identified the following four causes:

- Improper installation of insulation.
- Failing heat tracing.
- Improper heat tracing for the application.
- Inadequate monitoring to allow proactive action.

Once a problem occurred and the plant tripped, it was difficult for O&M personnel to identify all issues that had to be addressed quickly. Separating the problems and analyzing the issues, the plant identified the following main areas to focus on:

- Several heat-traced lines lost protection because the type of tracing used failed at high temperature. Thermostats were required to sense line temperature and turn off the tracing to avoid overheating. When the thermostats failed, the heat tracing turned off and the lines were left unprotected, leading entire lines to freeze.
- The instruments themselves had no temperature monitoring inside their boxes, so if the local heater failed, the transmitter would freeze, potentially leading to a plant trip.
- Several issues with the insulation itself rendered the installed heat tracing inadequate for some lines.
- After a problem occurred, there was no indication for the troubleshooting team to focus efforts to correct them.
- Boiler-feedwater-pump lube-oil heater was not able to maintain specified oil temperatures during cold days leading oil pressure to increase because of high viscosity, sometimes causing the pump—and possibly the plant—to trip.

Solution. Separating the issues in these areas, plant personnel started to define action plans to improve operations and prevent the problems from recurring. Heat-trace protection was the primary focus of staff efforts. Whenever a thermostat failed, an entire line would become unprotected leading to severe impacts on plant operations.

Plan was to replace the existing temperature-sensitive self-regulating (SR) cables with heat-tolerant mineral-insulated (MI) cables that did not require thermostat protection. Thus, heat tracing could be turned on and off based on ambient temperature. The new MI cables covered the tap-root connections of the instruments, assuring these areas also would be protected against freezing.

This was an extensive project with 55 lines (over 7000 ft) requiring upgrade of heat tracing, plus insulation. An additional benefit of the upgrade: Insulation of areas ignored by the original design.

After addressing the issues associated with heat tracing, thermostats, and insulation, staff provided operators the tools both to monitor the health of the heat-trace system while the unit is in service and to alert on possible problems by implementing capabilities incorporated into the plant's Ovation asset management system (AMS). Note that the Ovation DCS operates in conjunction with Mitsubishi's NetMation gas-turbine controls and Toshiba's TosMap steam-turbine controls.

Standard information from a transmitter in the field is passed to the DCS system using 4-20-mA signals. Using the Hart communications protocol connected locally at each transmitter, the AMS signal can talk to all transmitters at specific intervals to gather more information—that is, instead of the transmitter just sending pressure, for example, it also tells you how healthy the transmitter is and much additional useful information.

This information is used primarily for obtaining temperatures within an instrument enclosure to warn of impending freeze conditions, possibly saving the plant from a hard trip. In addition to the newly created alarms, the plant also developed a DCS screen with alarm lights on a plant layout to advise operators where a given problem is located.

Despite the flexibility provided by the Ovation AMS, it does not cover the critical instruments connected to NetMation and TosMap that could potentially cause the plant to trip. To address this concern, the plant took the following actions:

- Installed alarm lamps on each transmitter box not covered by AMS. Each box was equipped with an ambient thermostat that will turn on the lamp to alert the auxiliary operator making rounds whenever the temperature inside the box drops below 40F.

- Revamped cold-weather rounds to include the checking of the transmitter boxes noted above, and scheduling rounds based on ambient temperature. The colder it gets, the more frequent the rounds.

The other area addressed was boiler-feedwater-pump lube-oil temperature control. The lube-oil tank was insulated with a custom-fit blanket to maintain desired oil temperature year-round. The plant also replaced the oil-heater assembly with one of a higher rating and designed to better distribute the heat throughout the tank and to prevent oil degradation.

Results. Although ambient temperatures at the plant site did not get as low as they did last winter, the thermometer dipped below 10F several times. However, no instruments froze as they had last winter. Plant availability increased significantly, achieving 100% in December, January, and February this winter, versus 94.3%. 78.5%, and 80.7% for the same months last year (excluding non-weather-related events).

AMS will be used to gather more operating information going forward. Plus, it will help maintain records of calibrations and will support the ability to conduct valve calibrations from the control room. Troubleshooting advice installed in the system will help solve problems quickly. It also will facilitate prioritizing work based on the criticality of the asset and the urgency of the alert. Finally, the AMS also will gather information to alert on issues before they become a problem.

Project participants: Ben Sumrall, Dan Truax, Dino Padilha.

Benefit from knowledge shared by colleagues on rotor bowing, diaphragm dishing, more

An hour's investment pays dividends in cost-effective controls upgrades for vintage gas turbines, *TTS Power*.

If your site has a pre-F-class gas turbine, in peaker or combined-cycle mode, and you think there's more money to be had playing the spot-capacity or flexible-start markets, take an hour and listen to TTS Power's recorded webinar conducted a couple of weeks ago. Chances are, you'll come away with an option that not only makes sense but also is affordable.

For optimizing capacity to meet the spot market, the options include raising firing temperature, increasing mass flow, implementing dormant peak-firing capability (that is, originally designed into the unit but not used), and optimizing peak firing (especially for DLN units).

Most of these require a thorough evaluation of the unit's current operating regime compared to original design. The outcome can be as simple as discovering that the current firing temperature is what satisfied the commissioning criteria, not the GT's capability; or as complex as learning that mods deployed to increase mass flow (wet compression, for example) did not properly optimize for firing temperature.

1. Control system upgrades can improve functionality and flexibility while reducing the cost of maintenance

The key, noted Ricky Morgan, TTS Power's VP engineering, during the Q&A, is to ask yourself, "where could this machine fire," not assume that where it currently is firing is optimum.

Only a few vintage GT designs can meet 10-min start requirements without mods, noted VP Pat Begley. The biggest gain comes from eliminating the purge cycle via NFPA 85, but smaller gains—such as by upgrading wiring and cabling, replacing hydraulic/pneumatic valves with electric, eliminating single points of failure in transmitters, sensors, and switches, upgrading HMI, and otherwise replacing obsolete components—can add up (Fig 1).

The impact of any of these mods on GT maintenance factors and the site's emissions permit must of course be thoroughly evaluated. Plus, the more "vintage" a machine is, the more likely it is to be operating off of original design, if only because of deferred maintenance and component changes. Thus, you'll want to have a site evaluation study once you identify one or more options that could make sense.

How to straighten a bowed steam-turbine rotor, *MD&A*.

When you're sick, or something seems "off," what do you do? Many people search the web, often arriving at a WebMD, Mayo, or equivalent site, for some initial information. If symptoms persist, you go to your primary-care physician. The doc may tell you to see a specialist or even a surgeon.

Thankfully, when your steam turbine seems "off," and you suspect the rotor, you can get "integrated care" from the 500 folks at MD&A, including 200 seasonal traveling turbine experts. Who says doctors don't make house calls?

Think of the "Bowed Rotor to Straight Rotor" presentation by Rob Kilroy in MD&A's Spring 2021 Webinar Series (February 16), summarized here, as WebMD. If the turbine rotor needs an official diagnosis, MD&A will send inspection specialists to your site. If the diagnosis suggests repairs, the company will handle those as well.

If you are recording a gradual increase in rotor vibration over a long period, it may be time to listen up. The rotor may be bowed, caused by persistent asymmetrical heating or cooling of the shaft. Pre-1960s turbines rarely experienced bowing. Today's longer, more slender rotors with a reduced number of bearing pedestals and more aggressive operating parameters are more susceptible.

The MD&A crew is seeing around a dozen bowed rotors each year. That may not seem like a lot, but given the damage a bowed rotor can do, it's best not to find out the hard way.

In the webinar, Kilroy explains rotor bowing is defined by the total indicated reading (TIR). If the TIR is less than 0.03 in., the bowing is minor, if between 0.04 and 0.015 in., it's moderate, and above 0.016 in., consider it severe. Severely bowed rotors typically cannot be balanced, and will require an engineered straightening solution.

The turbine/generator repairs engineer delineates three categories of straightening options, once the detailed in-casing and disassembly inspections are completed: Machining/throwing of journals, stress relief/heat lathe, and thermal straightening (Fig 2). The last two typically do not require resizing of the bearings.

Best of all, Kilroy reviews seven case studies, the first three on the cusp of severe with max TIRs of 0.015. In general, the "surgeries" MD&A performed return the rotors to a TIR of between 0.001 and 0.005. In one case, a rotor with "all kinds of problems" and a 0.007-in. TIR at the turbine end and 0.053 at the generator end, MD&A's solution reduced the TIRs to 0.001 in. at both ends.

Rotors from a variety of manufacturers are featured in the case studies. Frequently, the rotor was subjected to multiple straightening options and ancillary machining and component replacements. You'll understand the innovative thinking that's required once you watch the video (users only). Simply click the QR code to gain access.

2. One rotor-straightening option includes thermal stress relief to relax internal residual stresses

Diaphragm dishing most severe in steam turbines installed during the last three decades, *MD&A*.

The "Diaphragm Dishing Issues" presentation by Steampath Engineer Jeff Newton in MD&A's Spring 2021 Webinar Series (February 18) addressed permanent axial distortion of steam-turbine diaphragms, commonly known as *dishing*. The effect is usually caused by deficiencies in main weld depths, weld materials, welding processes and/or steampath design with the maximum movement at the horizontal joint where the diaphragm is weakest, according to Newton.

Unless you are already an expert on steam-turbine condition, you'll want to see the photos shown during the presentation to get a good sense of dishing (not to be confused with thermal distortion) indicators, including: outer-ring distortion, evidence of main structural weld failure, reduced axial clearance at inner setback face, rubbing, packing high teeth out of location, horizontal-joint gaps larger on the discharge side, and packing bore diameters larger on the discharge side.

If you think you have a weld failure, get a second opinion quickly; that will require immediate repair, says Newton.

Steam turbines of 1950s to mid-1960s vintage typically experience the worst dishing in the third reheat stage. That's because it is the highest-temperature stage with carbon steel used as the seal weld material between the partitions and spacer bands, notes the steampath engineer. The condition is more prevalent after 40 years of operation; the expected design life of turbines from that vintage was 30 years. There also was a better pool of data because steam turbines underwent major inspections and outages every five or six years.

However, it is important to note none of the diaphragms from this time period actually failed, stresses Newton.

Things get dicier beginning in the 1990s. At least one manufacturer began to replace submerged arc welding in these areas with electron beam and MIG welding, which led to less consistency in weld quality; the CrMoV (chromium, molybdenum, vanadium) metallurgy was changed to just CrMo; dense-pack designs led to more stages with less axial space; and diaphragms were not as thick. Main weld depths as a percentage of partition axial height also were reduced. Furthermore, the time between major outages was extended to more than 10 years.

These units have experienced diaphragm failures (Fig 3). One Toshiba unit failed within five years at the first IP stage. In fact, the three examples Newton reviews are all Toshiba. A second unit also failed at the first IP stage; bucket and rotor material were found missing at disassembly.

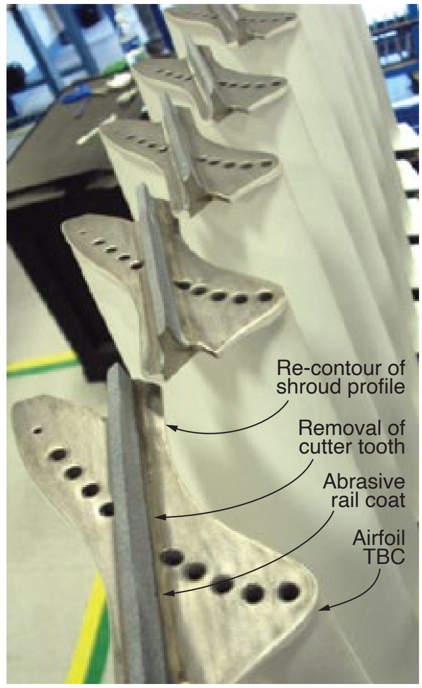
Three of the ways to proceed if you have evidence of dishing are do nothing and monitor, install offset packing rings, and/or shift the diaphragm upstream with a steam seal face insert. However, Newton stresses, these do not address the *cause* of the dishing. The component has to be reconstructed, or reverse engineered with design changes to address the cause (Fig 4).

Newton illustrates this for users with a photo montage sequence that drives home the as-found versus repair comparison. Simply click the QR code to gain access.

Maximizing the lifetime of gas-turbine hot parts, *MD&A*.

If you're having difficulty with your F-class

3, 4. Steampath failures, such as the diaphragm at left, typically require re-engineering and parts of new manufacture, as illustrated by the upper-half nozzle plate before (center) and after (right) installation



5, 6. MD&A's TBC coat for F-class first-stage nozzles (left) is said to offer superior oxidation resistance. Repairs to F-class second-stage blades make these parts better than when they were new (right)

gas turbine OEM when it comes to repair of hot-gas-path (HGP) components, MD&A wants you to know they not only have the experience you are seeking, but also enhancements, which will extend service life, plus better transparency and customer oversight throughout the repair process.

In the "Extending Service Lives of Gas Turbine Components" segment of MD&A's Spring 2021 Webinar Series (February 23), Director of Engineering Jose Quinones, PE, reviewed the company's capabilities, experience, and customer-care process, most pointedly through eight examples, including nozzles, blades, and shrouds for F-class GT stages 1-3 nozzles.

Key takeaway: Don't sell "scrapped" HGP parts until you let MD&A look at them. Watch to the end of the webinar (users only) and you'll see why. Simply click the QR code to gain access.

MD&A's sweet spot with these types of repairs is "single-crystal components where users have difficulty getting service." All steps of the repair process are done in-house except a hot isostatic press and an internal aluminide coat, if necessary.

Several "gates" are established during the repair sequence for process and quality reviews with the customer. As just one example of an enhancement, MD&A adds silicon, hafnium, and other elements to the thermal barrier coating which reduces surface degradation and crack propagation (Fig 5).

Perhaps the most captivating part of the webinar was when Quinones discussed how MD&A repairs components deemed "unrepairable" by others, such as, in one example, second-stage nozzles with creep deflection, cracks, oxidation, and clearance reductions. In this case, the cooling holes were exposed because of thinning (Fig 6).

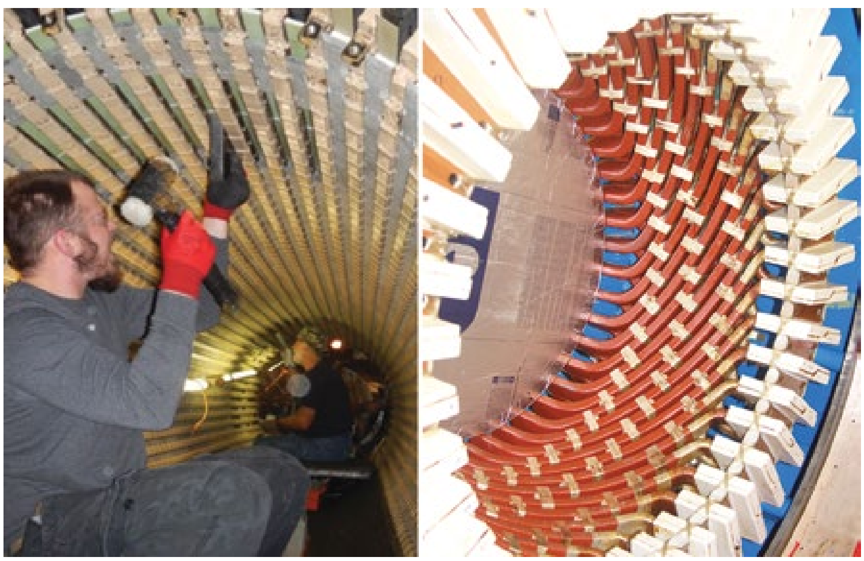
Quinones explained that there may not have been repair techniques available when some parts were sent to the graveyard. In an astonishing case, MD&A took components worth $7600 as scrap, repaired them for $1.3-million, and saved the customer many millions more.

As noted during the Q&A, best to loop your insurance company into the conversation regarding such repairs, especially when MD&A's assessment is different from the OEM recommendations.

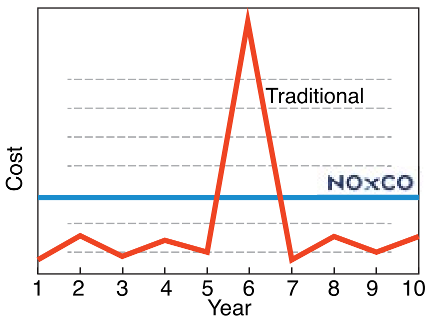
Stator repairs in the spotlight, *MD&A*.

If you are not a generator specialist, the things you probably need to know about stator wedges are that they hold the stator bars in the iron, there are lots of them (1200-1800), and they can loosen from age or unusual or persistent vibrations, which interrupts electrical contact, leading to spark erosion. Testing them for tightness is labor-intensive, and re-wedging, if necessary, can extend the outage by up to eight to 10 shifts.

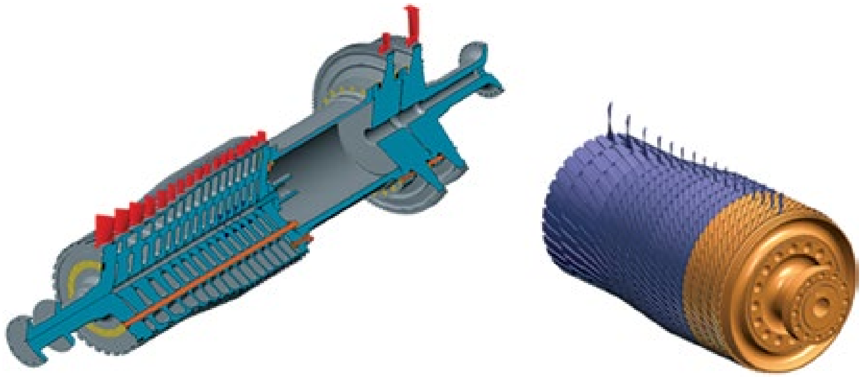
"Generator Stator Wedge Issues," included in MD&A's Spring 2021 Webinar Series (February 25), discussed by



7, 8. Piggyback wedge system for medium- to large-size machines being installed (left) has a history of proven performance and often is used as an upgrade solution (right)



9. Comparing the traditional aftermarket catalyst spend to the annual cost of Noxco's guaranteed emissions compliance program for ageing gas turbines



10. EthosEnergy Group's webinar explores the design limits of your GE gas-turbine rotor as outlined in TIL-1576, outlines the critical factors to consider when deciding to replace or extend an end-of-life rotor, and provides details of the company's EOL program

Generator Operations Manager James Joyce, offers a primer on the different types of stator wedges for machines made by different OEMs; inspection techniques; some of the nuances of tightening and re-wedging, such as maintaining core compression nuts at optimum torque value; and wedge-system enhancements—such as replacing flat wedges with the company's piggyback design (Figs 7 and 8). Simply click the QR code to gain access.

Guaranteed emissions compliance for ageing gas turbines, *Noxco.*

Jeff Bause, Noxco's CEO, opened the webinar by explaining to turbine users how his company is raising an industry bar with the first LTSA (long-term service agreement) for emissions compliance. He said that by removing the burden and responsibility for protecting and managing complex systems from owner/operators, Noxco delivers performance, predictability, cash flow, and 100% risk mitigation through a turnkey solution.

Bause is well-known to many CCJ readers for his deep knowledge of catalyst system maintenance, gained over the years as CEO of Groome Industrial Service Group. He is a frequent speaker at industry events on SCR and CO catalyst cleaning, repacking, and replacement, plus the cleaning of ammonia vaporizers and injection grids, as well as of HRSG tubes.

Noxco's turnkey solution, Bause says, increases the operational flexibility and performance of the SCR, CO catalyst, and ammonia injection system (AIG) to deliver sustained peak performance at the lowest lifecycle cost (Fig 9). LTSA benefits include all system maintenance, inspections, tuning, optimization, catalyst testing and cleaning, catalyst replacement with the optimal product for your site and operating conditions, spent catalyst disposal, AIG design optimization and tuning, and performance upgrades. Access the recorded webinar to get the details.

Your GE gas turbine can run longer: What to do when your unit is reaching the designed rotor end-of-life limit, *EthosEnergy Group.*

If your plant is equipped with a GE industrial gas turbine—Frame 3, 5, 6, 7 (A, B, C, E, EA, and/or F)—and mention of the OEM's Technical Information Letter 1576, "Gas Turbine Rotor Inspections," does not strike a responsive chord, obtain a copy today from your plant's GE representative.

TIL-1576, released in 2007 and updated in 2011 (1576-R1), identifies the equipment and personnel risks associated with operating gas-turbine rotors beyond 200,000 factored fired (FF) hours (144,000 for F-class units) or 5000 FF starts, whichever comes first, when specific intervals are not defined (Fig 10).

This TIL refers you to GER-3620, "Heavy-Duty Gas Turbine Operating and Maintenance Considerations," for overall guidance on centerline maintenance recommended by the OEM. The latest version of 3620 is Rev N, important because it considers the impact of forced cooling on rotor inspection calculations, replacing the "trip from load factor" in earlier versions.

Kale Dreymala, GT rotor project manager, and Jeff Schleis, product manager, walked webinar participants through the inspection scope recommended by EthosEnergy Group (EEG) for turbine wheels, distance piece/spacers/stub shaft, and compressor wheels. Here's the lineup of inspections typically recommended:

Compressor and turbine wheels

- Visual inspection of all surfaces.
- Semi-automated phased-array ultrasonic (UT) inspection of the bore, web, and rim areas.
- Semi-automated eddy current (ET) inspection of the through-bolt holes.
- 100% ET inspection of the dovetail serrations in the compressor wheels and the fir-tree serrations in the turbine wheels.

Distance piece, spacers, stub shaft

- Visual inspection of all surfaces.
- Semi-automated ET inspection of the through-bolt holes.
- Semi-automated phased-array UT of the bore.

Other inspections

- Hardness.
- Replication.
- Dimensional measurements.

If these inspections produce no findings, the rotor is reassembled with new bolts and your engine receives a certification for an additional 50,000 FFH (one time only).

If there are findings, the speakers say the OEM is likely to suggest buying a new rotor or possibly a replacement wheel or disc, if that is the life-limiting part.

By contrast, an affordable aftermarket solution suggested by EEG probably would be to obtain a used rotor with a documented history and refurbish it in the shop. The additional life certified (from 50,000 to 200,000 FFH) depends on an engineering review. Note that for peaking units, no extensions are allowed beyond the 5000-starts limit.

The speakers also describe EEG's capability for manufacture and qualification of new rotor components as might be required during the refurbishment process to get the best balance between cost and additional life. Other rotor options also were presented during the webinar, which was not recorded. However, you can write Dreymala for a copy of the presentation at kale.dreymala@ethosenergygroup.com. CCJ

Elections have consequences: Beltway execs portend what they might be

With a somber undertone from the recent death of its long-time leader, Barry Worthington, the United States Energy Association (USEA) held its 17th State of the Energy Industry meeting virtually on Jan 28, 2021, less than a week after President Biden was inaugurated. Executives from 22 separate beltway policy and advocacy organizations offered their glimpses into the next four years under a Biden administration and a razor-thin Democratic majority in Congress.

What was most revealing, however, had nothing to do with the actual presentations. The last speaker, Heather Zichal, represents the brand new American Clean Power Assn (ACPA), an umbrella group pulling together solar, wind, storage, and transmission interests, so that the "trillion-dollar renewable energy industry," in Zichal's words, can speak as one voice. We "need a deeper bench of Republican support for clean power and renewables," said Zichal, a bigger "coalition of the willing," for the transition to the clean energy economy.

By contrast, more than one-third of the organizations represented were associated with natural gas, six with gas in their name, one which qualifies if you make the largest component of natural gas (methane) into an alcohol (methanol), and one representing petroleum companies, almost all of which are also natural gas companies.

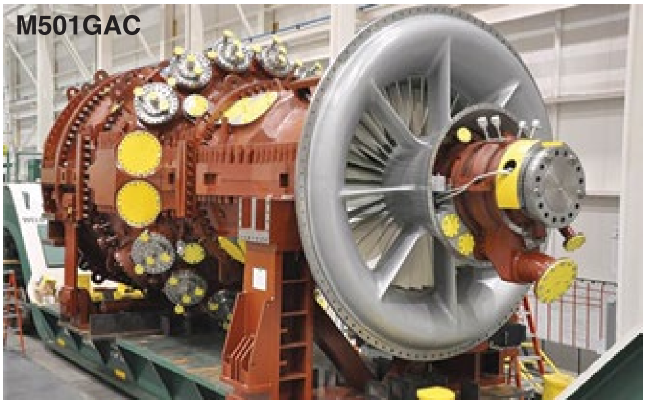
It seemed pretty clear which energy industry interests have acted to stand in "unity," a word Biden used over and over on the campaign trail and continues to use, and which appear fragmented.

Generally, these types of events are polite affairs laced with diplomatic, optimistic language about working with the new elected officials. If there was going to be an exception, one might suspect the coal group. But no. Mike Sommers, American Petroleum Institute, declared a "posture of strong opposition" to the Biden administration, seeing no "unity" in his early actions, most notably shutting down the Keystone Pipeline.

On the other hand, Rich Nolan, National Mining Assn, lauded the US mining industry as "on the cusp of a rebirth. Mining policy is energy policy," he said, referring to the soaring demand for metals and minerals critical to the renewable and non-carbon energy supply chain. Betsy Monseu, American Coal Council, forecasted that the natural-gas share in electricity will decline by 41% in 2021 and another 8.9% in 2022 because of price increases, and that coal is essential to "balance uncertain loads with uncertain supply."

Julia Hamm, Smart Electric Power Alliance, gave one of the more startling stats: The number of electric utilities with net-zero carbon commitments by 2050 increased from 18 last year to 39 this year. What better evidence is there that "elections have consequences?"

One issue that clearly concerns the electricity natural-gas interests is fugitive methane emissions from their infrastructure. Thomas Kuhn, Edison Electric Institute, noted his group's initiative to monitor methane emissions, one he called "important." Karen Harbert, American Gas Assn, also pointed to a "new framework for measuring and reporting methane emissions." Charlie Riedl, Center for LNG, noted his members' principles for enhanced measurement and reporting of methane, and that conversations around methane "are increasing."



API's Sommers pointed to earlier success reducing methane emissions by 70% "in the largest oil/gas producing regions," as did Harbert, who claimed that methane emissions have been reduced by 73% from the country's natural-gas distribution networks.

Not surprisingly, the most prevalent theme was the need to up federal money for more RD&D and commercial investment:

- Kuhn, "We need lots more R&D."
- Sommers, "Need more investments in American oil and gas."
- Nolan, "Need to advance technology for the fuels the world has to offer."
- Arshad Mansoor, EPRI, The nation "must make a commitment this decade to negative emissions technologies."
- David Carroll, Gas Technology Institute, "Many of the technologies needed to get to a no-carbon 2050 don't yet exist" and "federal energy innovation spending is 10% that of defense innovation spending."
- Monseu, The National Coal Council has been involved in carbon capture, utilization, and storage (CCUS) for many years. Biden included CCUS in his campaign, and robust funding for CCUS is a big part of the Energy Act of 2020 (passed during Congress' lame-duck session).
- Jim Matheson, National Rural Electric Cooperative Assn, "We need an infrastructure program at the federal level."

My job is better than yours. Jobs and economic activity didn't get the attention one might have thought, perhaps because most speakers were more consumed with getting through the Covid-induced economic fallout. Derrick Morgan, American Fuels & Petrochemical Manufacturers Assn, did make the case for why a petro job is better than a renewables job. Each job in his industry, he said, supports 32 others, 16 directly and 16 induced. His observation was a counter of sorts to the Biden administration ambition to retrain fossil-fuel workers for opportunities in the renewables sector.

Maria Korsnick, Nuclear Energy Institute, reminded everyone that nuclear powerplants are the largest source of carbon-free electricity, and "uniquely reliable." While NEI lauded the recent NRC approval of the first small-reactor design, the organization seems more focused on saving existing reactors from political threats at the state level.

Lest any in the CCJ community think small reactors are a threat to their business, the timeline from an NRC-approved design to a permit to construct (along with the commercial investment) is long and arduous, based on recent experience with the advanced light-water reactors. Better to worry about the goal set by ACPA's Zichal: 50% renewables on the electricity grid by 2030.

GTI's Carroll acknowledged the

"cycles of hype" with the "hydrogen economy," dating back to the 1960s. But, he said, "this time it's different," adding "famous last words, right?" He identified several hydrogen projects GTI is involved with, notably a broad infrastructure integration study for Texas, in which wind power is used to produce hydrogen for transport and delivery through existing pipelines.

Finally, Fred Hutchinson, LNG Allies, tempered the net-zero-by-2050 enthusiasm with a reminder that there is expected to be 2-billion more people on earth by 2050, the world will need 50% more energy by then, while 850-million people still lack access to electricity.

Therein lies the conundrum for the energy industry in the aggregate: The affluent want less carbon as soon as possible; the less affluent want more energy now.

USEA
United States Energy Association

New type of gas calorimeter said to benefit turbine users

Riken Keiki Co's OHC-800 (photo), a relatively new type of calorimeter, uses optical and sonic sensors to provide real-time monitoring with high accuracy. The instrument's use in optimizing turbine and boiler air/fuel ratios make it of interest to O&M personnel at gas-turbine-based simple- and combined-cycle plants.

Recall that competitor gas chromatographs provide highly accurate analyses of fuel-gas composition, but do not offer real-time monitoring. And combustion-type calorimeters can offer real-time monitoring, but they generally are not accurate enough for process control.

The OHC-800's sonic sensor measures the sound velocity of the gas, the optical sensor the refractive index of the gas. Stated advantage of the optical interferometric sensor is that because no chemical reaction is used—unlike methods relying on catalytic combustion and thermal decomposition—components do not wear out or deteriorate.

There also is no reported effect from the change in light-source intensity over time. While the sensitivity of an infrared sensor can deteriorate because of lamp ageing or cell contamination, the "light-wave interference" principle employed by the OHC-800 relies on a mirrored image unaffected by changes in light intensity.

Inlet for reference gas (instrument air or nitrogen)

Inlet for gas being analyzed

Advantages of the OHC-800 touted by Riken Keiki in the 12-min recorded webinar produced by the manufacturer are highlighted below. Click the QR code to watch the webinar.

- High accuracy. Comparison of calorific measurements of fuel gas containing nitrogen shows the OHC-800 and gas chromatographs have comparable high accuracies, but the former's advantage is the ability to measure calorific value continuously.
- Real-time monitoring with high response speed. Data can be updated every 0.25 seconds. The instrument's robust design is said to accommodate all measurement environments, eliminating the risk of "measurement outages." Response time to changes in calorific value is less than five seconds.
- Minimum effects of N_2, O_2, CO_2, etc. Use of both optical and sonic sensors eliminates the possibility of interference from gases that do not have heat content.
- Essentially maintenance-free because the physical-based optical and sonic sensors do not require periodic calibration.
- Easy parts replacement. The OHC-800 has only four parts—sonic sensor, optical sensor, main controller, and power supply.
- Installation flexibility. Explosion proof, operating-temperature profile extends from -4F to 140F.
- No carrier gas is required; instrument air or nitrogen is used as the reference gas.

If your interest is piqued by the webinar, a field-test demo is available.

Catch up on the benefits of remote support, and technologies for improving plant flexibility

Two relatively short white papers available from Mitsubishi Power can bring you up to speed on the state-of-the-art and future of remote operation and support and on digital strategies for improving steam-plant performance. Some of the insights shared on the latter topic also are of value to combined-cycle owner/operators.

"Remote Operation and Support—the New Normal?" tracks the rapidly growing demand for remote technology—including early-warning diagnostics using advanced analytics, plus access to offsite technical expertise for troubleshooting and response. It walks readers through the company's considerable analytics experience, which began in 1999 with a remote monitoring center at Mitsubishi's extensive engineering and test facilities in Takasago, Japan.

Since that first step, digital solutions, like the company's growing Tomoni™ suite of offerings, allow O&M staffs to leverage the massive amounts of data from the thousands of sensors in a plant to provide valuable insights, solve complex problems, and maximize performance.

Advancement through digitalization is a core focus of the white paper, which includes experience gained when a scheduled plant outage was shifted because of the pandemic and condition-based maintenance intervals provided a pathway to success. Another sidebar presents the case history on how a Tomoni digital solution improved efficiency by enabling a process to actively optimize the flow of gas-turbine cooling air.

"How Digital Strategies Improve Steam Power Plant Performance" discusses the new level of flexibility required by traditional fuel-fired generating assets to remain competitive in today's rapidly changing electricity markets. Fuel flexibility, faster starting and ramping, and reduced minimum load highlight are the challenges faced by industry participants.

PROFESSIONAL SERVICES

COMBINED CYCLE Journal CCJ No. 66 (2021)

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Products and services from over 60 companies support new unit construction, retrofit and maintenance activities at existing facilities, and plant operations. Solutions span gas and steam turbines, HRSGs, pumps, valves, piping, cooling towers, condensers, etc

Advanced IAQ Care USceanblast.com

Dry ice blasting of HRSGs, stators, rotors, turbines, substations, and other power equipment. ISN "A" rating for safety. 21 years of references from plants including Emera, NRG, Dominion, NY /NJ plants, NAES, and EthosEnergy. Price competitive and guaranteed excellent results.

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.

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.

Black Start LLC

Industrial, direct-hire contractor with a specialization of combined cycle power plant support, providing multi-discipline technicians for industrial start-up, commissioning, and outage field services. Field personnel are capable and prepared for turn-key projects, SME consultant services, and project management.

Braden

Global leader in the power generation industry for design, manufacture, installation and retrofit of auxiliary equipment for GTs and has established itself as the most experienced and trusted name in the design of auxiliary systems for GT power plants.

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.

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.

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 NO_x 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.

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.

IC Spares

Specializes in the supply of new, remanufactured, and repair services of GE Speedtronic turbine controls for GTs, STs, and drive controls with an extensive stock of new and remanufactured parts available for next day delivery and backed by 2-year warranty.

IOT Integration Services

Many years of experience in power generation building and deploying industrial networks and configuring control systems and plant data historians while ensuring network and security structures support the transfer of your information.

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.

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.

Lambda Technologies

Providing complete surface enhancement solutions and specializing in understanding, measurement and control of local residual stresses, Lambda is an established leader in materials testing and life extension technology. An integrated total solutions approach improves component life and performance.

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.

Millennium Power Services

Full-service valve repair, safety valve repair, and testing company. We deliver a complete package of solutions based on the optimal combination of technology, agile response, and expedited project completion. Our engineering skill and insight delivers solutions at considerable cost savings.

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.

RMS Energy Co

Industry leader, providing comprehensive solutions in isolated phase, non-segregated and cable bus systems, switchgear, substations, transformers, relays, commissioning, testing, engineering, advanced monitoring technology, professional services, and more.

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.

Schock Manufacturing

Designs and fabricates filter houses, inlet ducting, inlet silencers, exhaust diffusers/plenums, exhaust systems, exhaust silencers, turbine enclosure doors, and expansion joints.

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-cycle facilities where operating flexibility is beneficial.

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.