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CCJ

Number 67 2021

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COMBINED CYCLE Journal

POWER USERS

2021 Conference and Vendor Fair

August 23 - 27 • Marriott St. Louis Grand

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INDEPENDENT VOICE OF THE GAS-TURBINE-BASED GENERATION SECTOR

The Bad News: Like all conferences, the Covid-19 pandemic resulted in cancellation of the 2020 and 2021 physical meetings of the HRSG Forum. The same is true for the associated HRSG user conferences co-chaired by Bob Anderson (Competitive Power Resources) and Barry Dooley (Structural Integrity Associates): the Australasian Boiler and HRSG Users Group (ABHUG) and the European HRSG Forum (EHF).

The Good News: All these user conferences are back in virtual action in 2021. The HRSG Forum began conducting monthly two-hour virtual sessions in May (p 46) and a Vogt-sponsored Supplier Workshop in June (p 56). EHF held its annual meeting via four two-hour virtual sessions in May. ABHUG is scheduled to hold its annual meeting via virtual schedule similar to EHF's in November.

Anderson

Dooley

The Current Status: HRSG Forum maintains cooperative relationships with several world-class organizations—including Power Users, the Electric Power Research Institute (EPRI), the International Association for the Properties of Water and Steam (IAPWS), and Combined Cycle Journal (CCJ).

Attendees of the HRSG Forum virtual sessions have enjoyed the same level of expert and timely technical presentations and robust moderated question/answer and discussion periods previously experienced at HRSG Forum, ABHUG, and EHF physical meetings. Surprisingly, even with the time-zone challenges virtual events face, attendees at this year's HRSG Forum sessions have hailed from 36 countries, making it a truly international event.

Attendance at HRSG Forum virtual sessions is free-of-charge to all. As with HRSG Forum, ABHUG, and EHF physical meetings, in addition to HRSG owner/operators, OEMs, equipment suppliers, services providers, consultants, etc, are all welcome and urged to participate. In this way users can get their questions answered and problems addressed by experts across a wide range of subjects.

The Future: HRSG Forum will continue to conduct its regular monthly two-hour virtual sessions and occasional Vendor Workshops. These sessions are expertly hosted by Scott Schwieger of CCJ Online. Users and vendors wishing to make a technical presentation during an HRSG Forum session can submit an abstract to Bob Anderson at anderson@HRSGForum.com. Companies wanting to sponsor a Supplier Workshop can contact Scott Schwieger at scott@ccj-online.com. Details of future scheduled HRSG Forum sessions and recordings of past sessions can be found at www.HRSGForum.com.

While no plans are firm at this time, work is in progress to return the HRSG Forum to a physical event. Stay tuned to CCJ for information about that in-person conference and vendor fair as it evolves.

COMBINED CYCLE Journal

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to the Marriott St. Louis Grand meetings of the 7F, 7EA, Steam nd Power Plant Controls oups

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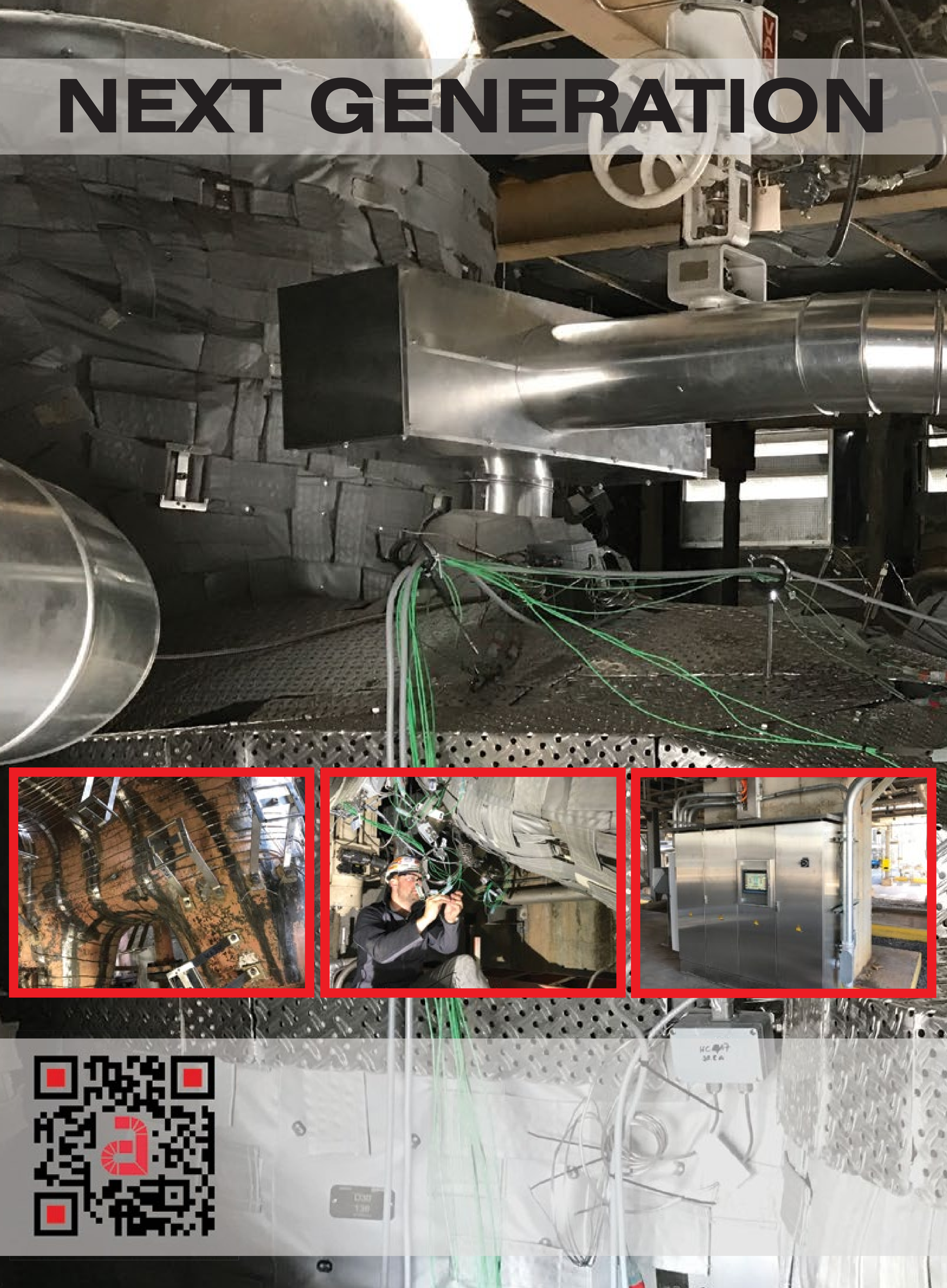
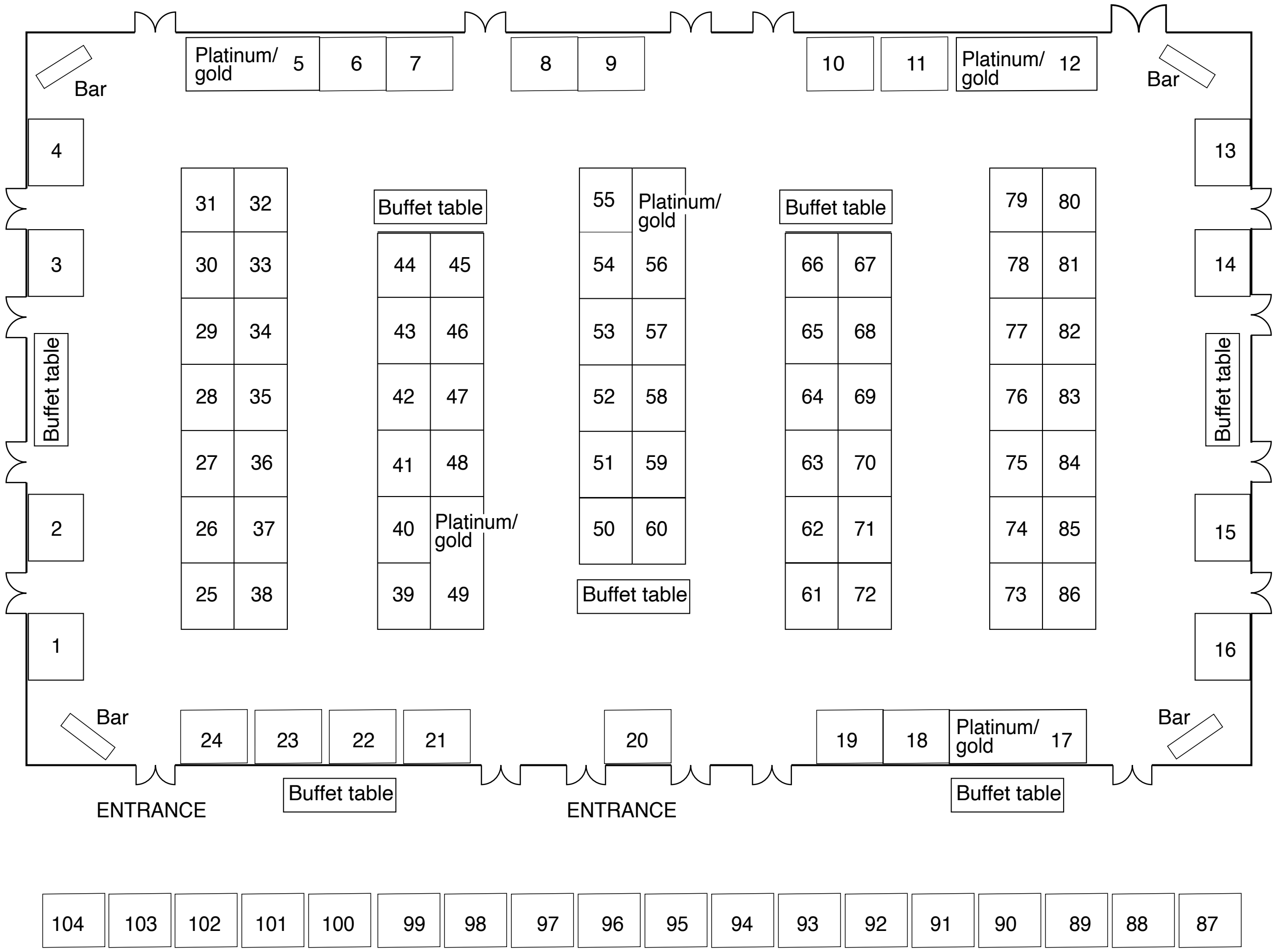


Marriott St. Louis Grand, Majestic Ballroom



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Booth number order

Booth number	Company
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3	Advanced Turbine Support
4	American Thermal Solutions
5	Allied Power Group
6	Independent Turbine Consulting
7	Young & Franklin
8	ORR Protection Systems
9	Sulzer Turbo Services Houston
10	Chevron Lubricants
11	C C Jensen Oil Maintenance
12	ARNOLD Group
13	Environment One
14	Camfil Power Systems
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16	Pioneer Motor Bearing
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18	Industrial Air Flow Dynamics
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28	Parker Hannifin
29	Mitten Manufacturing
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53	National Electric Coil
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104	Alta Solutions

7F USERS GROUP

Best Practices

The 7F Users Group returns to in-person conferencing Aug 23-27, 2021 when the world's largest assembly of GE F-class owner/operators gathers at the Marriott St. Louis Grand for the organization's 30th annual conference. Over 150 users and more than a hundred exhibitors are expected despite federal, state, and local rules tightly controlling the conduct of meetings during the pandemic. Recall that the 2020 conference, originally planned for May at the Fairmont Dallas Hotel, was presented online.

The technical program for this meeting is directed by an all-volunteer steering committee of industry engineers with deep 7F experience (Sidebar 1). Their companies have investments in more than 200 of these workhorse engines. Christa Warren of Tenaska Inc is the 2021 chair; Justin McDonald of Southern Company Generation is in the second seat. SV Events, headed by Sheila Vashi, manages the business side of the meeting.

1. Steering committee, 2021-2022

Chair: Christa Warren, *Tenaska*
Vice chair: Justin McDonald, *Southern Company Generation*
Luis Barrera, *Calpine*
Matt Dineen, *Duke Energy*
Bryan Graham, *Entergy*
Kaitlyn Honey, *Xcel Energy*
Riz James, *Dominion Energy*
Clinton Lafferty, *TVA*
Doug Leonard, *ExxonMobil*
Ed Maggio, *TVA*
Tim Null, *Eastman Chemical*
John Rogers, *SRP*
Terry Toland, *Clark Public Utilities*
Zach Wood, *Duke Energy*

Monday, August 23. The conference opens in the morning with tours of MD&A's Turbine/Generator Repair Facility, a short bus-ride away. RSVP is required for participation, as is a Covid temperature check and a mask. The afternoon "classroom" session, beginning at 2 p.m. Eastern US time, is sponsored by MD&A and includes presentations on the company's solution for 1-2 spacer cracking, gas-turbine alignment, component life extension, and thermodynamic analysis and performance testing. A welcome reception and dinner follow.

Tuesday, August 24. Introductory remarks begin at 8 a.m., with the Compressor Session next, from 8:30 to 11:30, featuring a user presentation on a Stage 5 vane failure. Safety Practices and Lessons Learned follows, with lunch scheduled for noon. Doors open for the afternoon session at 1 p.m. with a panel discussion on 7F Performance and Controls. Auxiliaries and Generator Session is next at 2:30.

Breakout Session One, from 3:45 to 4:30, features these concurrent presentations:

- *Advanced Technologies for 7F.03.* PSM.
- *7FH2 Generators: Crucial Spare Parts and Replacement Components,* AGT Services.
- *Turning Gear-Low Speed Drive and Maintenance,* Koenig Engineering Inc.

Breakout Session Two, from 4:45 to 5:30, features the following concurrent presentations:

- *7FA Rotor Lifetime Extension,* Ethos Energy Group.
- *Benefits of Electric Gas Control Valves and IGVs,* Young & Franklin.
- *Mitigation of Combustion Nozzle Failures on Dual-Fuel Turbine: Case Study,* JASC Controls.

A Vendor Fair, from 5:30 to 8:30, closes out the day.

Wednesday, August 25. The Auxiliaries and Generator Session, which started yesterday, concludes in the first half hour and includes a presentation on lube-oil detection software. The Combustion Session is next at 8:30 a.m. and features a presentation on in-situ fuel-nozzle flow testing before concluding at 10. The Turbine Session is last on the morning's agenda and contributes a user's experience with his company's first 7FA.05 hot-gas-path inspection.

The Turbine Session continues after the lunch break, concluding at 3 p.m. The Rotor Session is next, leading into the popular 7F Top Issues discussion session at 4. Breakout Session Three follows at 4:45, finishing at 5:30 to accommodate evening entertainment from 6 to 9. The three concurrent presentations in the day's breakout session are these:

- *Frame 7F Exhaust Frame Modifications and Upgrades,* Integrity Power Solutions.
- *Case Studies in Turbine Varnish Removal,* Chevron.
- *Hydrogen Auxiliaries: Best O&M Practices,* Environment One.

Thursday, August 26. This is GE Day. The eclectic and fast-moving program from 8 to 11 a.m. covers a wide range of topics, including the following: decarbonization, hydrogen, renewables, incumbent life extension, 7F fleet trends, FieldCore updates, reliability topics, Technical Information Letters.

Next is GE Breakout Session 1, which runs until lunch and offers three concurrent discussions: compressor, accessories, flexibility in simple and combined cycle. The hour-long interactive GE Breakout 2 hosts concurrent discussions on the turbine, controls, and performance troubleshooting, beginning at 1. GE Breakout 3 goes from 2:15 to 3:15 and covers the rotor, repairs, and "beyond the GT." GE Breakout 4 concludes the work day from 3:30 to 4:30 with controls and combustion, Generator 101, and ageing fleet strategies.

GE's social and open house promise a relaxing evening (RSVP required) from 6 to 9.

Friday, August 27. GE and the FieldCore team focus on outage conduct from 8 a.m. to 11:30, when the conference concludes. Topics include "Live Outage," making your outage better with LEAN, and outage planning.

Best Practices Awards

The 7F Users Group and CCJ are working together to expand the sharing of best practices and lessons learned among owner/operators of large frame engines. One of the user organization's objectives is to help members better operate and maintain their plants, and a proactive best practices program supports this goal.

Details of the 2020 entries judged Best of the Best appeared in CCJ No. 64, published last October. Recall that the plants recognized are the following: Hermiston Generating Plant, Green Country Energy, River Road Generating Plant, and St. Charles Energy Center.

Other entries in the 2020 program receiving Best Practices Awards are summarized on the following pages. They speak to work done by your colleagues at 13 7F simple- and combined-cycle generating plants (Sidebar 2). The more than two-dozen best practices are likely to offer one or more ideas for improving safety and performance at your facility.

The Best Practices Awards program for owners and operators of generating facilities powered by gas turbines celebrates its 17th anniversary in 2021. Over the years, more than 800 best practices entries have been received from more than 200 individual plants and fleets.

The most successful plant in the program's history is Effingham County Power, which has received seven Best of the Best awards. This year, General Manager Bob Kulbacki and his team share five best practices, beginning on p 22. Particularly noteworthy about Effingham's run is that it has spanned four owners, four plant managers, and several teams of judges.

2. 7F Best Practices Awards

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Rathdrum Power LLC.................44
Woodbridge Energy Center........14

Woodbridge Energy Center

Owned by Competitive Power Ventures
Operated by CAMS

725-MW, 2 × 1 combined cycle powered by 7FA.05 gas turbines, located in Keasbey, NJ

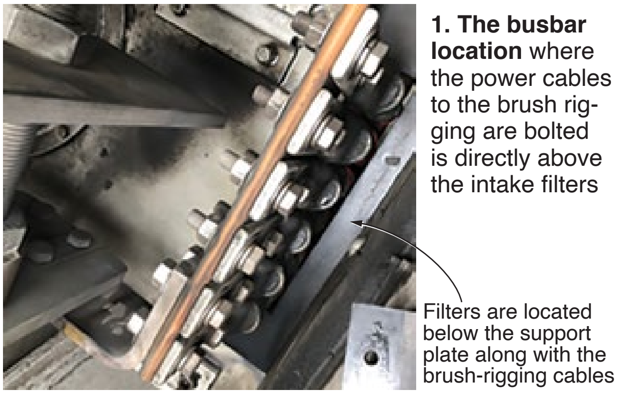
Plant manager: Chip Bergeron

Rearranging the collector air intake for better performance

Challenge. The GE D11-A steam turbine at Woodbridge Energy Center is an outdoor unit mostly unprotected from the elements. It is located about 40 ft above the condenser and associated balance-of-plant equipment and runs primarily baseload. The collector air intake filters for this unit were not safely accessible without locking out the exciter, regardless of whether the unit was online or offline.

Reason: The busbar location where the power cables to the brush rigging are bolted is directly above the intake filters (Fig 1). Plus, the collector air intake and exhaust were simply two holes cut in the concrete roughly 12 in. apart from each other (Fig 2). After a steam-turbine trip, caused by a collector ground fault during a heavy rain event, the collector's filters were removed and found caked in carbon dust. Plus, the collector was damp from the rain being pulled through the door seals by the vacuum created by the clogged filters.

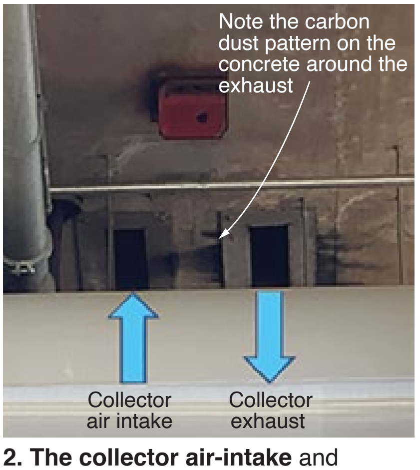
The week prior, an online ring grind had been performed which normally would not be a contributing factor except that the dust generated during the grind was being exhausted and then partially re-ingested by the collector filters. Plus, the filters, which are impossible to inspect or service with the plant online, also are subjected to an excessive amount of carbon dust from normal brush wear, because of the recirculation effect. These two issues eventually caused the aforementioned unit trip and maintenance headache.



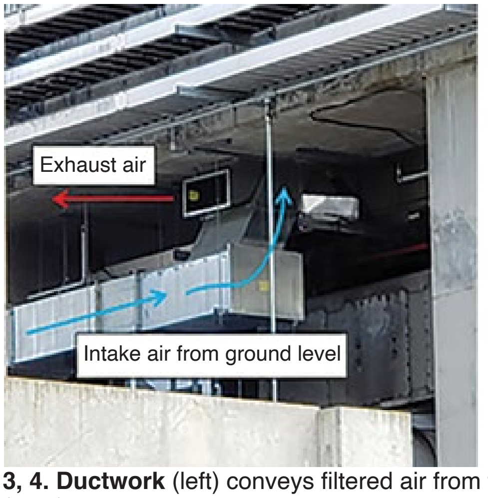
1. The busbar location where the power cables to the brush rigging are bolted is directly above the intake filters

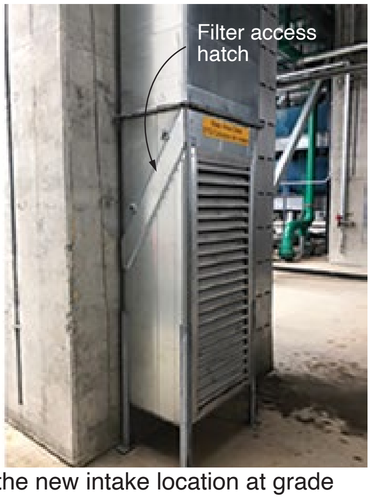
Solution. This two-fold problem was resolved by redesigning the air intake assembly. Specifically, ductwork was installed from the rectangular hole in the concrete that had been acting as the air intake, down to ground via a support column (Fig 3). Moving the air intake down to grade allowed staff to install new, and easily accessible, filters (Fig 4) that could be inspected and serviced with the unit online. Additionally, a 90-deg exhaust duct was installed over the existing exhaust port to direct any carbon dust well beyond the new air intake.

Results. With the filters relocated, the overall cleanliness level of the collector housing has improved dramatically and water ingestion is no longer an issue. This was most evident after the collector was inspected following



2. The collector air-intake and exhaust ports were in close proximity to each other





3, 4. Ductwork (left) conveys filtered air from the new intake location at grade (right) to the collector

a collector ring grind and found in near-perfect condition and free of carbon dust.

Additionally, the air intake filters have been removed, inspected, and cleaned several times with the unit online, without any issue. Lastly, the addition of a differential-pressure gage across the filters has further improved maintenance efficiency by giving the site team a real-time view of filter health.

Project participants:
Justin Hughes, production manager
Michael Armstrong, plant engineer

Doubling down on haz-gas analyzer reliability

Challenge. At Woodbridge Energy Center, major equipment is located almost entirely outdoors. When the site went commercial in 2016, it was one of the first to use a newly designed aspirated hazardous-gas detection system. It relies on instrument air and an aspirator to pull air samples from two different compartments on each gas turbine through dedicated LEL sensors.

These sensors have the capability to shut down the turbine should two in either compartment go into a state-of-alarm—that is, high LEL readings and/or a loss of sample flow through the LEL detector—at any given time.

Because the detection system is exposed to the elements, issues immediately began to arise with sensor stability on days when ambient conditions changed quickly. The issue was exacerbated when high winds were present. Sensor instability caused numerous false alarms which led to unit runbacks and in a few instances, trips.

Solution. Staff learned through testing that the factory-installed stainless-steel cover for the LEL sensors (Fig 5 left) was creating a thermal-sensitivity issue within the sensor itself. This was most evident during sudden rain events in the summer where the cover and sensor temperatures could drop by 20 deg F in a matter of seconds. That temperature drop was even greater (perhaps even 100 deg F) when the rain event occurred right after the sensor cover had been exposed to direct sunlight. Winter brought similar issues where the sunlight would warm the sensor but then high winds would cool it off rapidly and repeatedly.

5. Sensor with factory-supplied stainless-steel cover is at left; with plastic shield over the steel cover at right

To solve the problem, the steel cover required protection against the elements. Plant staff and the OEM decided the best option was to double up on the sensor covers. The factory-installed steel cover would stay as is, but a new plastic shield would be clamped around it (Fig 5 right). Plastic conducts heat very poorly and also blocks most, if not all, the rain and wind from reaching the steel cover.

Results. Since installing the secondary covers, performance of the 24 haz-gas detectors during weather events has been flawless. This simple and relatively inexpensive solution dramatically increased plant reliability.

Project participant:
Himansu Patel, senior technician

Color-coded plant drains expedite event response

Challenge. Woodbridge Energy Center, an outdoor facility, is boarded on two sides by wetlands. The site must properly capture and direct water from different sources—such as blowdown tanks, chemical containments, and various drain sumps. In order to perform this task, Woodbridge uses 128 floor drains and five sumps to direct water to two separate locations (cooling tower reuse or the local sewer authority).

Additionally, storm-water runoff is captured by large drains which empty to storm-water basins. Those basins then drain into a retention pond which discharges to the adjacent wetlands.

At face value, this is a typical configuration for outdoor powerplants; but Woodbridge was faced with a problem when it came down to how to properly react to an accidental release (chemical, oil, etc). Because the floor drains were not labeled, it would not be readily apparent (in the moment) what sump should be shut down to prevent the product from escaping to the larger systems and potentially the environment.

This was a significant concern because the sumps, which can only be shut down manually, could easily be several hundred feet away and/or obscured by a building or piece of equipment. Shutting down all sumps would be impractical and time-consuming. The site team had to develop a way to easily and rapidly identify what sump to shut down should a release event occur.

Solution. To expedite the drain/sump identification process, the site team developed a color-coded chart (Fig 6), which was broken down by sump. The color codes were then used to create permanent signs for each sump, calling out its name and discharge location (Fig 7). After the signs were in place, an identifying color-matched circle (Fig 8) was painted next to each drain. The color corresponds to the sump which the drain goes to. Now, if an accidental release occurs, the plant team will instantly know which sump to secure, saving precious time.

Results. Fortunately, there have not been any actual release events to test this new system under live circumstances. However, mock drills have been performed and the feedback from those drills has been highly encouraging and indicative of a dramatic decrease in incident response time.

Project participants:
Justin Hughes, production manager
John Szucs, gas turbine technician

Progress in driving towards cultural excellence

Challenge. As Woodbridge Energy Center entered its fourth year of



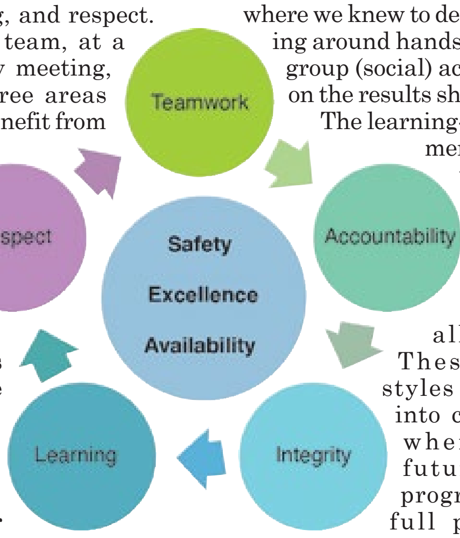
Sump designation	Discharge location
HRSG-1A sump	Cooling tower
HRSG-1B sump	Cooling tower
North plant drains sump	Oil/water separator
South plant drains sump	Oil/water separator
Auxiliary plant drains sump	Oil/water separator

6. Sumps, and the drains served by them, are color-coded

commercial operation, management wanted to focus on understanding how to reinforce the best elements of the plant's culture. The challenge the team faced was how to effectively gather and present information in a way that provided understanding and visibility of individual program elements and how they connect the team as a whole.

Solution. In November 2018, plant personnel were surveyed and asked to list their top five personal values and rank them in order of importance to themselves. The survey was anonymous to ensure that employees felt comfortable enough to put down their true top five. Once all of the results were collected, the responses were compiled, combined, and sorted in order to come up with the top five guiding values for the entire team.

For Woodbridge, those top five values were teamwork, accountability, integrity, learning, and respect. Results in hand, the team, at a December 2018 safety meeting, came up with the three areas they felt would most benefit from knowing our team values—safety, excellence, and availability. These were promoted on the graphic in Fig 9, which then was posted in various locations around the site (conference room, control room, etc) as a reminder of what we as a team use to guide and drive our daily decision-making.



9. Top five guiding values at Woodbridge surround the three areas that would benefit the most from them

During the six safety meetings in 2019, each of the five values was singled out and discussed in detail. The discussions focused on explaining what each value truly means to our team, how it applies to the work we do, and in most cases, a group activity or survey in order to continue building a positive work climate. Surprisingly, the deep dives on team values proved the most beneficial and rewarding part of the process.

This was particularly evident during the February 2019 meeting where the value of learning was highlighted.

7. Permanent signage for each sump has sump name and discharge location

Prior to the meeting, plant personnel were given a 70-question Learning Styles Survey and asked to answer each question from 0 (not like me) to 2 (exactly like me). Survey results were averaged across all 22 team members to create a radar plot (Fig 10) showing how the team learns best.

Using this information, we were able to cater to the remaining values discussions in a way that would be the most beneficial to the team. Example: A discussion around the value of teamwork where we knew to design the training around hands-on (physical) group (social) activities based on the results shown in Fig 10.

The learning-styles assessment allowed the team to design a teamwork exercise that encompassed the styles of all members. These learning styles were taken into consideration when creating future training programs for the full plant staff. This team-personalized approach to the values discussions, safety meetings, and training in general continued on through the remainder of 2019. It culminated in a year-end values survey to reflect on how this experience improved staff morale while creating a sense of ownership.

Results. After the values assessment on learning styles, the team was able to plan training for the remainder of the year that best met the needs of the plant staff. This intentional planning led to more successful training and higher concept retention. In addition, the remaining values that were focused on throughout the year were reflected on in the December 2019 safety meeting.

8. Drains have color circle to identify the sump to which is connected

A final anonymous survey was conducted to gauge how well the team felt that the Woodbridge team as a whole was doing in following the five values over the prior year.

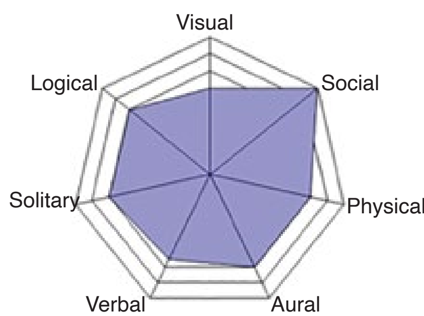
Survey participation was 100% and yielded interesting and positive results.

On a scale of 1 (strongly disagree) to 5 (strongly agree) the five values were scored and ranked. The average score for the five values was 4.06 with teamwork being the highest at 4.2 and accountability the lowest at 3.93.

While there was a feeling going into the survey that the results would be good, having an average score above 4.0 was beyond encouraging and showed just how much the team believed in this yearlong activity.

It also provided us with the knowledge that accountability, while having a very good score, is an area we can work towards improving in the coming year. Overall, the Woodbridge team was able to use the values survey to improve training throughout the year and continue to build plant morale based on what is important to everyone. CCJ

Project participant:
Justin Hughes, production manager



10. Radar plot shows how Woodbridge employees learn best

Newington

Essential Power Newington

Owned by Essential Power Investments

Operated by Cogentrix Energy Power Management

565-MW, dual-fuel, 2 × 1 combined cycle located in Newington, NH. Plant operated baseload from COD in 2002 until it began cycling in 2008

General manager: Tom Fallon

Rehabilitation of EHC fluid boosts starting reliability

Challenge. During a routine plant cycle/startup, the right-side HP steam control valve failed to open and allow steam to flow to the D11 turbine. The startup was aborted, the electrohydraulic (EHC) control system was secured by LOTO, and the servo valve controlling fluid flow to the valve actuator was replaced. Newington was restarted and the HP control valve responded as expected; plant operation was restored to "normal."

When the failed servo was shipped to Moog for rebuild, an in-depth failure analysis found what appeared to be a varnish-like substance on the nozzle top and flapper to the torque motor. An EHC oil sample was sent immediately to a certified laboratory for contaminant (varnish, water, metals) analysis, an estimate of the oil's remaining service life, etc.

Lab results: The deposits, originally thought to be varnish, actually were carbon. At the time of the servo failure, the EHC system included a kidney-loop varnish removal/filtration system. Site personnel, who relied on the fluid OEM for sample analysis (no charge), came to learn that the lab effort did not fully check the fluid for all required parameters. The only parameter that had dropped recently was resistivity and the reason for that was to be investigated.

Staff's first thought was to dump the oil and flush the system, which would have been extremely expensive.

Solution. Plant personnel embarked on a multi-faceted plan to review contaminated-oil sample results, discuss possible solutions with industry experts, implement corrective actions to mitigate system condition, and avoid a fluid change-out.

Site staff worked with Advanced Fluid Systems, a fluid-power solutions provider, and filter OEM Hy-Pro Filtration to develop the following approach for removing contaminants from the system:

- Change the EHC fluid filter media to eliminate sparking.
- Inject dry instrument air into the head space of the tank.
- Rent an electrostatic contamination removal skid to pull out the carbon deposits.
- Use improved oil analysis to monitor trends.

Also, a hydraulic fluid pump rep visited Newington to perform a system walkdown and make sure there wasn't some abnormality causing the fluid contamination.

Results. Following the EHC system changes, staff performed semi-monthly sample analyses to monitor trends in fluid cleanliness. With the results of the analyses showing improved fluid characteristics over time and the visual indication of the fluid becoming more transparent, staff knew the plant's approach was working.

By discussing Newington's problem with many industry experts, staff was able to get several opinions on what to look for regarding the source of contamination, which ultimately was carbon buildup. With expert input and the plant's commitment to finding a solution, staff was able to effectively clean-up the system and eliminate the need to replace the existing fluid.

This demonstrated to site personnel that by focusing on an issue and not letting the path of least resistance become your answer, you can effectively eliminate a problem long-term. Had we simply changed the fluid without performing the other steps in the process, carbon contamination would have reappeared in a matter of time.

Project participants:
Chad Harrison, maintenance manager
Tom Jamison, technician
Ted Karabinas, technician

PI tools help improve situational awareness, work processes

This best practice is divided into two different, but similar, business-challenge paths and targeted solutions surrounding the use of existing PI tools and control-room recordkeeping.

Challenges:

No. 1. Situational awareness and information-sharing is a best practice that should be used across multiple fronts. With regard to operational awareness and NERC compliance, Newington decided to further utilize the PI Notification Tool to automatically send e-mails to communicate several different key plant operational and NERC compliance conditions. PI Notifications included chemical tank levels, breaker operational counters, key equipment temperature monitoring, facility forced power oscillations, and NERC VAR-002 notifications.

Situational awareness for facility personnel is crucial to ensure timely and accurate response to changes in plant conditions. Understanding trends and future consequences are easily tracked using PI Notification tools at the facility level. These notifications are used for real-time monitoring, e-mail alerts, compliance requirements, and chemical-inventory reorder processing.

No. 2. CRO distractions are numerous and having the ability to reduce them is always a challenge. During the course of any major operational evolution—such as plant startup or shutdown—the ability to focus on the task at hand is extremely important. One of the requirements in any control room is log-keeping. For several years, the facility has used an electronic program called eLogger for this purpose, but entries in the database still required manual input.

In an effort to further reduce operator distractions, a new eLogger log-entry automation tool was developed, tested, and implemented by staff. The PI database was interfaced to the e-logger application, providing PI-generated log entries for key plant and equipment status changes, greatly reducing the amount of manual log entry required by employees.

Automating logging events is an extremely effective solution for removing distractions, yet still accomplish the record keeping needs of the facility. Automatic logging was setup for conditions such as blower or pump starts/stops, turbine starts/stops, etc.

Solutions:

No. 1. Newington personnel now are better tuned-in to operational and equipment status—including feedpump bearing trends, voltage schedule and Automatic Voltage Regulation (AVR)/Power System Stabilizer (PSS) status as required by VAR-002 requirements, chemical inventories for automatic notifications to chemical suppliers, breaker motor and cycle counters for equipment monitoring and forced megawatt oscillations. This allows multiple key personnel to be aware of conditions in the facility and increases the efficiency of many otherwise manual tasks.

Newington personnel created all PI Notifications based upon input from the operations manager on needed awareness tools. Several different notification categories were created, as noted above. Notification and alert levels were set up to track initial concerns and then, if necessary, any communication requirements based upon the condition.

No. 2. Using PI to communicate automatically with the eLogger database allows for a reduction in the hundreds of otherwise distracting manual logging tasks required by the operations staff. This drives better focus on the control system for operations to perform critical tasks while still completing certain required log-keeping "behind the scenes."

A plant employee designed and constructed the application necessary to allow the PI and eLogger databases to communicate continuously. The application monitors numerous PI tags for state changes then passes the event to eLogger, where a log entry is automatically generated.

Results:

No. 1. Currently, 10 notification elements are used by PI. Some look at real-time statistics, others at trends and future objectives necessary for compliance and equipment protection. To date, several notification e-mails have been used. They provide excellent awareness to plant conditions. Daily automated e-mails to the facility's boiler chemical provider from PI allow for automatic reorder tracking and awareness, eliminating the need for phone calls or e-mails to order chemicals.

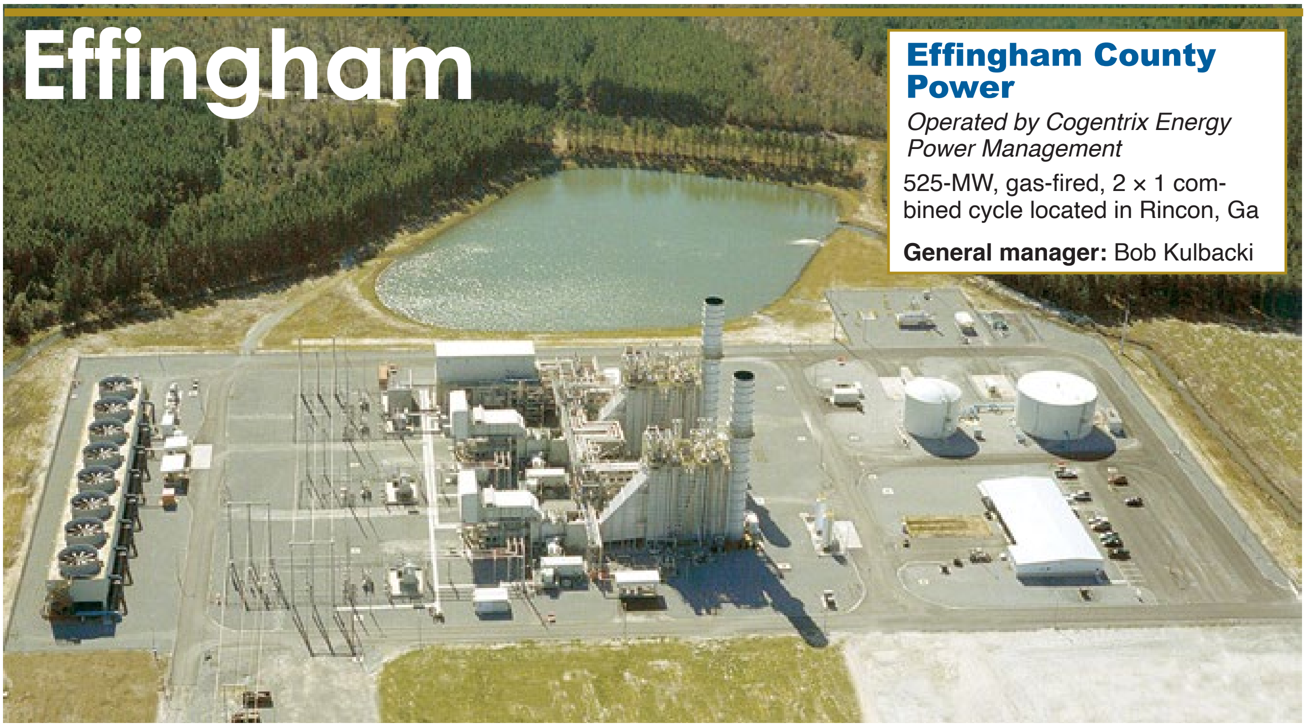
No. 2. There are currently over 60 different PI tags communicating with eLogger and recording as necessary. This list will be expanded continually based on need and efficiencies following input from others. Improved focus and attention on the control boards has been accomplished with reduced manual logging needs.

Both of these PI tools have proven extremely successful at Newington. Each has its unique success stories, but both ultimately provide excellent efficiency and awareness improvements to the site. Improving facility situational awareness and focus while reducing the many inherent distractions, and otherwise manual processes, is always a benefit. CCJ

Project participants:

Joshua Leighton
Tyler Engelhardt

Effingham



Effingham County Power

Operated by Cogentrix Energy Power Management

525-MW, gas-fired, 2 × 1 combined cycle located in Rincon, Ga

General manager: Bob Kulbacki

Maintaining fire protection during an outage

Challenge. Effingham County Power's fire protection system consists of one 2000-gpm motor-driven pump, one 2000-gpm diesel-driven pump, one 25-gpm electric jockey pump, and associated equipment and controls. The jockey pump maintains system pressure above the start setpoints for both fire pumps during no-flow conditions. Pressure switches automatically start the pumps when system pressure drops below the setpoints.

Power for the electric pumps and their associated equipment and controls is supplied from a common 480-Vac breaker housed in a switchgear with station service its only source of electricity. When the station-service transformer is taken out of service for maintenance, the two electric pumps are de-energized. Because the jockey pump is de-energized, it is unable to maintain system pressure above the starting setpoints of the fire pumps.

With the electric pump de-energized, the diesel unit will start once system pressure drops below its associated pressure-switch setpoint. When the diesel pump starts, it activates the plant-wide fire alarm; all staff and contractors must stop work and evacuate the plant when the alarm sounds.

Plant management needed a way to keep the fire main pressurized when the plant was on backup power and the electric fire pumps were de-energized.

1. When the station-service transformer is out of service, power is supplied to the jockey pump from an alternative source via the welding receptacle

2. Selector switch transfers electric supply for the jockey pump from station service to an alternative source connected to the welding receptacle

3. Jumper cable supplies a secondary source of power to the jockey pump when station service is not available

4. Jumper cable is ready for rapid-deployment in the event of a sudden loss in station service power

Solution. Plant personnel ran the diesel pump intermittently to maintain system pressure, to prevent erroneous fire alarms and work stoppage. This resulted in unbudgeted diesel fuel costs and excessive emissions, which could possibly lead to Effingham exceeding air-permit limits.

Plant personnel identified the nearest motor control center supplied by a backup source of power when station service was de-energized. The closest spare breaker was about 150 ft away and required extensive trenching to run supply cables to. But a welding receptacle, which has a secondary source of power, was located only 50 ft from the fire-pump building. Staff determined that the rating of the welding supply power was sufficient to operate the jockey pump.

The plant purchased a double-throw safety switch, one plug, and the necessary cable to connect the welding receptacle (Fig 1) to the switch located at the fire-pump building (Fig 2). Total cost of the materials to complete the project was $500. The two plugs were connected to the supply cable to make a jumper cable (Fig 3) to connect the welding receptacle to the fire-pump building.

During an outage, with station-service power de-energized, the switch was permanently wired to the jockey pump's primary power supply and one end of the temporary supply cable. Next, the temporary supply cable was connected to the welding receptacle. Then the welding receptacle was energized and staff swapped the jockey pump from normal to temporary power.

Results. The jumper cable is stored in the fire-pump building to ensure its availability at all times (Fig 4). Prior to securing station-service power, the jumper cable is connected to the designated welding receptacle. When station-service power is de-energized a technician energizes the welding receptacle and swaps the safety switch from normal to temporary power, thereby providing power to the jockey pump. Fire-protection integrity is maintained in this configuration because the diesel pump will start if system pressure drops below the setpoint.

With the jockey pump in service, spurious alarms and work stoppage have been eliminated. This project has been a cost savings because outage interruptions have been reduced and the need to operate the diesel pump intermittently to maintain system pressure is no longer required.

Project participant:
Russell Howell

Assuring voltage-schedule compliance

Challenge. The transmission operator has provided Effingham County Power four voltage schedules which change throughout the day: 0000-0600, 0601-1800, 1801-2100, and 2101-2400. Control room operators (CRO) are required to maintain the schedules within a ±2 kV band. In the past, the CRO ensured the plant was in compliance with the schedule by visually confirming the plant's "white line voltage" and adjusting the generator's output voltages accordingly.

To avoid operating outside the control band, a generic alarm was developed to alert operators. A narrower band was established but did not vary with the changes in the voltage schedule.

To prove to the regulatory agency that the plant was in compliance, staff developed a monthly comparison spreadsheet showing plant voltage and the allowable voltage band for each minute. This required manually inputting over 44,000 data points into the spreadsheet and reviewing to verify the information was correct.

The plant's output voltage values were populated into the spreadsheet from the DCS historian. Obtaining the necessary data for the control bands required review the shift turnovers for the past month and manually inputting these values. Once all data were entered, the spreadsheet was reviewed for compliance and saved for future audits.

Solution. The voltage schedule is determined by Georgia System Operations Corp under NERC standard VAR-002 and issued to the plant daily. If a change is made to the voltage schedule, the alarm will not change based on the current logic. This increased the potential for human error in keeping the plant operational within the established schedules.

To alleviate this issue, staff created a series of logics and graphics in our DCS (Emerson Ovation) that would allow the operators to select which schedule is currently in effect. This input is then compared to the time of day to generate the correct alarm band for the plant. The programmed alarm will alert the CRO if the plant's white line voltage deviates from the designated voltage schedule.

If the operator continues to operate outside of the required voltage schedule, a second alarm is generated notifying the CRO that the plant is still operating outside of the voltage range and that it is approaching compliance limitations.

The voltage schedule, control band, and time are new logic points designated in the DCS system. All values are fed into the DCS historian for retrieval as needed to show evidence of compliance to regulatory agencies. The need for manual data input has been eliminated, reducing human-error issues and saving time during monthly reviews of VAR-002 data.

Results. New graphics and logic have allowed both operators and management to ensure the correct voltage schedule is maintained. Additionally, the alarm points and trending capabilities have enabled Effingham personnel to accurately determine if the voltage schedule is consistently maintained for reporting requirements.

The monthly spreadsheet can be updated quickly and the plan can show compliance in the time it takes to retrieve the data from the historian.

Project participants:
Bob Kulbacki, general manager
Michael Sears
Jobie Seward

Relocation of grease fittings simplifies PM

Challenge. The original design of the inlet-chiller cooling-tower fan specified the location of grease fittings inside the fan enclosure, limiting accessibility to the fan bearings for maintenance (Fig 5). To perform bearing PM, technicians had to place a LOTO on each fan and post a confined-space permit before entering the enclosure to grease the bearings. The prerequisite steps to establish a safe work environment took approximately two hours for each fan, while greasing the bearings took only 10 minutes.

Greasing of fans typically occurred when the chiller was shut down, causing no loss of generation. But there were several instances when a fan required greasing when the chiller was online. In these cases plant output was reduced by about 2 to 3 MW.

Technicians were tasked with finding a more efficient and safe method for performing this PM.

Solution. The best option discussed was to locate the grease lines on the outside of the fan enclosure (Fig 6). This would eliminate the need to secure the fan and issue a confined-space permit. Staff purchased the ¼-in. stainless-steel tubing and fittings

5. Old grease fittings required LOTO for access

6. New fittings allow the operator to grease the fans and their motors without ever coming in contact with moving parts. No LOTTO required for normal PMs

7. Grease is supplied to the bearings (lower at left, upper at right) via flexible hose

required for about $500.

The remote fittings are attached to the bearings using the ¼-in. lines; flexible hose supplies grease to the fan housing platforms (Fig 7). A hole was made in the metal housing, and a zirc fitting mounted on the housing, to allow remote greasing.

Results. Technicians now can grease the chiller cooling-tower fan bearings when the fans are operating. This will help prevent bearing damage, and when an abnormal noise is detected, a technician can quickly apply grease to ensure proper lubrication.

The amount of time saved when performing the greasing PM allows the technician to perform additional work within the plant. Overall, the results are a more timely completion of the PM and improved fan reliability.

Project participants:
Howard Beebe
Mark Gunter

Split bearing facilitates bearing replacement

Challenge. One of the chiller cooling-tower fan bearings failed, resulting in the loss of tower cooling efficiency and of plant output. Because the fans are located 42 ft above grade, and the fan assembly is about 8 ft across, replacing the bearings without use of a crane would not be safe, or technically possible. With a crane it would take two days to remove the fan, replace the bearings, and reinstall the fan—with an out-of-pocket cost of about $3200.

The maintenance team was charged with finding an easier and less expensive way to replace the bearings.

Solution. The team researched alternative solutions for replacing the OEM's single-piece bearings and opted for using slightly more expensive split bearings of the same rating, which would not require fan removal. Another benefit of the split design: Less time to replace a bearing by a factor of four—4 hours versus 16 for the original.

The initial installation of a split bearing was time-consuming, and the limited work area made it difficult. One reason: The mounting holes for the split bearings were not a direct match to those for the OEM's bearings, so the mounting base required modification. Additional attention also was required to maintain correct shaft alignment to ensure proper fan operation.

Crews were rotated during the installation to keep everyone fresh and working safely. The new bearings were installed without incident and the plant has had no issues since the fan returned to service. Over time, as OEM bearings fail from wear and tear, they will be replaced with split bearings.

Results. By transitioning to split bearings the plant was able to return the equipment to service sooner than anticipated, increasing plant output. Plus, the new bearings eliminated the need for a crane, saving $3200.

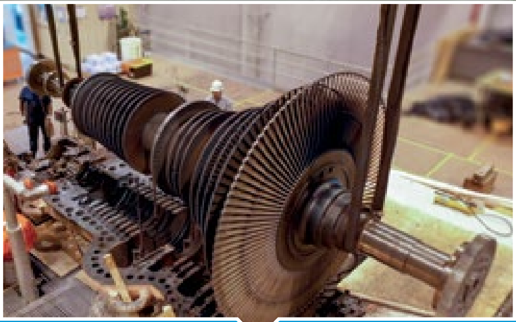
Project participants:
Sean O'Neill
Paul McKuhen
Russell Howell

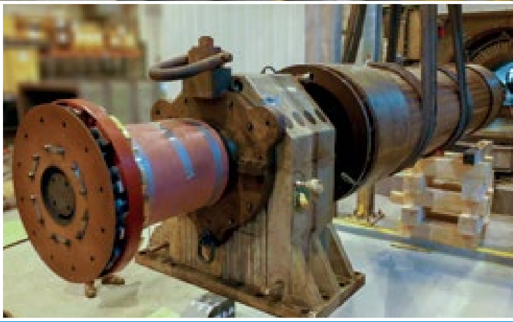
Squeezing a new air compressor into existing space without a forklift

Challenge. A compressor failure left Effingham County Power with only one source of compressed air. If the remaining compressor were to fail, plant production would be lost. A rental compressor was brought in to mitigate risk. However, the rental did not have auto-start capability, so it was unclear if this unit could be brought online fast enough to prevent a loss of control air, without which the plant would be forced to shut down.

A new compressor was ordered and quotes were received to remove the old unit and install the new one. Quoted cost for removal and installation was more than $11,000.

The maintenance crew was challenged to find a more cost-effective and safe method to replace the plant air compressor.





Solution. Team members responded with a more efficient and inexpensive solution. The air-compressor room configuration made it unfeasible to remove a wall, or the roof, to make the switch. The size and weight of the compressor was a consideration when planning the replacement (Fig 8).

The limited space in the compressor room did not allow for the use of a forklift or other powered equipment. With building modifications unacceptable, team members decided to roll out the old compressor and roll in the new one using caster rollers and jacks. Four caster rollers rated for 17,600 lb each, and two jacks rated 40,000 lb each, were purchased ($600) for the task.

The old compressor was lifted using the bottle jacks and placed on channel iron supported by the four swivel caster rollers. This allowed maneuvering the compressor in the restricted space. The old unit then was rolled out of the compressor room and the process reversed to install the new compressor. With the new unit in place (Fig 9), plant personnel completed the installation of the required ductwork plus all control and power terminations. The compressor OEM commissioned the unit.

Results. The exchange of air compressors was completed safely in about 32 man-hours at a cost of $1100. But the cost saving of performing this task in-house was only one benefit. Another was the experience gained by plant personnel, as well as the increased level of reliability that the new compressor added to Effingham. The tools purchased for this project will be reused in changing out the second air compressor as well as other limited-access projects in the future. CCJ

Project participants:
Sean O'Neill, Paul McKuhen
Russell Howell

8. The new compressor, 89 × 54 × 76 in. high and weighing nearly 5500 lb, is lifted (left) to allow the placement of four caster rollers (right) for maneuverability

9. Tight squeeze moving the new compressor into existing space

Pesqueria

Central Eléctrica Pesquería (CEP)

Owned and operated by Techgen

900-MW, 7FA.05-powered 3 × 1 combined cycle located in Pesquería, Nuevo León, Méxicó

Plant manager: Mario Ontiveros

The benefits of lean-outage planning, execution

Challenge. Following the plant's first hot-gas-path (HGP) outage in 2018 (COD December 2016), personnel met to discuss the pain points identified during the work just completed. These were considered opportunities for improvement in the facility's outage planning and execution process. The challenge was to reduce the time of scheduled outages and to optimize resources by ensuring the integrity of people and equipment.

The following were the pain points identified:

- Scaffolding installation.
- Installation of electrical panels, hoists, and compressors.
- Removal of blades and nozzles.
- Lifting and dismantling of package roof.
- Disassembly and reinstallation of turbine electrical instrumentation and wiring.
- Work-permit release process.
- Lotus application.
- Onsite coordination and supervision.
- Dead times and communication.

Solution. Goal was to control the pain points to reduce the time of scheduled outages and optimize resources, thus ensuring the integrity of people and equipment. The methodology selected was "Lean," which focuses on quality assurance, time reduction, resource optimization, and effective communication. The implementation of this methodology was led by the engineering department with support from the O&M department and an external consultant. The rigor applied to outage planning and execution is evident from the details on view in Fig 1.

Results included the following:

- A visual scaffolding installation plan was implemented and strategic scaffolds were assembled prior to turbine disassembly.
- An installation plan was implemented for electrical panels, etc. Previously, the equipment was installed and tested.
- Scaffolding was designed and installed to allow work in tandem in the disassembly of turbine elements and combustion chambers.
- A lifting plan was implemented to disassemble the entire roof, previously disassembled in sections. Plus, pre-location of mechanical lifting elements for easy availability.
- A plan for disassembly and reinstallation of turbine instrumentation and wiring was implemented.
- The schedule developed had no tolerance for the release of work permits in a critical route. A paramedic was added to the outage crew. Safety talks for personnel and contractors were held daily.
- Execution staff was reorganized to assign a higher percentage of personnel to the activities on the outage critical path. The most experienced personnel were assigned to coordinate and supervise critical-path activities.

Perhaps most important was that there were no disabling accidents during the HGP outages. Plus, the execution time of the second and third HGPs was reduced by 15% compared to the first outage, which lasted 19 days. Quality standards were maintained and there were no problems during and after the outages. Finally, GE recognized the outage team as the best in Latin America based on the results of the second and third HGPs.

1. Outage planning and execution were conducted from this "war room"

Project participants:

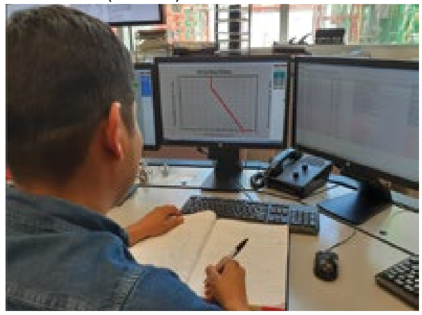
Arturo Gonzalez, technical control chief

Odon Acosta, maintenance chief

Francisco Espinosa, technical control engineer

Mario Ramirez, operations chief

Plus, the entire O&M Team



2. Piping is installed to inject cooling air in the HP and IP stages of the steam turbine (left)

3. Temperature differential between the HP and IP zones is monitored in real time (below)

Optimizing the steam-turbine cooling process

Challenge. Develop a methodology to cool the steam turbine in the shortest time possible to conduct minor maintenance while adhering to the manufacturer's cooling curves and delivering the output required to satisfy contractual obligations. Plant had determined previously that this could be accomplished by operating one of the three gas turbines baseload at 210 MW and the other two in temperature matching for nine to 12 hours.

Solution. Plant staff sought an alternative method that allowed the steam turbine to cool down without using temperature matching, without dropping below the 400-MW minimum contractual load, and without affecting the outage critical path.

Working together, plant and OEM personnel determined that dry-air cooling was the optimal method. It maintained turbine integrity, did not adversely impact the cyclic life of the rotor and housings, and did not affect the housings or the critical path of the outage.

The method consists of injecting a regulated amount of air gradually into the HP and IP stages of the turbine while assuring that the temperature differentials between the stages were not so great as to stress the rotor.

Pesqueria's operations department coordinated preparations with GE. Together they implemented the mechanical arrangements for the air supply (Fig 2) and conducted real-time monitoring of the temperature differential between the HP and IP zones (Fig 3). Goal was to cool the unit to the point where the turning gear could be shut down.

Results. The plan developed was successful, allowing cooling of the steam turbine while generating more than 400 MW during the outage without incident. About 30 hours of turbine operation were gained using this procedure in place of the previous (standard) method.

Project participants:
Mario Ramirez, operations chief
Jeisson Villanueva, operations shift coordinator
Juan Carlos Facio, mechanical coordinator
Aldo Martinez, operations coordinator
Plus, the entire O&M Team

Water treatment plant

Pesqueria's water treatment plant (WTP) treats Monterrey waste water for use in the facility's cooling tower, evaporative coolers, and other systems. The WTP has a sulfuric-acid dosing system for the control of clearwell pH and for use in the wash-water, zero-liquid-discharge, clean-in-place, and ultrafiltration systems. Plus, it is used in WAC (weak acid cation) regeneration.

The sulfuric-acid dosing system provides about 170 tons of acid monthly. It has a nominal 5500-gal storage tank, and a distribution and pumping system that includes 11 diaphragm-type positive-displacement acid pumps.

Redesign sulfuric-acid dosing system to eliminate leaks

Challenge. Since commissioning, Pesqueria's sulfuric-acid dosing system for water treatment (sidebar) had leaked frequently—typically three or four leaks per month totaling up to about 5 liters of acid—jeopardizing the integrity of personnel and equipment. The challenge was to address the root causes of the problem and correct them.

Solution. A project team was formed from Techgen O&M and contractor personnel and led by the water treatment plant (WTP) operations manager. The existing problem was analyzed and an action plan developed with these proposed changes and improvements:

- Change all the PVC suction and discharge hoses for the diaphragm pumps to PVDF (polyvinylidene fluoride) pipe, known for its chemical resistance.
- Upgrade pipe to Schedule 80 from Schedule 10.
- Install a strainer filter with blocking valves to prevent fouling of pump check valves, thereby reducing the exposure of personnel to the risk of intervention.
- Change the type and model of connectors in pump suction and discharge lines.
- Install an atmospheric respirator (resin) in the tank to prevent entry of moisture.
- Install electrical trace and insulation to the distribution pipe.
- Increase the frequency of verification of acid installations.

Results. All the improvements noted above, and a few others, were implmented successfully. No acid leakage event had been identified at the time this best practice was developed 1500 hours later. CCJ

Project participants:
Luis Melgarejo, chemical chief
Antonio Torres, security and environmental chief
Odon Acosta, maintenance chief
Marco Lopez, WTP operator
Rolando Goytortua, WTP operator
Mauricio Guerrero, security supervisor
Juan Carlos Facio, mechanical coordinator

Plant Rowan

Owned and operated by Southern Company (Southern Power)

985-MW, gas-fired, one 7FA-powered 2 × 1 combined cycle and three simple-cycle units located in Salisbury, NC

Plant manager: Chris J Lane

Training videos promote shop safety

Challenge. Following an extensive maintenance-shop overhaul and retooling at Plant Rowan, staff was challenged by management and the site safety council thusly: How do we ensure everyone operates and maintains the equipment according to our company safety policy, common industry practices, and manufacturer equipment procedures?

Plant operators may only use a certain piece of equipment infrequently—such as during outages. The lack of daily use concerned staff because proficiency conceivably could be lost during periods of low maintenance.

Solution. The management team, together with the site safety council, provided direction for the creation and implementation of a series of Just-in-Time (JIT) "refresher" videos. A primary goal of the effort was to keep the videos short, each averaging only about five to six minutes per piece of equipment, but including as much information as possible.

The belief was that in this amount of time an experienced operator could demonstrate safe and effective operation or maintenance of a given piece of shop equipment with adherence to all company safety policy and equipment procedures. Equipment covered included pedestal bench grinders, horizontal band saw, drill press, various machining coolant systems, etc.

No narration was used; narrating the videos was deemed time-prohibitive at Plant Rowan. Instead, video editing software was used to add detailed on-screen "pop-ups" during final editing. This included pertinent information and hazards at each step of the equipment's operation. Examples: When PPE is required and what type; tips for safe operation; hazards and examples of improper operational practices, etc.

Once completed, the videos were loaded on a 40-in. wall-mounted LCD monitor located in the maintenance shop for anyone to access prior to equipment use and as part of their pre-work job safety analysis.

Representative examples relating to the video on dressing a fouled pedestal grinder wheel are presented in Figs 1-4. Fig 5 shows Plant Rowan's shop safety desk with monitor for viewing JIT videos.

Results. There have been significantly fewer occurrences of improper tool/equipment use—such as non-ferrous metal fouling on bench-grinder wheels, prematurely worn metal band-saw blades, and less wear and tear on equipment. There also have been no safety issues. CCJ

Project participants:

Shaun R Lynch, operations technician III

Dan Leone, maintenance team leader

Rebecca Young, compliance team leader

1 – 4. Non-ferrous metal fouling is observed on grinder wheel in Fig 1. Dressing is illustrated in Fig 2 and in close-up in Fig 3. Job is complete in Fig 4

5. Shop safety desk (right) has monitor for viewing JIT videos

Protect plant personnel, visitors with machine guards

Bastrop Energy Center
Owned by Blackstone
Operated by NAES Corp
550-MW, 7FA-powered 2 × 1 combined cycle located in Cedar Creek, Tex
Plant manager: Kelly Fleetwood

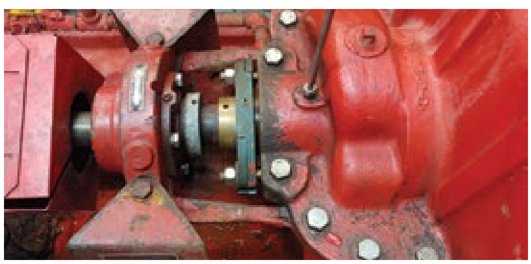
Challenge. Protect operators and others against injuries caused by exposed rotating shafts with machine guards.

Solution. Machine guards are your first line of defense against injuries caused by rotating equipment. Each machine must adequately protect from injury employees and contractors in the immediate work area. Bastrop Energy Center identified a potential hazard with the diesel- and motor-driven fire pumps. The shafts on both sides of the pumps were exposed, creating a potential hazard (Fig 1).

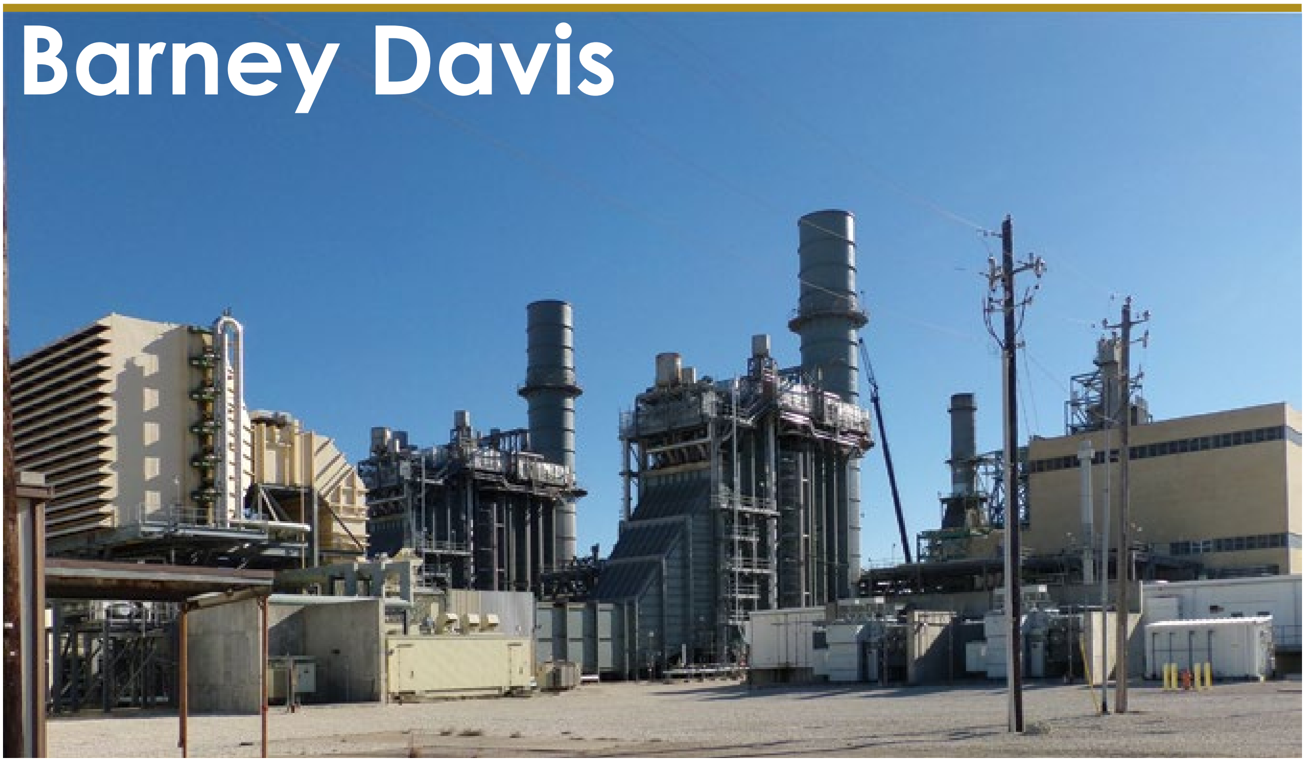
Plant personnel fabricated machine guards to cover the exposed areas (Fig 2). Expanded metal guards were used so visual inspection of the packing follower and lubrication of the bearings were possible.

Results. The machine guards installed have protected staff, contractors, and visitors from possible injury.

Project participants:
Brad Miller, lead maintenance technician
David Henderson, mechanical maintenance technician



Barney Davis



KPI index for water chemistry

Challenge. Improve plant water chemistry.

Solution. Barney Davis Energy Center implemented an EPRI-recommended water-chemistry KPI (key performance indicator) index. The plant's original analyzers were updated and more instruments were installed. Two dissolved-oxygen analyzers were added, plus one sodium analyzer; four silica analyzers were replaced (Fig 1).

All of the new analyzer readings were added to the DCS. KPI index recommended-action alarms, Levels 1 and 2, were added to the DCS in accordance with EPRI recommendations. An action plan was developed to guide operators when an alarm level is reached.

1. Upgraded and expanded panel/instrumentation underpins the KPI index developed for tighter control of water chemistry

When conducting water-chemistry tests with manual grab samples, the number of samples and tests performed increased. Grab-sample data added plant rounds documentation which is imported into the data historian via a hand-held device.

Results. After readings are entered and uploaded they are imported to an Excel file where the KPI scoring system is applied. It gives the plant an indication of where it needs to go regarding water chemistry. The score sheets are archived to allow quick reference to previous scores and to identify developing trends.

Project participants:
Jay Langley, plant manager
Garrick Alexander, O&M tech
Chris Nelson

Replace haz-gas detector without compartment entry

Challenge. Make replacement of turbine-compartment hazardous-gas detectors safer by eliminating the need for personnel entry into the compartment to perform this task. The compartment is extremely hot immediately following shutdown and requires cooldown to allow entry. Also, scaffolding is required to access the compartment ceiling. All this takes time and costs money.

Solution. The modification described here makes replacement of haz-gas detectors easier and requires little downtime, primarily because no scaffolding is required. Detector replacement, which takes place from the roof, can be performed in a few minutes—during an overnight shutdown, for example, without impacting unit availability (Fig 2).

When a detector must be replaced and the unit has been removed from service the change can be made. Following completion of site LOTO and safety procedures, the rail that contains the bad detector can be unbolted by removing four small bolts. Simply disconnect the calibration gas compression fittings and remove the rail. The flex conduit allows rail removal and its placement on the roof.

Steps:
- Gain access to the bad detector conduit LB and cut the wire.
- Disconnect and remove the remote

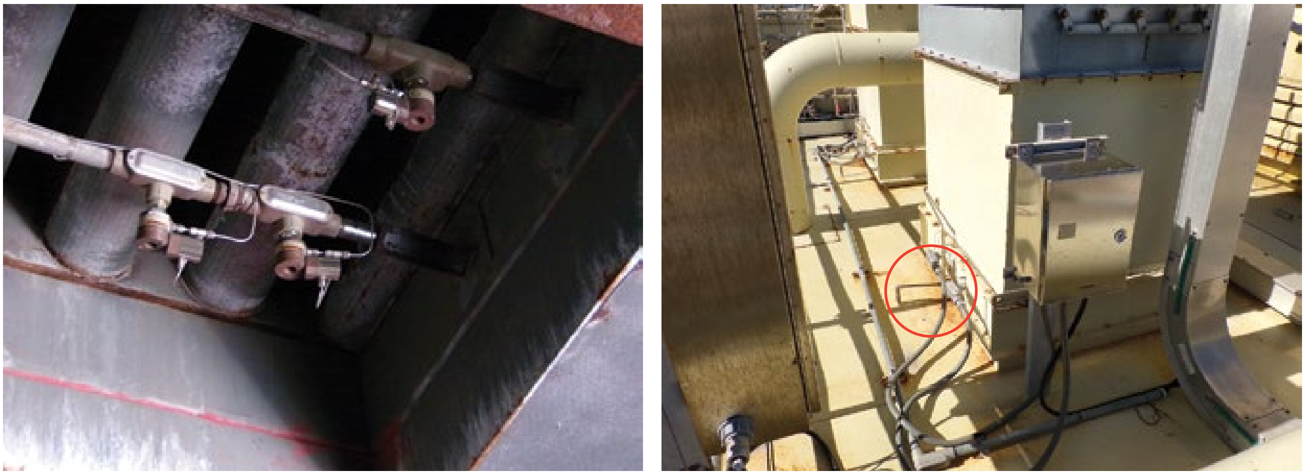
Barney Davis Energy Center

Owned by Talen Energy

Operated by Consolidated Asset Management Services (CAMS)

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

Plant manager: Jay Langley



2. Haz-gas detectors (left photo) can be accessed from the compartment roof (circle in photo at right) where the analysis equipment is located

calibration-gas assembly.

- Remove the bad detector.
- Insert wire for new detector into the conduit fitting and feed through to conduit LB.
- Attach wire of new detector to existing wire and pull through the conduit—all the way into the main junction box.
- Verify detector tightness and reattach the cal-gas assembly; verify tightness.
- Reinstall rail, making sure it is resting in the cradle.
- Reinstall the small bolts and tighten.
- Reconnect cal-gas fittings.
- Connect new detector to the terminal block.
- Calibrate new detector.

Results. The process to change out a detector went from 24 hours to 20 minutes. The cost dropped by several thousand dollars because scaffolding is no longer required for access. Employee safety also improved because staff is no longer exposed to the high compartment temperature. CCJ

Project participants:
O&M technicians Garrick Alexander, Chris Soliz, MacKenzie Mackey, and Lance Jones

Calhoun Power Co

Owned by East Alabama Generating LLC

Operated by Consolidated Asset Management Services

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

Plant manager: Mike Carter

Safety enhancements

Challenge. Reinforce the safety culture at Calhoun Power Co by making ongoing enhancements to plant systems that protect site personnel and visitors.

Solution. Plant personnel recently completed these two safety enhancements:

- Pipe extension to facilitate access. Prior to this mod, technicians would have to complete a confined-space permit to pump out the contents of the drain tank shown in Fig 1. Extension of the drain line allows staff to reach behind the handrail to connect the vacuum truck, eliminating the need to enter the space.
- Eliminate need for a ladder. Prior to the installation of the safety platform shown in Fig 2, technicians needed a 4-ft ladder to reach over the closed-cooling-water pipes to access the generator belly-pan level switch requiring a monthly test. It was a challenge to access the switch without stepping on the pipe shown. The Calhoun team brainstormed and came up with the platform idea shown.

Results:

- The pipe extension allowed pump-out of the drain tank without need for entry into the confined space, thereby eliminating the permit requirement. Time was saved, and safety enhanced, by not having to enter the pit area.
- The platform negated a safety hazard and provides easy access to level switch. CCJ

Project participants:
Mike Carter, plant manager
Neil LaMantia

1. Pipe extension promotes safety by eliminating the need to enter the pit to pump out the tank

2. Staff-designed platform provides access to level switch without need for a ladder

Hunterstown

Hunterstown Generating Station

Owned by Platinum Equity
Asset management by Competitive Power Ventures
Operated by NAES

810-MW, 7FB.04-powered 3 × 1 combined cycle located in Gettysburg, Pa

Plant manager: Tom Hart

Attention to leaking valves slashes water use

Challenge. Identify leaking valves and schedule repairs to improve heat rate and reduce steam and water losses in the cycle.

Solution. A vendor was contracted to perform valve leak surveys beginning in late 2016; observations over time indicated losses from leaking valves.

From 2017 to 2019, many valves were tested and numerous large-to-medium leaks were documented. Valve repairs and replacements were planned in advance and implemented during several outage cycles. Cost savings have been documented through a reduction in demin water production each year. Secondary surveys were performed to verify repairs and cost savings. Heat-rate improvements were achieved but not calculated for this report.

Results. Cost of demin water production dropped by $100,000 over two years while capacity factor increased by 8.3% during the same period.

Project participants:
Tom Hart, plant manager
Noah Matesa, maintenance manager

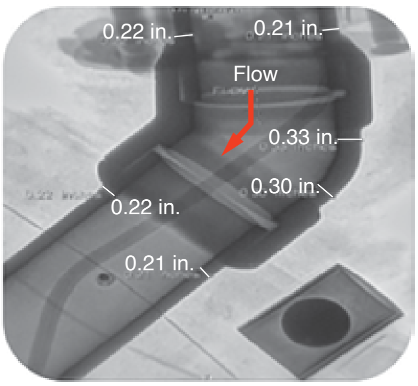
NDT program eliminates forced outages caused by steam-drain failures

Challenge. In 2016 and 2017, Hunterstown experienced eight unplanned outages to repair drain-line leaks caused by steam erosion. These outages represented 18 days of unavailability in the two-year period. The challenge was to eliminate forced outages related to steam leaks from drain-line fittings and to reduce the cost of necessary repairs.

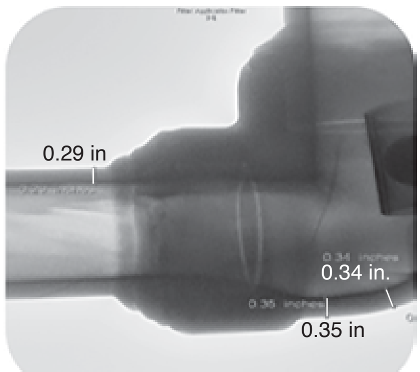
The leaks occurred most often during startup and shutdown operations and presented potential hazardous situations to personnel because of their locations. Repairs were unplanned which greatly increased cost. Scaffolding often was required to access the leaking drain line for insulation removal and weld repair.

Solution. Here's the plan developed to achieve the desired result:

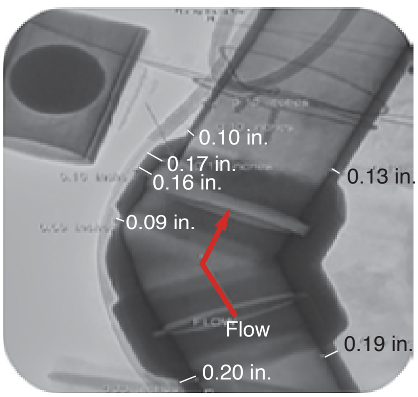
- Reviewed work-order and weld-log histories to identify the most frequent recurring failure locations—HP and IP continuous blowdown drain lines. These lines are characterized by large differential pressure gradients and two-phase flows which accelerate pipe-wall erosion rates.



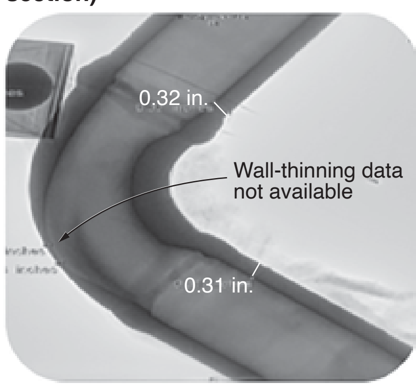
1. Normal elbow



2. Sidewall thinning (downstream section)



3. Elbow thinning (early)



4. Elbow thinning (advanced)

- Created prioritized inspection plans for HP and IP continuous-blowdown drain elbows. Plans included drain-line isometric drawings showing elbow IDs based on upstream MOV tags. Elbow IDs were sequentially numbered in the direction of steam flow to more easily track x-ray inspection images and reports, and to build a tracking spreadsheet for repairs.
- Reviewed scaffolding estimates of up to about $100,000 to support the NDT effort. However, the selected vendor offered an alternative access plan that eliminated the need to install scaffolding, thereby reducing overall cost of inspecting the drain valves to about $40,000.
- Radiographed the targeted drain-line elbows during normal plant online operation periods, to the degree possible.
- Performed digital radiography on small-bore drain elbows without removing insulation or lagging by using larger receptor panels to capture the entire elbow and part of the downstream piping in single-exposure shots (Figs 1-4).

Results:

- All areas were inspected and repair work was planned for the 2019 spring and fall outages. This eliminated all unplanned outages attributed to HP and IP steam-drain-line fitting failures.
- Rope access eliminated the need for scaffolding to access the various drain lines in the pipe racks, saving about $60,000.
- Radiography eliminated the need to remove insulation required by other types of NDT.
- Weld repairs were scheduled well in advance of planned outages and before failures occurred, reducing cost.
- Cost to date for this project at the time the best practice was prepared was about $85,000 (total over several years). There was no spending for scaffolding and insulation removal, which often are associated with such projects.
- Eliminated the safety risks of steam leaks near personnel access areas during startups when drains are open.

Project participant:
Noah Matesa, maintenance manager

Maximize GT generation with evap coolers in service

Challenge. Maximize operation of gas-turbine evaporative coolers (Evaps) while permissives for automated operation were established.

As the plant was designed, operation of the Evaps required the CRO to recognize the need for more power and manually start/stop the coolers from the HMI.

Solution. Implement control logic to automate starting and stopping of the Evaps based on the following inputs:

- Ambient temperature.
- Inlet temperature.
- IGV angle.
- Inlet bleed heat (off or on).
- Evap sump level.

Results. After identifying permissives to allow automated Evap operation, control logic was installed to stop/start the coolers. This change maximized operation of the Evaps while permissives were satisfied. In 2018 Evaps operated 67% of the time permissives were satisfied; in 2019, 80%.

This represents a gross-margin increase in 2019 of approximately $41,000, compared to operating without evap-cooler automation, based on an $11 spark spread for 3 MW per unit. The cost of implementation was about $16,000 for a first-year gross-margin increase of approximately $25,000.

Project participants:
Tom Hart, plant manager
Noah Matesa, maintenance manager

Transitioning from CO_2 bottles to bulk storage

Challenge. When generator purges were needed, Hunterstown relied on portable 160-liter CO_2 bottles. Pressure in the bottles decreased over time (outdoor storage, exposed to sunlight), rendering the bottles minimally effective. Multiple bottles were required to complete a singe purge.

Plus, time-consuming operator manipulation of the bottles was needed to complete each purge. Staff had to transition between units and the CO_2 storage facility and to secure spent bottles and line up new ones. Such maneuvering was critical during emergency generator purge situations because of the time required to begin flowing CO_2 to a generator. On more than one occasion, nearly 30 minutes elapsed between the time a purge was started and gas began to flow.

Solution was simple: Install a bulk storage system. Key components are the following:

5. CO_2 bulk storage system holds enough gas for 10 generator purges

- Storage tank with a capacity of 1550 gal (Fig 5).
- Electric vaporizer to convert liquid CO_2 to vapor to prevent two-phase purge flow.
- CO_2 condenser to convert excess vapor back to liquid, thereby preventing tank losses to atmosphere.
- Safety shutoff device to ensure liquid CO_2 cannot reach the generators.
- Instrumentation for tank level and pressure with data routed to the DCS to monitor consumption rate and to reorder CO_2 when necessary.

Results. Cost of the bulk storage system, installed in February 2020, was less than $350,000—including equipment, engineering, installation, and commissioning. Bulk storage eliminates bottle demurrage charges of about $11,000 annually and simplifies operator actions to start CO_2 flow, saving several minutes over the bottle alternative.

Expectation is that the four units on site can be purged twice before a refill is needed, while retaining sufficient gas for two more unit purges (total of 10). CCJ

Project participant:
Noah Matesa, maintenance manager

Marcus Hook

Marcus Hook Energy Center

Owned by Marcus Hook Energy LP
Operated by GE

813-MW, 7FA DLN2.6+ powered 3 × 1 combined cycle located in Marcus Hook, Pa

Plant manager: Frank Meade

Upgraded stack for cooling-tower fans facilitates maintenance

Challenge. Marcus Hook Energy Center has a 12-cell mechanical-draft counterflow cooling tower with multi-speed fans. Blade-tip-to-stack contact was causing wear on both components. The original stack was made of molded fiberglass, with only vertical ribbing (Fig 1). It was constructed in sections through-bolted together on the inside. If hardware loosened while in operation, a confined-space entry and extensive scaffolding would be required to replace or tighten.

Solution. The new stacks have ribbing in both the vertical and horizontal directions, making this design less susceptible to flexing and reducing the probability of blade-tip-to-stack contact. This also lessens the chance of hardware coming loose. The new stacks connect sections with a completely exterior face-to-face flange (Fig 2), allowing the tightening of all hardware from the outside. This contributes to safer, less expensive, and more effective routine maintenance.

Results. Increased fan-stack rigidity allows use of gear reducers with standard output shafts—typically more readily available and less costly than the original gear reducers. This allows the blades to be located lower in the stack—hence closer to the sidewall—increasing cooling efficiency by decreasing tip vortex. The plant has replaced several of the OEM stacks with the improved design and will continue to do so over the next few years until all cells are retrofitted with the new stacks (Fig 3). CCJ

Project participants:

Keith Vickers, GE Gas Power, maintenance specialist
Chris Mahalik, FieldCore, Maintenance production technician
Brian Mozzoni, FieldCore, Maintenance production technician

1. Original stacks were made of molded fiberglass, with sections bolted together on the inside

2. New stacks have hardware on the outside, making for easy maintenance access

3. Stack replacement is relatively easy

Elwood

Ensuring quality service by OEMs during gas-turbine outages

Elwood Energy
Owned by J-Power USA
Operated by NAES Corp
1350-MW, gas-fired, nine-unit, 7F-powered peaking facility located in Elwood, Ill
Plant manager: Joseph Wood

Challenge. How does a powerplant manager ensure the OEM delivers quality work during turbine/generator outages? Here "quality" is defined as work safely completed with no rework required. Even with a strong contractual services agreement, an OEM's failure to deliver the job correctly the first time can be a lose/lose situation for the owner and OEM.

Powerplants may no longer have the talent available to adequately ensure OEMs perform their work properly. In addition, the quality of the OEM's talent appears to be in steady decline with crews being thoroughly fatigued towards the end of outage season.

Solution. Elwood Energy confronted this problem by contracting Viking Turbine Services to provide oversight, typically on day and night shifts, through major turbine and generator work. With major work being performed on one or more turbine/generators, Viking maintained a skilled and dedicated eye on the OEM's performance. This freed-up Elwood's small staff to administer safety programs, perform other outage-related work, and respond to dispatches of other units.

The following is one example of Viking's value: While doing routine checks, the company's personnel noticed that two of the transition pieces completed on day shift had significant gaps between the bullhorns and bullhorn support blocks. You're likely aware that bullhorns must be snugged down tight prior to recording set-back clearances.

Viking requested that the OEM's contractor tighten down the bullhorns and recheck set-backs. Proper fit-up remained elusive for some of the transition pieces and the OEM decided to change all bullhorn blocks.

Results. Over the last 10 years and numerous turbine outages, Elwood has experienced two outages requiring significant rework—when Viking was not a participant. Numerous other outages have been performed with oversight that have not required rework. During these outages, Viking routinely identified issues during routine observations and during agreed-to quality hold points.

The conclusion that can be drawn from this is that by having an experienced representative on hand for the owner, the OEM is compelled to perform more deliberately and execute higher quality work. With less of a chance for quality issues impacting the post-outage startup, and operation between scheduled outages, the total cost of the outage can be reduced.

Project participant:
Joseph Wood, plant manager

Rathdrum

Rathdrum Power LLC
Owned by Tyr Energy
Operated by NAES Corp
270-MW, 7FA-powered 1 × 1 combined cycle located in Rathdrum, Idaho
Plant manager: Richard Ihrig

Catwalk around clarifier makes maintenance safer, easier

Challenge. Rathdrum Power is permitted as a zero-discharge (ZD) facility. As such, the plant does not discharge any process water. Undesirable solids are removed from the various process-water streams by mechanical means in the ZD area of the plant.

An issue with the plant's ZD system was the design of its ageing clarifier. Sodium carbonate (soda ash) carries over and plugs discharge holes around the clarifier's weir (Fig 1). Occasionally plant personnel have to clean the weir and service the sulfuric-acid discharge piping, tasks requiring use of an extension ladder (Fig 2). Putting up a ladder and climbing to the top of the clarifier to tie off the ladder posed safety concerns and was not viewed as efficient use of employee time.

Solution. With help from a local engineering firm, staff decided to resolve the problem this way: Build a catwalk around the outside of the clarifier so O&M personnel could access all areas at the top of the vessel. It was designed with a grating of Type-304 stainless steel and handrails and supports of carbon steel.

Results. The catwalk enables access to the clarifier weir and sulfuric system without need for an extension ladder requiring fall protection (Fig 3). With easier access, cleaning intervals have been reduced. Plus, fewer personnel are required to do the work. Plus, plus, scaffolding no longer is required for deploying the tarp to enclose the clarifier before high-pressure cleaning of its internals during annual outages (Fig 4).

However, the greatest overall benefit of the clarifier catwalk installation was elimination of the fall hazard while accessing the weir.

Project participants:
Shawn Gregg
Jim McCorkle
Tim Mortimer

1. Weir at the top of the 26-ft-diam, 14-ft-tall clarifier requires frequent cleaning

2. Clarifier had few ladder tie-off points to assure safety during maintenance

3. Catwalk is suspended from the clarifier with supports bolted to the weir frame and support legs free-floating and interlocked by the catwalk itself. This fastening arrangement was selected to avoid damaging the clarifier's 40-mil internal epoxy coating

4. Access provided by the catwalk is in evidence here. The tarp is used to cover the clarifier during annual high-pressure cleanings to capture fugitive dust and debris

MEAG Unit 9

Bearing-tunnel fire alarms enhance personnel protection

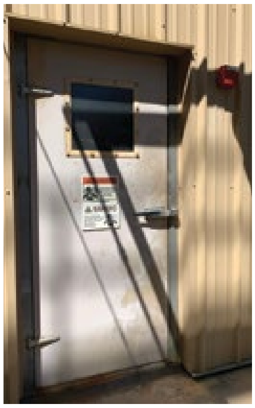
Challenge. Assure a high level of fire safety for personnel working inside the gas-turbine exhaust enclosure.

NFPA-12 provides guidance for carbon-dioxide extinguishing systems typically specified for generating plants powered by gas turbines. The standard provides the minimum requirements for a system designed to flood the compartment with CO_2, which does not support combustion, should a fire be detected.

While an effective method for fire suppression, CO_2 poses safety risks for human occupancy since working in a GT exhaust enclosure is not an unusual occurrence in the power industry.

There is the potential that an individual could be working inside the enclosure, unaware of a fire event, and could be a long distance from the nearest exit. Example: What if the CO_2 vented out of the adjacent lube-oil drains and into the exhaust enclosure?

At MEAG Unit 9, as in most plants, mandatory signage is in place as a warning, but is that sufficient?



One of the new fire alarms is located at the entrance door to the exhaust section

Plant Wansley, MEAG Unit 9
Owned by MEAG Power
Operated by NAES Corp
570-MW, gas-fired, 7FA-powered 2 × 1 combined cycle located in Franklin, Ga
Plant manager: Timothy Williams

Solution. Staff decided an additional measure of protection was required since there were areas where CO_2 could be present, but no visual or audible alarms were available.

Result. To correct this shortcoming, MEAG Unit 9 installed additional three-horn-and-strobe-light combination alarms at the following locations:

- Near the bearing-compartment vent.
- At the entrance door to the exhaust section (photo).
- Inside the exhaust-section enclosure.

This now provides personnel working inside the enclosure immediate and effective notification of the danger in the unlikely event a fire were to occur in the compartment.

Project participant: Jason Land

This year's annual HRSG Forum is being conducted in monthly installments. The first was held May 3, 2021. This report is a compilation of the presentation and discussion summaries from the first three meetings (May, June, July). Dig into the details by simply scanning the QR code with your smartphone or tablet to access the recorded proceedings.

Looking ahead, follow www.HRSGForum.com for announcements of meeting dates, times, and content, and for registration links. There is no registration fee for powerplant owner/operators, consultants, and vendors with an interest in heat-recovery steam generators.

Hex chrome, HP-bypass trim erosion addressed in deep dives with the pros

The two issues focused on in the first online HRSG Forum were hexavalent chromium and trim erosion of high-pressure (HP) bypass pressure control valves (PCV). Both are vexing issues for combined-cycle facility operators and even incremental additions to users' knowledge/experience base are worth paying attention to. Hex chrome is covered here; the following article summarizes key points extracted from the valve panel discussion.

To tackle the hex-chrome issue, venerable HRSG expert and consultant, Bob Anderson, and co-chairman expert chemist/metallurgist Barry Dooley of Structural Integrity Associates Inc, enlisted David Addison, principal consultant, Thermal Chemistry Ltd, a world-class authority on powerplant water chemistry.

Addison began thusly: The tell-tale bright yellowish deposits of the highly toxic hexavalent chromium show up on air/gas side equipment downstream of high-energy chromium-containing piping, especially in areas where water ingress occurs. Typical areas reported out to the industry include gas-turbine hot-gas-path components; steam-turbine hot external components, such as bolts; and HRSG hot-pipe external surfaces.

Hex chrome is a known and manageable problem in the welding of chromium alloys. Protocols for dealing with it are well-established. Turbine OEMs have issued technical bulletins on it. While those bulletins have not specified the chemical form, XRD/XRF testing confirms that it manifests as calcium chromate. Sources of calcium include anti-seize pastes (containing calcium oxide, CaO) and some lagging/insulation materials.

Precautions and protections

Follow these recommended precautions and protections when inspecting areas that have tested positive for hex chrome (or suspected of containing the toxic chemical) and/or when removing the material.

Activity: Inspections in areas where hex chrome residues are present but the residues have not been disturbed.

Exposure. Skin absorption, ingestion.

Controls: Eye protection, disposable nitrile gloves, particle-resistant disposable overalls. Plus, no eating, drinking, smoking, or bathroom breaks should be taken without first washing hands and face.

Activity: Removal or disassembly of items with hex-chrome residues present.

Exposure: Skin absorption, ingestion, inhalation.

Controls: All the controls recommended for inspections (above), in addition to the following: P2 respirator and, where possible, ultrasonic cleaning of parts.

Activity: Grinding, wire brushing, finishing, welding, etc, of surfaces with confirmed hex-chrome residue.

Exposure: Skin absorption, ingestion, inhalation.

Controls: All the controls recommended for inspections and removal/disassembly (above), in addition to the following: goggles, upgraded respiratory protection (to powered air-purifying respiratory protection), mechanical ventilation HEPA filters, and use of controls to limit the aerosolization of hex-chrome residues.

If you see bright yellow deposits on your equipment, first, don't panic. But also don't think it is sulfur-bearing. That's not possible, though some have made that mistake.

Second, make sure you don't disturb a deposit, until you are ready to remove it completely. Left to its own devices, calcium chromate will not vaporize or melt. When you are ready to remove it, follow protocols to avoid both worker exposure and inhaling the dust (sidebar). The good news is that Addison said he is not aware of any health issues associated with hexavalent chromium from powerplant operations.

Eliminating the calcium source avoids the problem. If possible, select anti-seize pastes and insulating materials with no calcium oxide. Preventing water ingress also goes a long way towards mitigating the problem. Adding a reducing agent will convert the hexavalent form to the benign trivalent form. One OEM recommends spraying an ascorbic acid/surfactant formulation on the deposit, and field experience suggests this works well.

Other areas which exhibit the right conditions for hexavalent chromium—chromium-containing components, oxygen atmospheres, high temperature, presence of calcium, and water ingress—should be suspect, including superheater and evaporator upper and lower crawl spaces, gas-turbine exhaust ductwork (insulation side). Testing is underway to confirm presence in these areas.

Panel digs into the details of trim erosion on HP-bypass PCVs

To address trim erosion on HP-bypass pressure control valves (PCV), HRSG Forum's Bob Anderson put together a panel of experts—including Ory Selzer, IMI/CCI; Justin Goodwin, Fisher™; Vasileios Kalos, GE Gas Power; and Consultant Joe Schroeder. The erosion occurs when high-pressure steam entrains water droplets (not to be confused with saturated steam) and passes through the valve trim at high velocities "like sandpaper." The damage can be so severe that some users thought their trim had melted!

Once the trim has eroded, the valve will leak steam and overheat the downstream carbon steel piping.

The bad news is that you can't buy a valve that avoids this problem. All models are susceptible. Using better trim materials, reducing velocities by increasing the seat diameter by 10 to 15 mm, and/or lengthening the control plug, may buy you some time and keep the valve tighter for a longer period, but that's about it.

The root cause of the problem lies in details of the HP-bypass piping design and the peculiarities of starting up a multiple-GT/single-steam-turbine combined cycle. The lag cold-start unit (the second GT to start up) on a 2 × 1 design usually is the culprit. Because the HP isolation valve for the common manifold of the main-steam header is closed, something that does not happen for the lead cold-start unit occurs. Reason is that there is no flow path for steam to warm and dry the HP steam pipe between the HPSH outlet and the isolation valve prior to opening the HP-bypass PCV.

Once the PCV begins to leak enough to overheat the downstream piping, the only safe action is to operate with the PCV at its minimum-open position until the valve can be repaired. Opening the desuperheater-water injection valves to cool the piping—with the PCV closed—is, by consensus, "definitely a bad idea," Get the details by listening to the panel discussion. Scan the QR code above for access.

Interest in the subject was revealed through the extensive questions delivered ahead of the meeting. One attendee asked if there is another source for the erosion—such as magnetite. Panelists answered that magnetite would pass through all the valves and this erosion is heavily biased towards the HP-bypass PCV. One panelist noted he'd only seen one valve that had experienced solid-particle erosion rather than water-induced erosion.

Another asked about chromium or tungsten carbide materials for the trim instead of Stellite-6, and the response was they weren't used in steam applications. "Promising alternative trim materials have not seen many operating hours," one panelist noted, including a temporary repair technique using Inconel 625 or 718 or superalloys with high titanium or aluminum content as a "buttering layer."

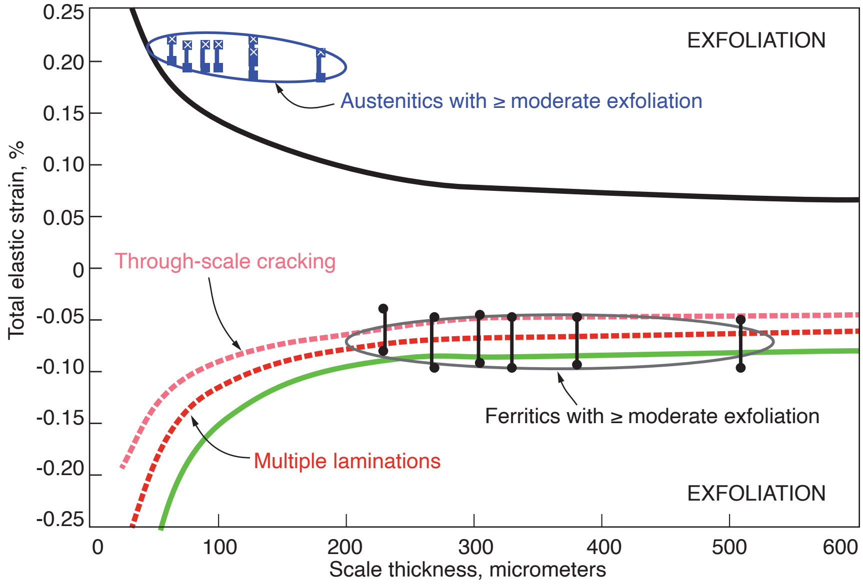
Anderson suggested that establishing a proper steam flow path to warm the piping from the superheater outlet to the common manifold isolation valve prior to opening the PCF is needed to avoid condensate ingestion. This may require enlarging the drain upstream of the isolation valve. Pre-warming the valve body and steam line with warm-up nipples has shown inconsistent experience. One panelist made the wry comment that "spray valves leak and drain valves plug." So, to will HP-bypass PCV valve trim erode and leak—at least until further notice.

Steam-side oxides, poor NH_3 distribution tackled at the second forum

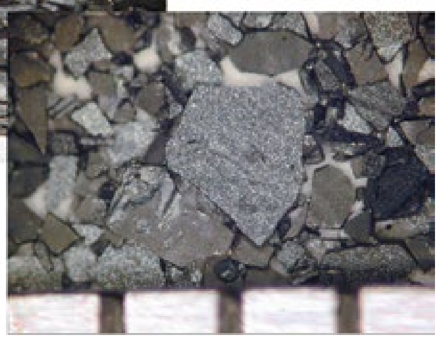
During the HRSG Forum's second monthly meeting, June 2, 2021, hosted by Bob Anderson and Barry Dooley, close to 130 owner/operator representatives from 34 countries (out of 219 total attendees), were enlightened on two vexing issues with HRSGs: (1) steam-side oxide growth and exfoliation (OGE) from superheater (SH) and reheater (RH) tubes, and (2) the use of computational fluid dynamics (CFD) and field testing to improve selective catalytic reduction (SCR) unit performance.

Judging from the number and quality of the questions for both presenters, these attendees weren't just staring at their screens. You don't want to miss listening to recordings of the presentations; simply scan the QR code above with your smartphone or tablet. They are rich in detail with a methodical sequence of illustrations for truly understanding the problems, impacts, and solutions.

Barry Dooley, a senior associate at Structural Integrity Associates Inc, whose experience dates back decades to some of the early work done at the UK's CEGB, Ontario Hydro, and EPRI on OGE, explained how SH and RH ferritic steels like T11, T22, T5, T9, T23, and T91 are susceptible to oxide growth on inner surfaces containing greater amounts of hematite versus magnetite, which can lead to exfoliation of particles under the right thermal stresses (Fig



1. Data points below the green line in this graph (famous with OGE specialists) indicate a higher risk of exfoliation from ferritic steels typically used in the manufacture of superheater and reheater tubes. The original oxide failure map was developed by Armitt and others in 1978; Dooley and Patterson added exfoliation data in 2003



2. In the extreme, an OGE event can result in a massive amount of material downstream, as this photo of a P91 superheater header shows

1). The progression of formation for different alloys, from laminations in the oxide layer to cracks to exfoliation, is well depicted in the slides.

The varying alloy compositions—chromium and molybdenum contents specifically—help determine how fast deposits grow, and the risk of exfoliation. The specific environmental factors are saturated or superheated steam, gas-turbine exhaust temperatures from 1100F to 1150F, use of duct burners, and tube temperatures ranging up to 1200F.

The deposits themselves can lead to tubes operating at higher temperatures, resulting in an ever-increasing oxide growth rate. The exfoliated material causes erosion, plugging, and sticking in valves; erosion of downstream HP and IP steam-turbine inlet-valve and steam-path components; or simply collects in a header (Fig 2). Impacts tend to show up after many thousands of operating hours but of course are aggravated by deep unit cycling and starts/stops, once the oxide reaches the critical thickness for exfoliation. Dooley shows one HRSG case in which material began to exfoliate after only 24,000 operating hours.

Unfortunately, OGE cannot be controlled through steam/water chemistry changes. It's not dependent on O_2 concentrations, but instead on O_2 partial pressure. The influence of film-forming substances in the chemistry is uncertain. Shot-peened Type-304H stainless steel and S304H SH tube alloys will exhibit a Cr-rich layer along the surface which slows the rate of exfoliation. "It's rare for them to exfoliate," Dooley said.

Among the insights that emerged from the Q&A session:

- No relationship has been developed among operating parameters (for example, total operating hours, number of starts, etc) and OGE to predict its onset before impacts occur.
- Cycle modifications which increase gas-turbine exhaust temperature raise the risk of oxide growth.
- UT analysis can detect oxide-scale thickness but only lab metallographic analysis can reveal the characteristics of the oxide layer critical to OGE.
- Early theorists suspected that steam/water O_2 levels contributed to hematite formation, but deeper research has proved this false.
- Small additions to the alloy, like vanadium and tungsten, will alter iron-ion migration patterns.

Improve NH_3 distribution to reduce NO_x and ammonia slip

Bill Gretta, principal, SCR Solutions LLC, presented two case studies in which a unique field test method combined with sophisticated CFD analysis suggested modifications for improving distribution of ammonia through the SCR catalyst modules to improve NO_x reduction and ammonia slip. Old units, and many new ones, are not equipped with a permanent NH_3 sampling grid downstream of the SCR, and it's costly to add, Gretta said.

He described a method that makes use of a flexible weighted probe with NO_x and NH_3 sensors which is lowered into the SCR inlet and exhaust gas flow fields from multiple ports on the roof (Fig 3). Then EPA Test Method 320 is applied. Subsequent CFD analysis revealed the reasons for areas of high and low NH_3 concentrations after the ammonia injection grid (AIG).

In the first case study, a 2 × 1 501F-powered combined cycle with close to 500-MW output, this approach resulted in removing and rebuilding the AIG, locating it three feet closer to the CO catalyst, and adding mixing baffles and plates to reduce the root mean square (RMS, an indication of the quality of distribution, the deviation from the average of many values) of ammonia-slip variance from 70% to 10%; additional tuning got it down to 6%. Buildup of ammonium bisulfate in zones of high ammonia slip decreased dramatically.

In the second case study, a 2 × 1 501D-powered combined cycle installed more than 25 years ago had to meet a lower emissions profile, so a dual-function catalyst was selected, but failed to meet the new standards. Analysis showed there was plenty of catalyst, so other system issues were at play.

Gretta and his team simulated 501D exhaust, sampled at 50 data points in a 5 × 10 array of SCR inlet and outlet locations with the weighted probe, and then did an inspection and CFD modeling when an RMS value of 19.3 indicated poor distribution. Causes of poor distribution and solutions were similar to those identified in the first case study.

Insights gleaned from the Q&A included the following:

- In both case studies, AIG heavy support elements (which Gretta said probably would be found only in early SCRs) were getting in the way of flow; the replacement was designed to be self-supporting to eliminate the old support structures.
- Rust and scale were blocking the AIG ports. The new AIG uses stainless steel instead of carbon-steel pipe and includes cleaning and vacuuming ports in each lance. Hole diameters also were increased and rearranged.
- Monitoring NH_3 slip for process control may not be practical because the values can be "really different" from what the CEM is reporting to the authorities.

Weld repair clinic particularly valuable to users with limited HRSG experience

You'll want to click the QR link to Bill Kitterman's "Tube Repair Clinic: The Good, the Bad, and the Ugly," even if just to see the pictures of the "uglier" and the "ugliest" tube-to-header welds (Fig 4). In true photojournalism fashion, Kitterman, head of Bremco Inc, now part of SVI Industries, described six different styles of such welds and the four methods for accessing leaking tubes, including the one fit for an action movie title, "cut your way in, weld your way out."

Kitterman encouraged the industry to "do more to determine the root causes of tube failures." He also asked users in the audience to understand that, for repairs of creep-strength-enhanced ferritic tubes (such as P91), the downtime required to do quality work could be longer than they might expect. Welding is the fastest part of the procedure, he noted. Stress relief, code requirements (national, state, and local), official inspections, and insurance-company compliance factors take most of the time.

Example: "Bremco has modified its Alloy 91 weld procedure four times since initial qualification—for pre-heat and post-weld heat treatment and weld-wire requirements." Proper wrapping to maintain the heat during heat-treat is critical.

Kitterman discussed Weld Method 6, a repair that avoids post-weld heat treatment (PWHT) but is only good for butt welds and on tubes with a wall thickness of less than 0.5 in. "This reduces downtime considerably since PWHT can take up to 14 hours," he added. He also mentioned Supplement 8 for thicker pressure parts, which also avoids PWHT. It's good for attemperator piping, although Kitterman conceded that Bremco isn't yet comfortable with the procedure.

One attendee asked about tube plugging, but Kitterman cautioned that plugging a tube can change the flow patterns. It's no longer being steam-cooled so the hotter gas can impinge on adjacent tubes, and failures could cascade. Another asked if Bremco undertakes turnkey scope; Kitterman answered yes, but prefers to add third-party specialist heat-treat and inspection companies to the team.

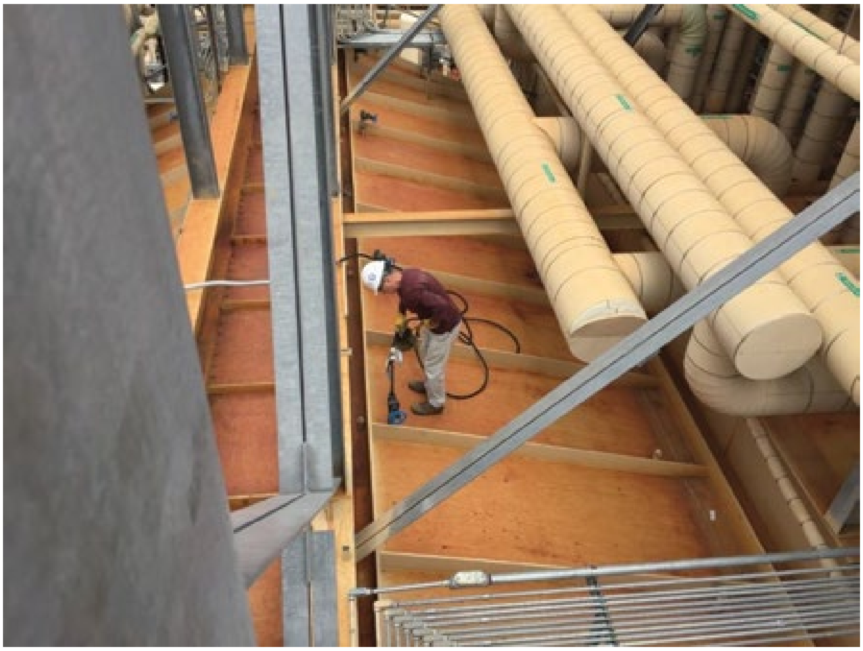
Other questions and responses addressed sonic leak detection methods—all captured in the video recording a couple of clicks away.

With pressure parts, so much depends on high-quality welds. Even if welding "isn't your thing" at the plant you are responsible for, it's worth watching this presentation to gain a cursory understanding of what's involved.

Novel attemperator for reheater circuits eliminates legacy issues

Since virtually everyone at a cycling plant faces issues with their attemperators (Fig 5), you'll probably want to know about a unique design retrofitted to several Duke Energy combined cycles, one that uses the existing spray ring.

Key to the design is use of HP steam to provide the energy to atomize the spray water (Fig 6). This creates a much finer distribution of droplets, regardless of water flow, pressure drop, or steam velocity in the steam pipe, noted Justin Goodwin, director,



3. In the top-traverse test method, a weighted probe is lowered to desired locations in the inlet and outlet flow planes to measure NO_x and NH_3; Gretta says it usually takes only three to four hours for adequate sampling in each plane

4. Six different weld-repair styles kicked off Bremco's tube-repair clinic, after the audience gasped at photos of the ugly, uglier (left), and ugliest (right) welds in service

Steam Conditioning Group, Emerson Automation Solutions.

Steam-atomized nozzles are not new, but are considered unsuitable for high temperature applications like HRSG attemperators. Emerson reached out to corporate colleagues at Fisher™ to design new steam-atomized nozzles that fit into the existing radial-spray, spring-loaded nozzle ring. 3-D printing the nozzles (patented method) of a hardened cobalt chrome alloy (similar to Alloy 6) eliminated the many weld joints, and failure points inside the nozzles of a conventional steam-atomized unit.

"There are no droplets [of water] falling because they are so fine, which avoids the common attemperator failure mode of water impingement leading to damage on internal pipe surfaces. Plus, the design is highly resistant to plugging and corrosion," Goodwin stressed. A tap at the HP drum serves as the source of steam.

Note that the design is not applicable to the HP attemperator, only the reheater units. But good news for designers of new HRSGs: Smaller droplets can lead to a 30-40% reduction in piping lengths.

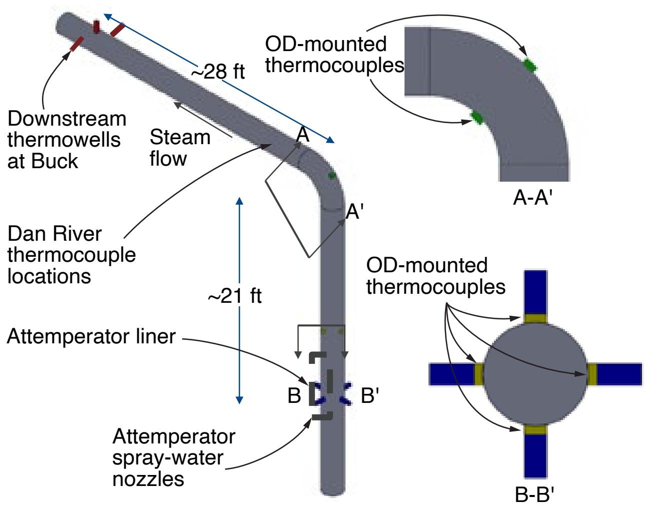
Lessons learned during the field trial are that a 1 in. to 2 in. connection in the atomizing steam supply piping was a choke point, as was use of a Y-pattern valve instead of a full-bore ball valve (a pressure transmitter was added to troubleshoot these issues). Modified control logic design is critical to a successful retrofit. In response to a question, the presenters noted that they replaced the water temperature control valve, but not the block valve.

Eugene Eagle, HRSG engineer, Duke Energy, and Goodwin's co-author, said that Duke was pleased enough with the initial field trial on one unit at the utility's Buck Combined Cycle Plant that they installed the new design at Dan River Generating Station on four additional units. The attemperator with the longest service life had 18 months of operating experience at around 85-90% capacity factor at the time of the presentation.

Duke has eliminated several failure modes, as well as the two-year inspection and test schedule for the previous spring-loaded nozzles, and is in the process of determining the cycle life for the new design. Current thinking is that the nozzles could warrant replacement every three years and that the internal piping liner should be borescope-inspected every two years. Thermal fatigue is the expected nozzle failure mode.

Many of the other questions addressed aspects of the control system (such as the operation of the block valve with the control valve), leakage at the block valve (you need a good block valve and trust it to be tight), the potential need for a second block valve, and possible issues with wet steam in the atomizing steam piping. CCJ

5. Spray pattern of a mechanically atomized fixed-orifice spray nozzle can be disrupted by inadequate water pressure, clogging, damage to the sharp edges required to produce droplets of uniform size, etc. Photo shows what happens when a spring-loaded nozzle operates below the minimum pressure required



6. Attemperator effectiveness was analyzed using these arrangements of thermocouples mounted on the outer diameters of the 24-in. OD, Sch 80, Grade 22 reheater piping at Duke Energy's Buck and Dan River plants. T/c data have been collected in the DCS system since May 2018

Shines spotlight on tube failures, cycle chemistry, materials issues

Co-Chairs Barry Dooley of Structural Integrity (bdooley@structint.com) and Bob Anderson of Competitive Power Resources (anderson@competitiv power.us) hosted 90 participants from 17 countries at EHF2021, a virtual event conducted May 18 and 20. More than 60% of the attendees were from 15 generating companies.

The 18 presentations made during the meeting covered new information and technology related to HRSGs, plus case studies of plant experiences and solutions. Topical open-discussion sessions among users, equipment suppliers, and industry consultants were integrated into the program.

The mix of different topics (including materials chemistry, operation, valves, tube failures and assessment techniques, inspection, and cleaning) proved of great interest to attendees judging by the robust Q&A and discussion—thereby confirming the value of forums promoting the global exchange of technical information.

The European HRSG Forum is supported by the International Association for the Properties of Water and Steam (IAPWS) and is conducted in association with the Australasian Boiler and HRSG Users Group (ABHUG) and the US-based *HRSG Forum with Bob Anderson*. EHF2021 was sponsored by Trace Analysis and Swan Analytical Instruments and organized by PPChem AG.

Conference highlights

HRSG tube failures (HTF) remain a major concern, with these aspects among those discussed:

- Flow-accelerated corrosion (FAC), with clarification of the effect of oxygen levels and the use of oxidizing treatments (no reducing agents) in addressing single-phase FAC.
- The major features associated with creep and creep-fatigue. Note that, while HRSGs typically operate in the cyclic mode and for periods at relatively constant output, that does not mean failures can be attributed to creep-fatigue.
- The importance of metallurgical analysis to identify/confirm the mechanism of failure was emphasized as the first important step in addressing HTF.
- Several of the attendees attributed pressure-part failures in superheaters and reheaters to condensate, drains, and attemperators.

Updates on HRSG cycle chemistry from around the world included the following:

- The latest chemistry-influenced reliability statistics, referred to as Repeat Cycle Chemistry Situations (RCCS), showed overall improvement for the first time in 10 years. For background, retrieve the special report, "Trends in HRSG reliability, a 10-year review," published in CCJ No. 61 (2019), p 44.
- An update on the application of film-forming substances (FFS)—both amine- (FFA) and non-amine- (FFP) based—reminded users that a significant reduction in the quantity of corrosion products can be achieved, but that tube failure problems and deposits (a/k/a "gunk") can occur if the FFS is not applied with expert guidance.
- Assessment tools and instruments for monitoring film-forming amines (FFA) using OLDA (oleyl propylenediamine) were introduced.
- The latest IAPWS Technical Guidance Documents for combined-cycle/HRSG plants were reviewed.
- A good example of optimal cycle chemistry for a dual-pressure HRSG was presented.

An overview of the problems associated with HP bypass-valve erosion by wet steam were highlighted based on a successful recent workshop held on the topic at the HRSG Forum. (You can listen to a recording of the panel discussion at www.hrsgforum.com.) Information shared confirmed the need for plant designers to focus greater attention on providing for sufficient warming steam flow in the HP piping between the HPSG outlet and the isolation valve at the HP common manifold.

EHF2021 featured several presentations related to materials of construction and analysis. Points made included these:

- There can be challenges associated with introducing creep-strength-enhanced ferritic (CSEF) steels in HRSGs, including T/P 91 and 92. Discussion included the relatively new "zinc effect," which has caused cracking in welds where zinc-based paint was used to protect material prior to fabrication. A poll of EHF2021 users indicated only a small percentage of the attendees had knowledge of this application and failure/damage mechanism.
- A compilation of different failure modes associated with welds, and the good (and bad) welding and repair practices used.
- Advanced approaches to component fatigue evaluation.

The latest research and case studies on pressure-wave technology for fireside cleaning of HRSGs. Some discussion also focused on the possibility of internal oxide/deposit dislodgement.

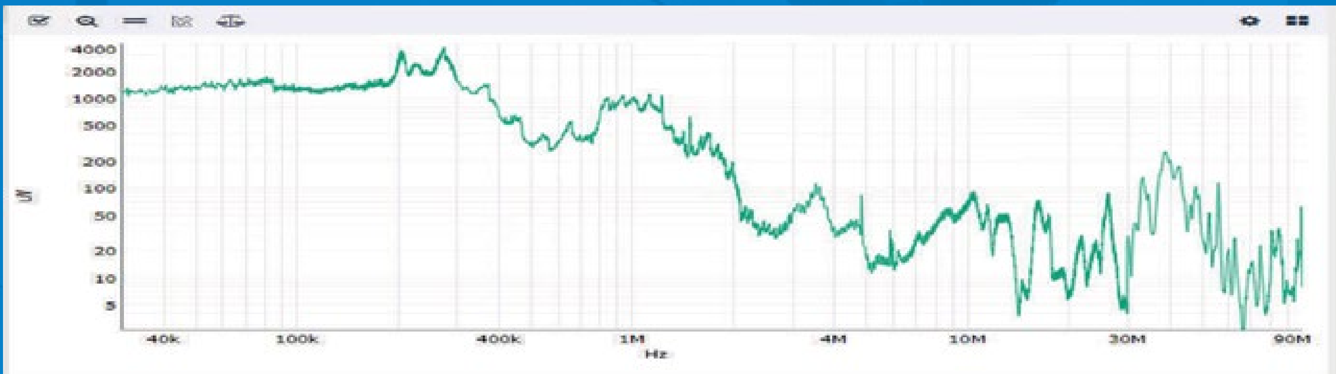
Large sidewall casing penetration seals: The latest approaches applied to design and fabrication.

An update on drum-level instrumentation and regulatory requirements.

Introduction of new, retrofittable steam-cycle technologies—including modular once-through boilers rated less than 100 MW to accommodate flexible operation. CCJ

BETTER OUTAGE PLANNING
LONG TERM PLANNING TOOL

Power Spectrum



Assesment Table

Range	Noise	Corona	Tone	Discharge	Arcing	RMS
30kHz-500kHz	0.6428	0.6377	0.3018	0.6826	0.3475	1095.7615
500kHz-5MHz	0.9352	0.6084	0.1161	0.8347	0.3945	253.9154
5MHz-30MHz	0.9252	0.0257	0.1300	0.8631	0.1388	11.4877
30MHz-100MHz	0.9898	0.0107	0.0082	0.3058	0.0118	7.3244

- **Cutsforth Enhanced EMI system:**
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  - Identifies specific failure modes without the need for experts to review the data
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Two case studies: Flawed original designs get corrected

With just a few excellent slides and a tag team of a design specialist and a construction specialist, Greg Rueff, Vogt Power International, and Tim Holland, TEiC (a Babcock Power company), showed attendees at the first installment of the HRSG Forum's Supplier Workshop Series that sometimes you have to "redesign and replace" to relieve your pain points, rather than keep taking painkillers.

"The OEM clearly tried to skimp on piping cost and routing" for the attemperator in the first case study, said Rueff. There was insufficient straight length of pipe in the original (Fig 1), triple-wide candy-cane design (each with a discrete attemperator) for the water to completely atomize. How insufficient? "So much that the new loop had to be dropped down the side of the unit," he said. Simply replacing the attemperator with an improved version would not have solved the root cause of the problem.

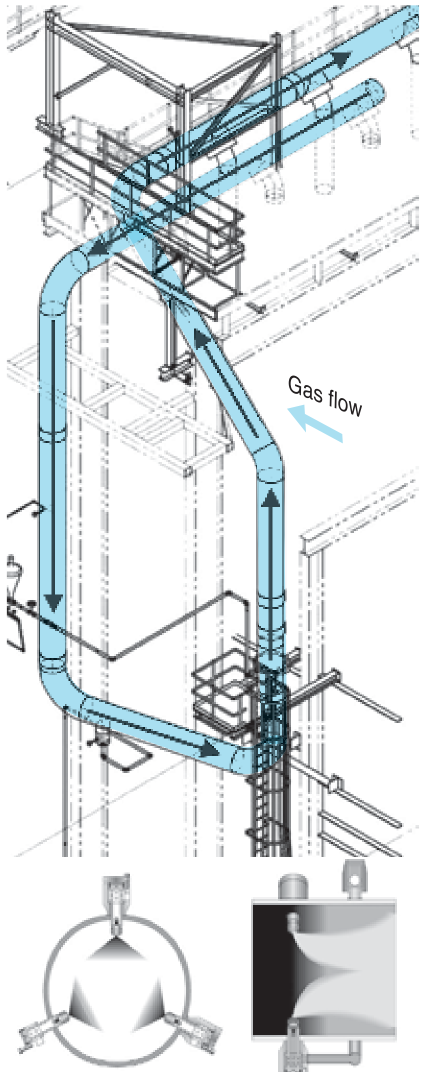
Today there's a single attemperator loop of larger pipe size (Fig 2), and lower bulk average velocities, with one ring-style attemperator/external control valve to maintain reheat steam temperature. Although it handles three times the amount of steam as the original system, there's only one attemperator to maintain.

Since the original design provided no means for preventing leaking spray water from entering the heating surfaces below, a goal of the project was to protect the heating surfaces by collecting water in new drains below the attemperator," said Rueff.

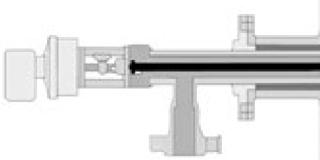
Holland added that the spray-water line now runs from the ground. "The length of pipe was crucial to the engineering design," he said. "By pre-installing many of the piping supports while the units were running and limiting the number of field welds, we were able to fit this replacement in the outage window," Holland added. He called the project execution "flawless."

Responding to audience questions, Rueff noted that the new attemperator still employs a liner but it is "not quite as long as the original." He recommended that units like this be borescope-inspected and maintained at least annually, especially if the HRSG is being cycled. However, you may be able to back off on the frequency depending how aggressive the cycling is and on what the components, especially the spray nozzles, look like.

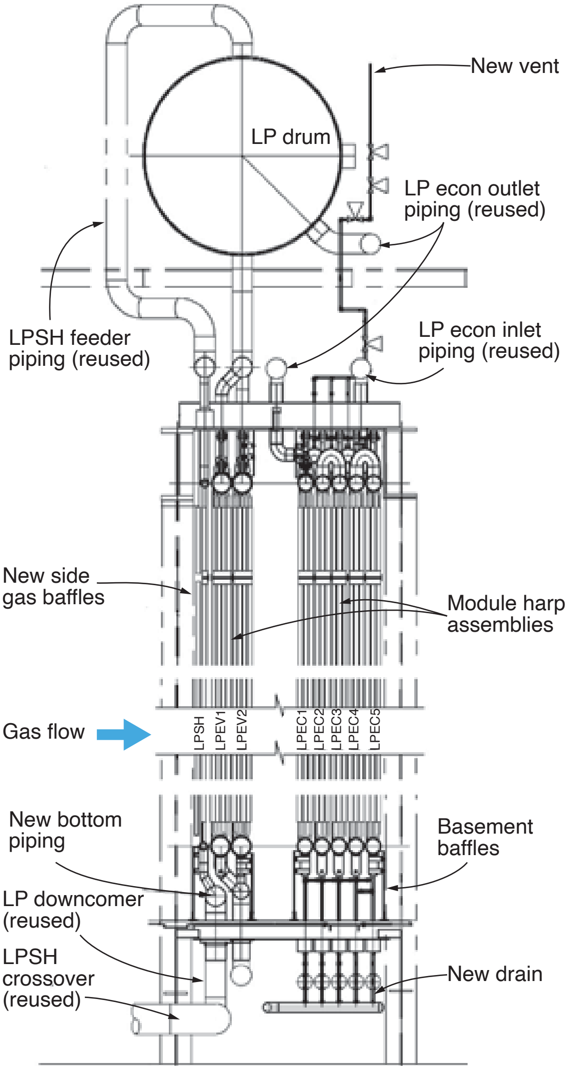
In the second case study, a site was experiencing persistent degradation and disrepair of its LP evaporator and economizer HRSG sections, which had been in service for around 17 years. Leaks resulted from flow-accelerated corrosion (FAC) and exterior corrosion. All of this tubing was carbon steel. "Although FAC weakened the tubes,



2. **Redesign** replaces the triple-wide spray valve design with one loop equipped with a ring-style injection nozzle without an integral valve



1. Original attemperator did not have enough straight length of piping to fully evaporate the spray water, leading to water impingement on heating surfaces, bowed tubes, and cracks at the header-tube interface



3. New T11/P11 LP evaporator and economizer modules are designed to handle cycling, and for ease of draining, venting, access, cleaning, and installation

the flawed support system design led to the mechanical failure," stated Rueff. Plus, tube spacing did not allow for ease of cleaning, and since everything was tied together, it was difficult (if not impossible) to replace any single tube.

The replacement (Fig 3) uses T11/P11 materials, is fully ventable and drainable, includes staggered tube pitch for ice-blasting cleaning lances to pass through all tube banks, and has an access lane between the evaporator and economizer sections large enough to scaffold-up in. Independent supports accommodate thermal growth of each module. Best of all, it performs equal to the original so no unit re-rating was necessary.

The field work was performed in a 30-day breaker-to-breaker outage. To save valuable schedule time, the customer witnessed a shop hydrotest, rather than having it done in the field. With the use of a discrete header design, harps could be lifted and loaded individually. Catalyst change-out was conducted during the same outage.

For both case studies, Rueff and Holland stressed that Vogt and TEiC were awarded the jobs on a turnkey basis, which allowed them to coordinate internally to optimize routing and fabrication, and other factors. In the LP system case, the two firms were able to employ a proprietary engineering and lifting plan which allowed the use of a smaller crane and special unloading and uploading frames (proprietary to Vogt) to avoid distorting the tube harps while they were being lifted into place and permanently affixed to the unit—*without lifting the drum.*

In a moment of levity, Rueff ballyhooed just-in-time delivery as great in theory but not accounting for the realities of trucking.

During the Q&A, Holland and Rueff cautioned that these retrofits must be planned over a 35-40-week timeframe. "It's rare," they said, "that any vendor will have stock tubing to replace a harp: You're at the mercy of the mills." Dr Barry Dooley of Structural Integrity Associates, a Forum host, noted that it is extremely rare for a plant to conduct an inspection specifically for FAC. The failure usually comes first. He also noted that tube materials containing chromium at levels as low as 0.1% can help prevent FAC. CCJ

HRSG FORUM

Listen to the recordings of these and other HRSG presentations, and their follow-on Q&A/discussions, at www.HRSGForum.com. Fastest access is by scanning the QR code below with your smartphone or tablet.

TURBINE TIPS, No. 14 in a series

Load-gear alignment: The old-fashioned way

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

Turbine Tip No. 14 from the PAL solutions library applies to General Electric package power plants (PPP) incorporating MS5001 and MS6001 gas turbines.

GE offered these two gas-turbine models requiring speed-reduction gearboxes to drive 2-pole ac generators:

- The MS5001 package power plant manufactured by the OEM in Schenectady from 1960 to the mid-1980s.
- The MS6001 cogeneration engine also made in Schenectady—from 1978 to about 1988.

These plants had gas turbines operating at approximately 5100 rpm, with speed-reducing gearboxes driving generators at 3600 rpm. Good alignment of the gas turbine to the load gear was critical for vibration-free operation of driver and driven equipment at those speeds.

Today, laser alignment often is used when servicing these PPPs. But because the gas turbines have liberal allowed alignment tolerances, Pond & Lucier LLC believes laser technology in this application is engineering "overkill." You can save money by bringing in an ex-GE field engineer with the knowledge and skills to do it the "old-fashioned" way.

The skill requires the use of various dial indicators and the "how to" knowledge used during the original installation by a GE engineer. A tubular version of the alignment fixture (Fig 2) can be used with various dial indicators (Starrett or equivalent) to measure and establish the deliberate *vertical* offsets shown in GE technical publications.

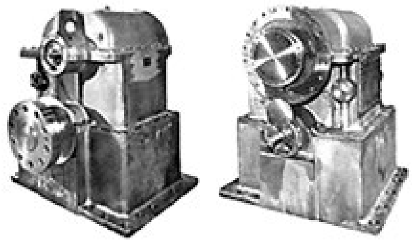
Alignment of the load gear to the gas turbine takes into account the following factors:

- Relative vertical growth of the gas-turbine exhaust (including the exhaust hood and the No. 2 turbine bearing) with respect to the load gear when at baseload.
- Proper loading of the common bearing shared by the load gear and generator rotor. This alignment is commonly known as the "quill drop" check. A shim under the generator pedestal bearing was chosen to assure the front-end weight-bearing of the generator rotor (field) rotor (bearing No. 3 in Fig 3). This may have to be changed to get the proper "drop."
- Bearing centralization for the generator rotor, as measured at the front of the load gear. This includes a "crank check" to assure the straightness of the quill shaft.

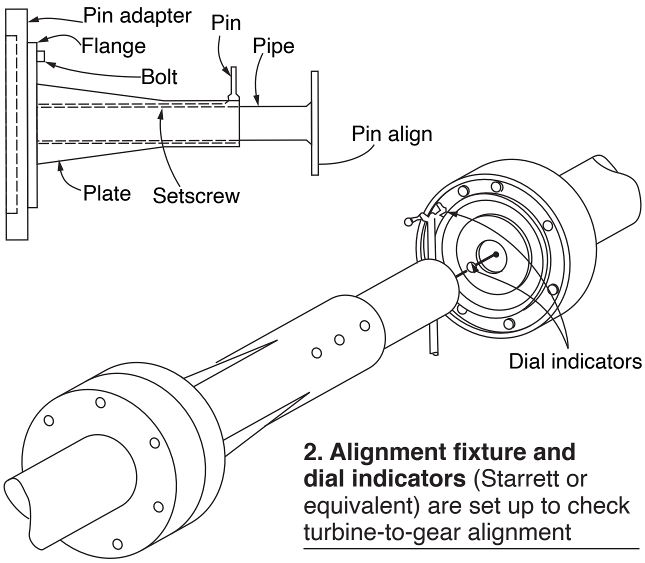
GE specifies the amount of vertical offset between the turbine and high-speed gear shaft flanges. Of course, the load coupling must be removed and the alignment fixture installed to accomplish this measurement. With the fixture attached to the turbine-end flange and dial indicators reading on the face and rim of the pinion-gear flange, the turbine should be lower than the gear by approximately 50 to 60 mils. That would be a total indicator runout (TIR) of 100 to 120 mils with the rim dial indicator initially set at *zero* at the top 12 o'clock position.

Note that these offset numbers will vary depending upon the GE model: MS5001K, L, LA, M, N, or P; the MS6001B will be somewhat different.

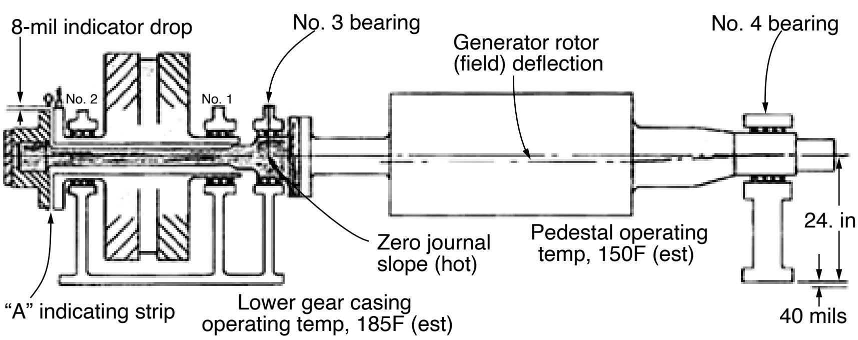
It is important that once the load coupling is installed after alignment, it not be internally bound. Radial clearance can be checked as shown in Fig 4.



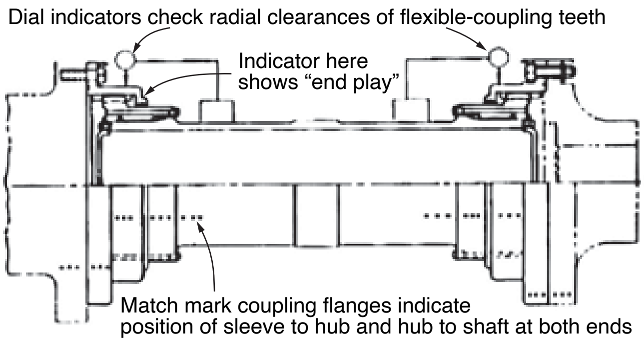
1. Typical speed-reduction gears (a/k/a load gears) used on MS5001 and MS6001 gas turbines made by GE



2. Alignment fixture and dial indicators (Starrett or equivalent) are set up to check turbine-to-gear alignment

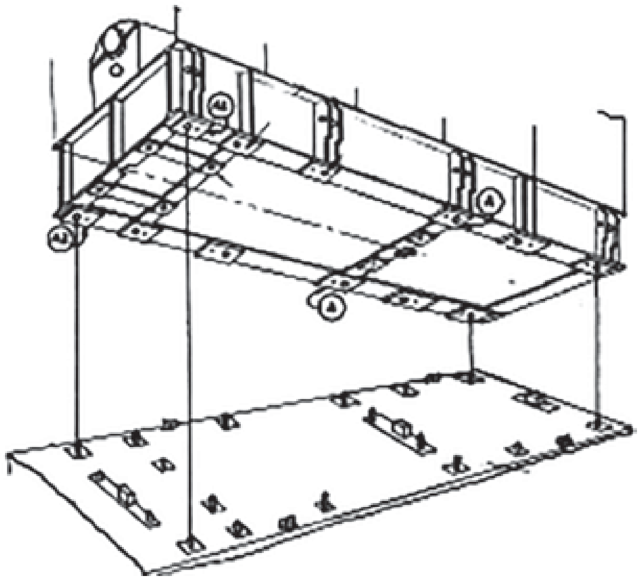


3. Quill drop check is a critical measurement in the alignment process. Note that "Y" on the generator coupling lines up with "Z" on the load-gear coupling



4. Radial clearance check is conducted with dial indicators positioned as shown

5. Load-gear nameplate indicates the proper GE document to access for information



6. Foundation pad locations are important to personnel checking alignment

GE provides data sheets and nameplates with the gas turbine. Example: In Fig 5, the nameplate indicates that information for the S-624-A reduction gear is in publication GEK-25774.

The generator foundation supports are shown in Fig 6. The calculated "move" takes into account the vertical and horizontal moves for all the pads, with shim changes required on each pad to achieve the "perfect" move. A well-trained engineer can follow the GE specifications to elevate the generator to the proper level using the principles of trigonometry and geometry learned in high school.

In conclusion, look to GE's gas-turbine instruction books for the document addressing field alignment. This is not "rocket science" and does not require lasers to accomplish. Hire a grey-haired or balding ex-GE engineer who installed a Frame 5 or 6 gas turbine in his early years in field engineer services. CCJ

Dave Lucier has devoted much of his 50+ year career to solving problems with legacy GE engines.

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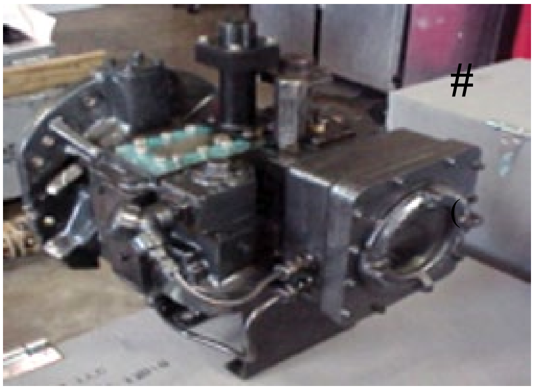
Immediate Delivery

Frame 5L, M, N auxiliaries

Young & Franklin Fuel Regulator



Application: GE Gas Turbine Models: MS5001D, J, K, L & LA

GE Part Number: 733E813 G2

NY Airbrake (Dynapower) Fuel Pump

GE Part Number: 226A1708 P1

Model Number: 890851

Roper Liquid Fuel Flow Divider

GE Part Number: 185A1819, Rev 1

Model Number: 890851

Oil Gear Fuel Pump

Model Number: PVAZKM-054-ZZN

GE Part Number: 158A7701-1, Part 1 Rev. B

For pricing and other information, contact Dave Lucier today.

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Industry aims for more accurate assessment of creep damage in high-temperature components

Compiled by Steven C Stultz, Consulting Editor

The High-temperature Defect Assessment conference has drawn international participation since its inception in April 1998. HIDA began as a European Commission and industry supported research project aimed at unifying defect-assessment procedures validated on materials of interest to high-temperature processes—primarily power generation.

HIDA continues to meet periodically in response to industry developments and with a strategic focal point. The first two events, in France and Germany, concentrated on the beginning and end of the original four-year European Commission program. HIDA-3, held in Lisbon, Portugal, focused on crack growth and repair of high-temperature welds.

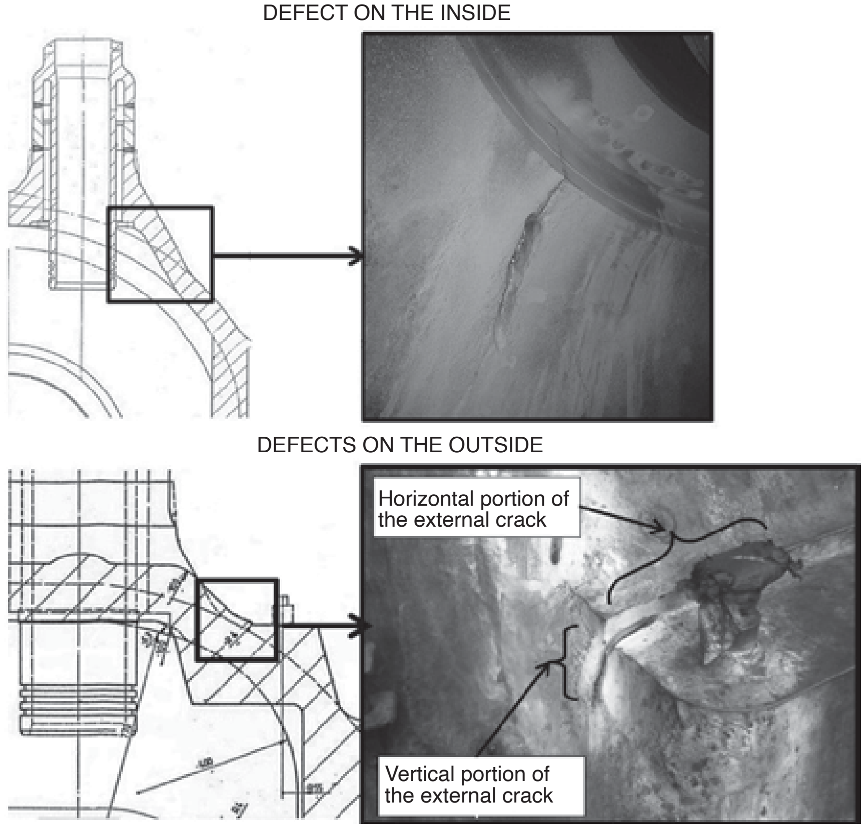
HIDA-4, in the UK, saw an industry need to dive further into probabilistic assessment, and was followed by HIDA-5, again in the UK, to discuss fitness-for-service and risk-based inspection. Moving to Japan in 2013, HIDA-6 concentrated on martensitic steels and creep-fatigue interaction, followed by HIDA-7 (UK) discussing life and crack assessment for industrial components.

Like the first seven events, HIDA-8 was organized and coordinated by European Technology Development Ltd, Leatherhead, UK (www.etd-consulting.com). Its focus: crack inspection and assessment, repair options, and monitoring of cracks and pre-crack damage. Participants represented Australia, Belgium, Germany, Ireland, Italy, Japan, the Netherlands, Poland, Spain, South Africa, Sweden, Switzerland, the UK, and the US.

Dr Ahmed Shibli, managing director of ETD, opened the virtual meeting, held April 20-22, 2021, by stressing the values and benefits of this ongoing, dynamic collaboration thusly:

"Assessment of the behavior of high-temperature plant components containing defects and operating under steady and/or cyclic load conditions has become an area of urgent need and interest. We have strategically organized HIDA-8 into sessions dedicated to inspection, damage, and cracking under creep, fatigue, and oxidizing conditions; defects/cracks and life assessment; and martensitic steels—cracking, life assessment, and modeling."

Selected highlights from the more than 30 presentations and online discussions follow.



1. Defects found inside and outside of the outer HP turbine casing

Casting repair

Casting weld defects have become a significant industry concern.

Ronnie Scheepers, Eskom, South Africa, discussed acceptability assessments of casting weld defects under transient thermal loading. The basis of this presentation was weld repair of castings during both manufacture and operation, emphasizing the need for qualified welding procedures and strict quality control.

In many cases, cracking (on initial assessment) is attributed to in-service creep damage accumulation. However,

2. Surface-breaking defect in the LP-turbine bypass valve

consideration of specific geometry and operational stress distribution often suggest stress relief or reheat cracking because of an original manufacturing weld repair.

"Weld repair of castings during manufacture," he stated, "is a well-known and acceptable practice if conducted in accordance with approved standards and procedures. However, cracking of these weld repairs in high-temperature and ageing plants, especially those operating beyond design life, is all too common.

"Structural-integrity assessments of such components must not only consider reduced material toughness caused by temper embrittlement, but also the stress intensities generated during transient thermal events, such as start/stops and quenching incidents," he continued.

"Most defects are detected during outage inspections of in-service plants," the speaker explained. "The focus then becomes a management strategy of replace, repair, excavate, or leave as-is."

The first of two case studies presented by Scheepers discussed the acceptability of weld-repair defects in the outer casing of an HP turbine. This 1980s-vintage unit for a 618-MW site had logged 220,000 hours and 328 starts. Material of manufacture is GS17CrMoV5-11 (1.7706). Operating conditions are 4.3 MPa at 330C to 430C.

Phased-array NDT showed an internal defect about 48 mm deep in a wall of 114-mm thickness. An external vertical defect was about 78 mm deep where wall thickness (WT) was 108 mm; an external horizontal defect about 63 mm deep (108 mm WT). Refer to Fig 1. Remaining ligaments were clear of indications.

Microstructural evaluation showed a mixture of ferrite and mostly bainite, and confirmed cracks in both the weld and in the heat-affected zone. Cracks were oxide-filled with decarburization along crack lengths, and no indications of propagation.

Metallurgical assessments concluded significant temper embrittlement had occurred. This was considered in a finite-element-based structural-integrity assessment that reflected design operating conditions as well as a hypothetical quenching event.

A second case considered an LP-turbine bypass valve, 1980s vintage from a 686-MW unit with 190,000 hours and 155 starts (Fig 2). Operating conditions were 4 MPa/535C during startup and shutdown; the baseload operating temperature, 248C. Material: GS17CrMoV5-11.

A 67-mm-long surface-breaking defect was identified by magnetic-particle test (MT); phased-array ultrasonic testing (PAUT) indicated a depth of 44 mm within 65-mm wall thickness. No other defects were found. A macro crack in the weld repair area was oxide-filled and micro cracks were found with stress-relief voids.

Weld repair had not been reported during manufacture.

In this case, the material temper embrittlement was found to be less severe, but the criticality of pre-warming to reduce transient thermal stress and, by extension, crack stress intensities during trips or shutdowns, was clearly demonstrated.

Remaining life assessments, in both cases, considering creep or fatigue crack growth and allowable defect sizes concluded the defects to be acceptable for operation to the next planned outage.

Predicting creep damage

Rolf Sandström, Materials Science and Engineering, KTH Royal Institute of Technology, Stockholm, Sweden, provided a tutorial on creep damage.

During creep deformation, he explained, several changes in the microstructure occur that tend to reduce the time to rupture. These changes include cavitation, substructure coarsening, particle formation, particle coarsening, and recovery of hardening phases. These are often referred to collectively as *creep damage*.

"Information on creep damage is used to predict the remaining life of materials and components and to improve the properties of existing materials," he said. "To make predictions, accurate data about the creep damage is essential. Since extrapolation to longer times is almost always involved, methods must be available to perform this. Considering the number of damage types, it is a challenging task."

He then clarified: "In recent years, creep models based on physical principles have been developed that do not rely on the use of adjustable parameters. These models are referred to as *fundamental*."

Such models, he explained, represent a major advantage, since damage types that have not been possible to measure precisely can be predicted. In this way, a more complete picture of the creep damage can be obtained.

For several materials, rupture is controlled primarily by cavitation—at least when the stresses are not too high. Fundamental methods have been formulated that can predict the observed strain dependence of creep cavitation.

Referring to published works, Sandström noted that a common way to determine the creep damage has been to analyze tertiary creep. Changes in the dislocation structure are the main cause of tertiary creep, so the mechanisms are different in comparison to those controlling the failure. However, the data from tertiary creep still give valuable insight. "Fundamental models for tertiary creep have only recently been developed," he said.

Sandström demonstrated that by taking all the main damage mechanisms attributed to dislocations, particle formation, and cavitation into account, the rupture life of austenitic stainless steels has been predicted successfully.

Sandström's presentation was designed to review recent modeling of creep damage using fundamental methods. "In all work on creep," he stated, "it is important to identify the operating mechanisms. To generalize and extrapolate the results can only be done if the operating mechanisms are known."

He reviewed several examples where mistakes have been made in applying empirical approaches:

- The stress exponent n is used as an adjustable parameter in many models, even in those that have a partially physical basis.

- At the same time, the n value traditionally has been used to identify the creep mechanism.
- This is problematic knowing that, for example, the creep exponent for dislocation creep can take values from 1 to 50.
- It is documented that a stress exponent of 1 is not enough to identify the mechanism as diffusion creep.

Resolution, he stated, is in the use of basic (fundamental) models where the derivation of the model is based entirely on physical principles and all parameters are well defined and their values are known. There are no adjustable parameters involved.

He reviewed several models fulfilling these requirements, including:

- Models for dislocation creep covering low-to-high stresses.
- Models for solid solution and precipitation hardening during creep.
- Influence of prior cold work on creep life.
- Models for primary and tertiary creep.
- Initiation and growth of creep cavities.
- Development of cell and sub-grain dislocation structures.

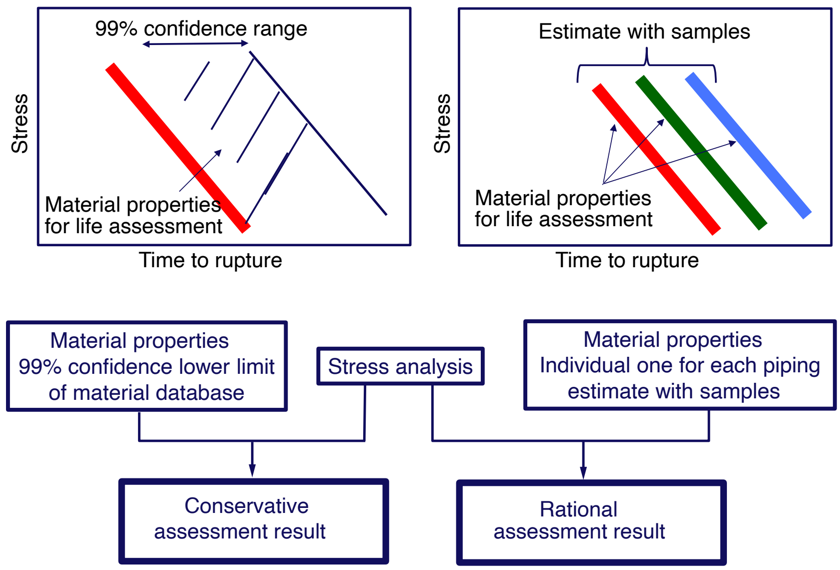
"These models have been established for some materials but not yet for a wide range," he stated.

He then listed and reviewed the basic models for predicting creep damage:

1. Particle formation, transformation and coarsening. Can be handled with commercial thermodynamic software such as Dictra, Prisma, and MatCalc.
2. Coarsening of substructure (important for 9Cr and 12Cr steels).
3. Initiation and growth of creep cavities.
4. Tertiary creep.

He went on to give specific examples.

"These models are predictable," he stated, "and can be used for generalization and extrapolation."



3. Comparison of conventional and proposed assessment methods

Single-crystal materials

Kurt Boschmans, ENGIE-Laborelec, Belgium, addressed evaluation of high-temperature creep degradation in single-crystal gas turbine materials through both conventional creep testing and small punch testing, comparing the methods.

In 2020, ENGIE performed a study to stretch the maintenance intervals of a gas turbine within its fleet by evaluating the condition of post-service turbine blades and vanes. In the framework of this study, the high-temperature creep properties of the materials were thoroughly evaluated.

"Historically," said Boschmans, "this evaluation has been performed by conventional creep testing on airfoil and root materials, and by comparing the test results to the known properties of the superalloys in question."

Boschmans then explained traditional comparisons of creep properties using a material-specific LMP (Larson-Miller Parameter) curve.

In the framework of the new and expanded data project, a comparison was made between the results of conventional creep testing (CCT) of sub-size creep samples and results of small punch testing (SPT). The goal was to evaluate whether or not SPT could replace CCT in cases where there is insufficient material available to extract an acceptable creep sample from the available hardware.

"Conventional creep testing," he explained, "has a minimum size requirement: M5 sample with diameter of 3 mm to allow creep testing in air. Sample extraction thus becomes critical for first-stage blades, as well as for evaluating aeroderivative gas-turbine hardware, putting limits on the method."

The option of using sub-size samples, he explained, is possible but expensive. SPT requires much less material (a 0.5-mm-thick disc-shaped sample), but at the time of this study:

- No internal experience was available.
- Registered exporter (REX) data on single-crystal superalloys (anisotropic material) was limited.
- There were no known comparisons of both methods on the same turbine blade.

Several studies were reviewed indicating that a relationship (conventional versus small punch) appears valid for highly anisotropic materials such as single-crystal superalloy in certain conditions. A good LMP-curve correlation was reviewed.

"Results confirmed that the material properties at high temperatures are still corresponding to the requirements of new material, suggesting a stretching of the maintenance interval is possible for the specific blade studied." However, this study is recent and microstructural evaluation of the test sample is ongoing (as of April 2021).

Conclusions:

1. Evaluation of high-temperature mechanical properties of the same turbine blade by means of CCT and SPT verified both the feasibility and accuracy of small punch testing, for which no internal experience was available on single-crystal superalloy materials.
2. Test results illustrate the SPT results show a good correlation with the CCT that was performed in parallel.
3. For superalloy materials where the extraction of creep test samples is not possible, the application of small punch testing can provide an economical alternative to sub-size creep testing.

Operation in creep conditions

Jerzy Trzeszczynzki of Pro Novum, Poland, discussed the conditional operation of boiler components working under creep conditions until replacement, using a large utility boiler as an example.

One of the more serious operational problems is thermal-fatigue damage detected on internal surfaces of pressure elements (steam coolers and superheaters), especially those working under creep conditions. "Such damages are practically irreparable," he said, "especially during a planned outage. They typically require fabrication of new elements."

Using the technology of *digital twins*, fracture mechanics, and remote diagnostics, Pro Novum has developed and implemented a methodology of conditional operation (until the element is replaced or the boiler is shut down) that allows supervision of the damage under the control of an appropriate software. "The system can simultaneously control the possible development of a dozen or so damages and assess the condition of the element online," he explained.

The elements operating the longest in these test conditions have worked for two years. Ultrasonic testing during operation, and destructive tests after the disassembly of the elements, confirmed the possibility of computational monitoring of crack propagation with an accuracy sufficient for practical operational purposes.

Examples also were described for headers that received endoscopic examinations during a utility boiler renovation in 2018. Crack depth ranged from 2 to 10 mm.

These components work in creep conditions, but periodically are exposed to thermal fatigue and thermal shock because of water-injection and condensate events.

The program goal was to further assess damage through fracture mechanics and achieve a schedule for conditional operation. This would include monitoring of working conditions, and periodic assessment of the technical conditions.

Trzeszczynzki summed it up: "Component replacement time can be determined with acceptable accuracy by monitoring conditions of the initiation of new cracks and the propagation of the existing cracks using the online calculation method and by verifying the calculations with controlled endoscopic and ultrasonic tests."

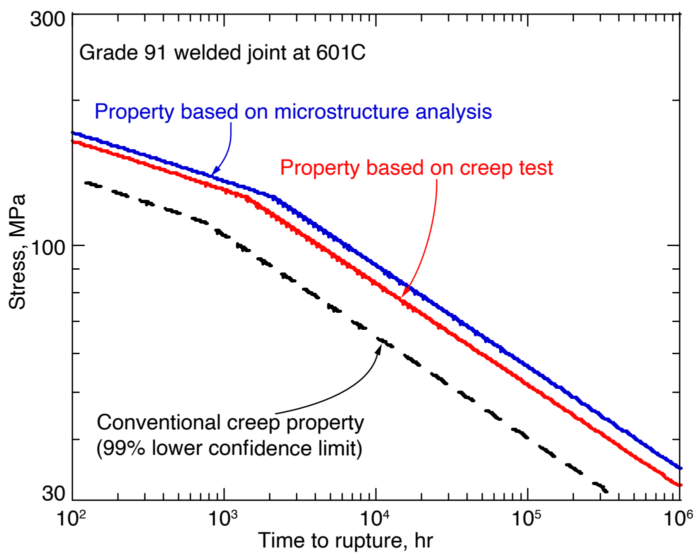
Using data scatter

"There is a large amount of scatter in the creep properties of welded joints of the steels; however, the scatter is not considered in conventional remaining-life assessments of welded joints of in-service piping." This was the presentation opening by Masatsugu Yaguchi, Materials Science Research Laboratory, Central Research Institute of Electric Power Industry (Criepi), Japan.

"Thus," stated Yaguchi, "we have developed a new method of assessing the individual creep properties of welded portions of actual pipes."

This presentation explained the assessment method and described the actual implementation for Grade 91 steel, as an example.

The premise: "Data scatter (heat-to-heat variations) has not been considered for remaining-life assessment. Test specimens are taken to conduct creep tests and to analyze the data, but there is no data for the actual component."



4. Application of remaining-life assessment to piping weld joints at an ultra-supercritical power station

In Japan, the common method of remaining-life assessment for materials is the 99% lower-limit curves for data obtained at various temperatures, on a typical stress versus time-to-rupture diagram.

The question remains: "Is the 99% lower limit, or minus-20% strength, really 'the weakest?' Also, materials used in creep tests do not cover all specification ranges of Grade 91 steels (Fig 3)."

"Therefore," stated Yaguchi, "consideration of heat-to-heat variations is important."

The institute's program objectives: Propose a life-assessment method considering heat-to-heat variations, develop a database and elemental technologies for Grade 91 welded joints.

In the method described, the creep property of the welded joint is related to that of each base metal because the creep properties of welded joints strongly depend on the creep life properties of the corresponding base metals.

Microstructure analyses and small punch creep tests on samples cut from the base metals at the outer surface of pipes in service were conducted, and the results were compared with a material database to estimate the creep property of each base metal of the target pipe.

The precision of the remaining-life assessment of pipes is significantly improved using the developed method because it can consider variations of the creep properties of their materials, which are not considered in existing life-assessment methods. Then, the method was applied to the welded joints of the pipes in ultra-supercritical power stations during periodic inspections, and remaining lives of the components were estimated (Fig 4).

Research continues at the Central Research Institute of Electric Power Industry, Yokosuka, Japan.

Looking ahead

European Technology Development has been deeply involved in HIDA conferences for more than two decades and will continue to both participate in and organize future conferences. Cooperation and knowledge gained from these events are critical elements of ETD's ongoing commitment to the global power industry.

Other examples of the consultancy's involvement include a recently published study titled "Review of 9-12Cr Martensitic Steels for Pressure Vessels, Steam Piping and Tubing," focusing on Grades 91 and 92.

The guidelines presented in this report are based on the experience of ETD Consulting, the reports and experience of its International P91 Users Group and ETD's network of consultants, the experience of international industry in general, EPRI guidelines, and latest research findings. It can be a valuable resource to plant owners/operators for material quality control, fabrication/welding, inspection, monitoring and repair, and for understanding the incidents of cracking/failure and how to deal with these.

The guidelines are of greatest value to decision-makers at plant design firms, plant owner/operators, service providers, and steel producers. For more information, contact enquiries@etd-consulting.com. CCJ

Blackhawk

Trending data 24/7 helps improve plant availability, reliability

Challenge. Operate at high availability to assure reliable steam flow to the plant's host refinery. Any forced outage has the potential to cause the steam host to lose millions of dollars in product.

Solution. To help assure reliable steam and electric production, Blackhawk personnel implemented a PI trending system to track plant performance around the clock (Fig 1). This upgrade has proved effective in detecting potential problems and enabling timely fixes.

The PI system is used to collect data in Microsoft Excel and PI Processbook, thereby allowing operators to view trends on a computer screen above the DCS operating screen (Fig 2). Blackhawk currently runs a set of PI trends that coordinate with the operating screen. Example: If the DCS screen is on the drum and deaerator page, the PI trend above that screen will be trending drum and deaerator levels, valve positions, temperatures, and pressures.

Running PI system trends above the relevant DCS operating screen has proven vital to plant operation. The PI trends let the operators know exactly how their equipment is functioning. It has prevented equipment damage, unit trips, and environmental impacts, while keeping staff informed on how efficiently the equipment is performing. PI trends also assist as a great training tool, allowing new personnel to see how plant equipment and processes respond to operational changes.

Results. Here's an example of how the PI trend above the operating screen prevented a unit from tripping: A CRO was dispatched to make load changes on his units to match grid demand. Power output was reduced on both units and monitored after reaching the desired megawatt setting. Everything was within normal limits; units were on set point with no abnormal DCS alarms.

The operator glanced up at the PI trends to double-check his moves and the system. He noticed that turbine vibrations were slowly increasing after the megawatt change. While they were not enough to trigger a DCS alarm at that time, the vibrations had changed

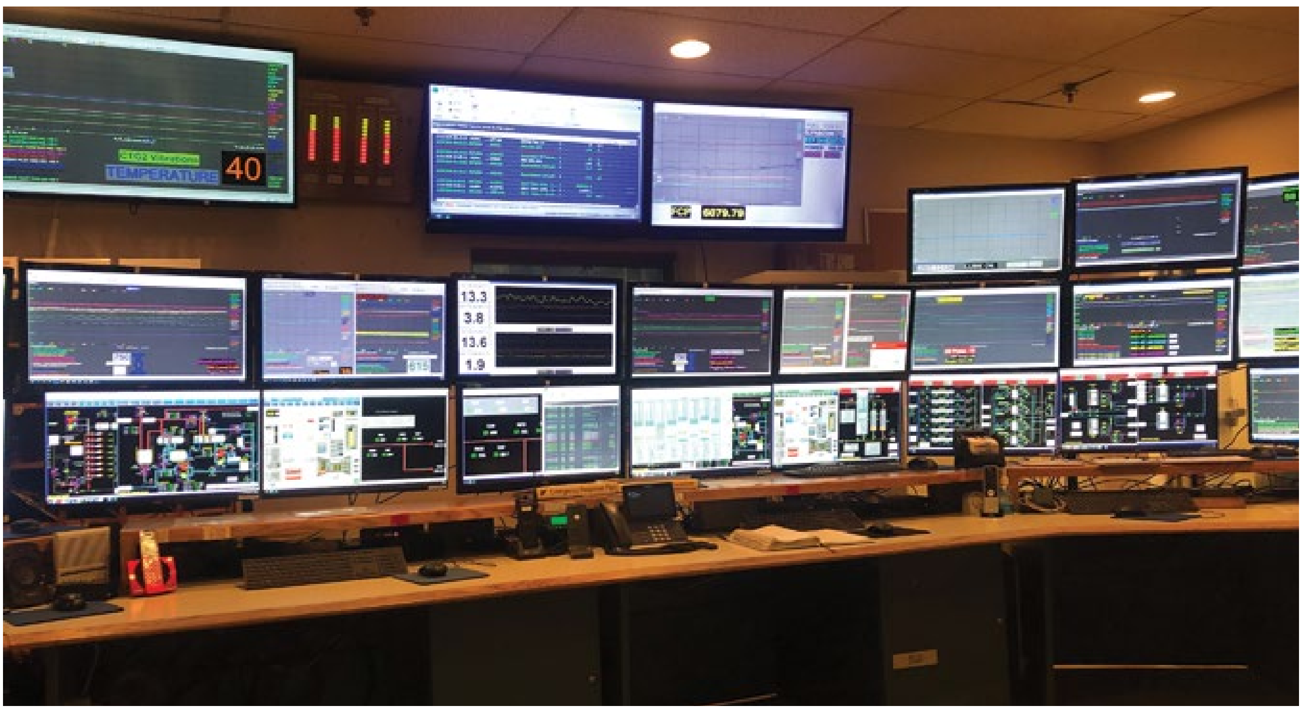
Blackhawk Station

Owned by Western Generation Partners LLC

Operated by CAMS

230-MW, gas-fired, 501D5A-powered 2 × 1 combined-cycle cogeneration plant located in Borger, Tex

Plant manager: Bryan Stout

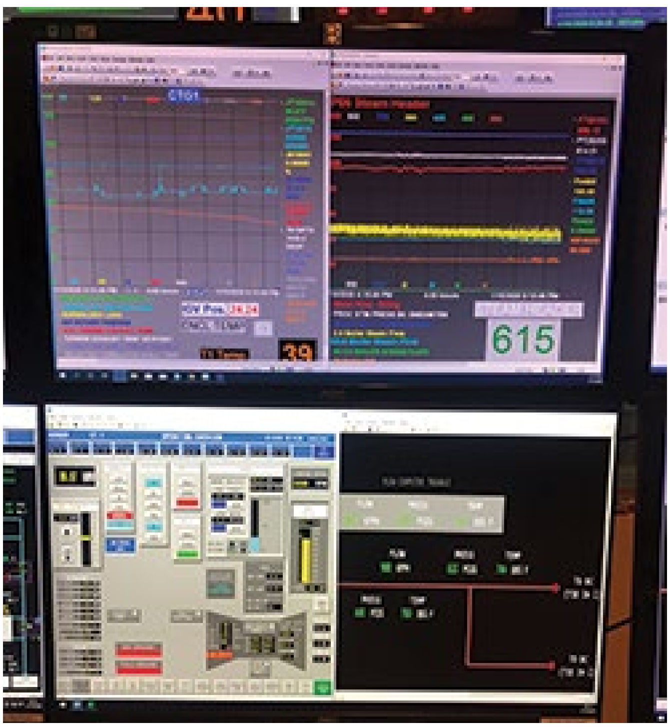


1. Data trending is critical to top performance at Blackhawk from where they normally were at this load on the turbines. The operator watched the vibrations continue to climb.

The supervisor was informed of the situation. A solution was suggested and implemented, resulting in the vibrations backing down to a normal level. Had the PI trend not been available, the operator would not have known turbine vibrations were increasing until a DCS alarm was activated. At that point it would have been too late to call the supervisor to discuss the situation.

Here's an example of how PI trends above and operating screen help boost efficiency: The deaerator (DA) at Blackhawk can use saturated or superheated steam for pegging. To increase efficiency, saturated steam is supplied to the DA from the boiler drum.

While returning a unit to service after a scheduled outage, with a new operator on the board, the startup went well and everything was looking fine. The outside operator came in from making rounds and looked over the PI trends to see how things were going. He noticed that the temperature of the pegging steam was trending higher than normal.



2. PI trends at top coordinate with the lower operating screen

The CRO was informed; sure enough, the pegging steam was superheated, not saturated. The cause: A check valve did not close for some reason. The operator went back outside and made some valve adjustments that allowed the check valve to close and supply saturated steam for pegging. The operator was able to glance at a set of trends and catch the issue early.

PI trends also have proven vital during gas-turbine trips, to help understand why the trips occurred.

Blackhawk has experienced increased reliability, efficiency, and other benefits from running PI trends above the corresponding DCS screen.

Project participants:
Steven Frick, CRO
Michael Martinez, CRO

GENERATOR USERS GROUP™

GUG2020

Concluding coverage

The 2021 conference of the Generator Users Group was a virtual event like the highly successful 2020 online meeting. This year's conference, conducted under the Power Users umbrella, aired on consecutive Thursdays from July 15 through August 5, plus Wednesday, July 21—too late for technical coverage in this issue of CCJ.

Steering Committee Chairman Dave Fischli of Duke Energy opened the meeting on the 15th at 11 a.m. Eastern US, the starting time for each day of the conference. Sessions ran through 3:30 p.m. each day. Topics addressed in user and consultant presentations include axial migration of rotor coils, rotor failure after flux-probe test uncertainty, rotor tooth-top cracking, retaining-ring inspection and testing, radiographic inspection of phase straps, stator-winding collateral damage attributed to an isophase bus fault, EMSA mapping of a stator, fault inspection criteria for large current surges, and stator-winding resistance tests.

Presentations are available to registered owner/operators in the GUG area of the Power Users website at www.powerusers.org. Included are the PowerPoints from several of the leading vendors in the generator community—including Cutsforth, National Electric Coil, Magnetic Products and Services, Omicron Technologies, BPhase, and AGT Services.

If you have never attended a GUG event, the summaries of user and sponsor presentations from Weeks Three and Four of the 2020 virtual meeting in this issue of CCJ will speak to the value of participation in a future conference. Information shared at these forums, vital to your professional development and your plant's success, is available only through Power Users.

Registered owner/operators also can access the user and consultant experiences and presentations made by third-party products/services providers during Week One of GUG2020 (November 12) on the Power Users website. For technical presentations made by the OEM during Week Two (November 19), visit GE's MyDashboard website at https://mydashboard.gepower.com.

Weeks Three and Four

User and consultant presentations

Use of an ultrasonic device for locating hydrogen leaks

A handheld ultrasonic instrument commonly used for detecting vacuum and air leaks in powerplants is good for locating leaks of hydrogen and other gases as well, reported an experienced user.

The Fluke ii900 Industrial Acoustic Imager (a/k/a sonic leak detector) relies on an array of 64 digital mics to locate the source of the sound (Fig 1) within a frequency band of 2 to 52 kHz. Practically speaking, the instrument can detect a 0.005-cfm leak at 100 psig from up to 33 ft away. It doubles as a camera capable of capturing stills and video, and has a USB-C port for data transfer.

Fig 2 shows the acoustic signal developed by a small hydrogen leak from a generator bushing.

The speaker cautioned that sound can reflect off surrounding surfaces and could be misinterpreted as a leak in the wrong location. If a potential leak source is identified, he recommended viewing the same location from a different angle or distance to verify that the leak source is "true" and not a reflection. Fig 3 is an example of a leak indication caused by sound reflection. The false indication was verified with helium testing.

A thorough understanding of a turbine's gas piping system and design benefits accuracy. The user added that the default frequency range and filter settings are acceptable for most compressed gas leaks but may require adjustment in noisy environments. This is a trial-and-error "tuning" process.

User safety—avoidance of slips, trips, and falls—was stressed. Surveyors should remain aware of their surroundings while walking and viewing the screen during scans, attendees were told.

Origins of EMI: History and New Research Users Group

The value of radio frequency (RF) for sensing incipient arcing faults in large generators is well known to electrical engineers serving in powerplants. However, questions remain on how to interpret the RF spectrum signature created by high-frequency currents flowing in the neutral connection. The speaker said there are many possible sources of RF signals—some are within the generator, some external to the generator.

GUG steering committee for 2021

Chairman: Dave Fischli, *Duke Energy*
Vice chair: Jeff Phelps, *Southern Company*
Jane Hutt, *International Generator Technical Community*
Joe Riebau, *Exelon*
Craig Spencer, *Calpine*
Kent Smith, *Duke Energy*
Jagadeesh Srirama, *NV Energy*

Founding members of GUG who recently retired from the committee are John Demcko of EUMAC Inc and Ryan Harrison of Heartland Generation Ltd (Canada).

The idea for a generator users group, and the energy behind its launch came from Clyde V Maughan, president, Maughan Generator Consultants, Schenectady, NY. Maughan retired from active participation in the organization a couple of years ago. He turned 95 early this month.

In the first group are the following:

- Partial discharges (corona) within the stator-winding insulation.
- Slot discharges between coil surfaces and the stator iron.
- Sparking from exciters with brushes.
- Arcing between adjacent ends of a broken coil strand.

The second group includes the following sources:

- Corona and partial discharges in the associated high-voltage power system.
- Lightning and switching surges.
- Motors, switches, and other sources in the power station.

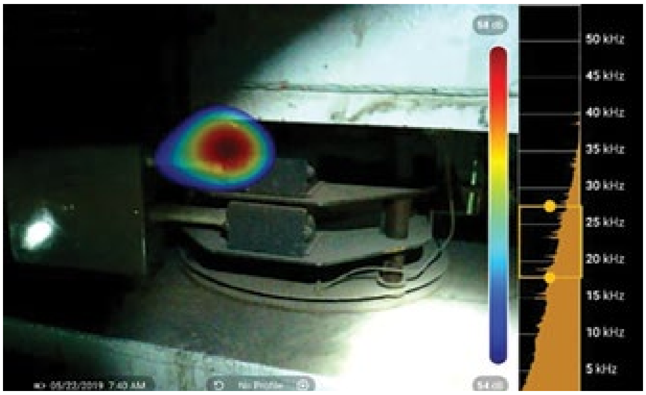
Application of the RF arc-sensing technique is straightforward. To measure the complete spectrum, simply clamp an RF current transformer around a generator neutral. Radio noise meters covering the frequency range of interest—about 10 kHz to about 32 MHz—provide the measurements in microvolts quasipeak (µVQP). This is explained as sort of a weighted average approaching the true peak value of the frequency component being measured.

Numerous RF measurements from operating machines have resulted in recognizable RF spectrum signatures, generally repeatable and believed to represent the background levels of normally operating machines free of any arcing condition.

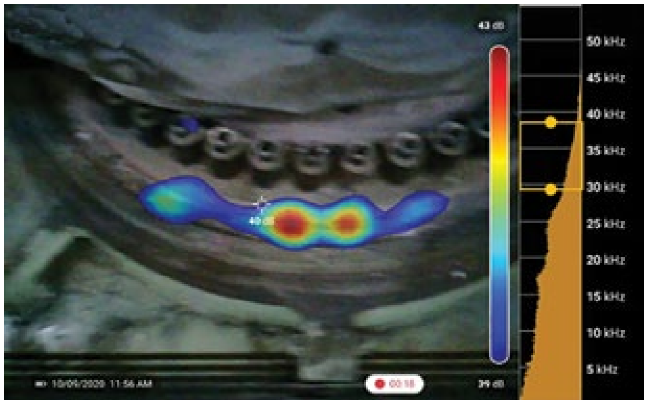
Note that preliminary measurements suggest that RF noise external to the generator (refer to short list above) is insignificant.

The speaker called for the formation of a new industry group—perhaps something like one of the users groups covered regularly by CCJ—to research EMI (electromagnetic interference) signature correlation to a given fault condition, develop tools to interpret the signature to fault conditions, and document and communicate the knowledge worldwide.

1. Sonic leak detector relies on an array of 64 digital mics to locate the source of the sound



2. Small hydrogen leak from a generator bushing is identified here



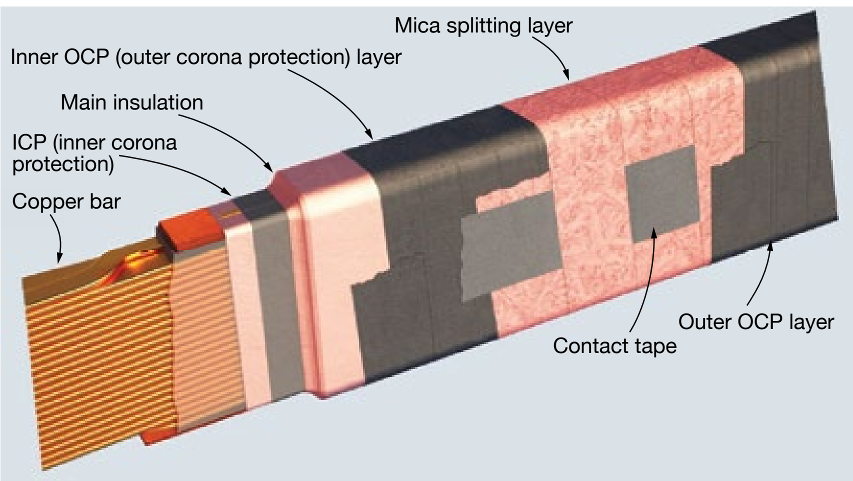
3. Helium leak testing can be used to confirm leak location where sound reflection is suspected

One of the tools at the disposal of the proposed research group is an electromagnetic transients analysis program, called ATP, developed by Bonneville Power Authority under a federal grant. The speaker said the program has a significant number of users sharing results globally.

GVPI stator-bar failure root cause, lessons learned

This is a well-illustrated presentation many O&M technicians can learn from. It addresses the failures of two different SGEN6-1000A generators serving gas turbines in a 4 × 1 combined cycle. The four units are characterized by globally vacuum pressure impregnated (GVPI) stator windings (Fig 4).

The first failure was on a 245-MVA, 15-kV machine after nine years of operation. An incorrect cable termination was used during plant construction. The spec called for unshielded cable, but 2/0 shielded cable was used and the shielding was not removed for the approximately 8 in. needed at termination. Because the shielding was not stripped back, it was within strike distance when the fault occurred. The current jumped into the shield rather than travel in the cable conductor, thereby overheating and failing the cable.



4. Global vacuum pressure impregnation (GVPI) system for stator windings, introduced in 1988, has been used on well over 1700 stator windings in service with a total capability of about 250,000 MVA

5. Bearing electrolysis damage and a broken shaft grounding brush were revealed during an inspection to determine the cause of high vibration

The second unit failed a stator-winding hi-pot after 10 years of operation. The test target was 33 kV, 2.2 times rated voltage, as it was for the first unit discussed above. In one phase a bar failed at 30 kV and in another phase a bar failed at 16 kV. Visual inspection showed an "insulation anomaly" on the top surface at core exit on both failed bars. Two other bars that had not failed also displayed the same insulation anomaly.

Several stator bars were extracted for root-cause analysis. A full rewind was performed on this stator. The slides did not comment on the difficulties of removing bars from a GVPI winding.

A CT scan on two failed bars showed signs of what appeared to be insulation cracking internal to the bar at the location of the ridges on both bars that failed the hi-pot, as well as the other two bars with ridges in the insulation. These flaws would be a very serious concern to the fleet of similar units, but the slides did not comment on this issue.

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

In-service inspection of generator retaining rings became an industry standard practice for plant owner/operators in North America and Europe during the mid-1980s, reminded Neil Kilpatrick, principal at GenMet LLC, a respected consultancy on generator metallurgical matters. Many 18Mn5Cr rings, the standard until that time, were found to exhibit significant stress corrosion cracking and most were replaced with 18Mn18Cr rings, which are not susceptible to SCC in water.

But the materials change does not mean you no longer have to perform periodic ring inspections, Kilpatrick said. You never know what might go wrong. He said the following are typical of the failure mechanisms which could cause concerns:

- Fatigue fracture (start/stop).
- Fault-related electrical damage to rings.
- Fault-related friction damage to rings (rubbing).
- Subsynchronous oscillation, with torsional fretting and fatigue cracking.

GE 7FH2 extreme vibration during LCI operation

Generator vibration observed during a turbine start using a LCI (load-commutated inverter) was "impossibly" high, the speaker said, showing comprehensive data plots on two slides. Focus of the initial inspection was on bearings (wiped? debris in lube oil?), LCI function, and lift oil (working properly?). LCI was later dropped from the list because it was shared with a sister unit onsite with no issue.

GE suggested the cause might be turn shorts, based on its review of the data.

The engineering inspection and evaluation team identified electrolysis at the bearing (Fig 5), significant wear of hydrogen seals, broken shaft grounding brush, and a highly magnetized rotor (upwards of 450 gauss). Bearing repaired, shaft demagnetized to the extent possible with the rotor in place, a restart of the heavily instrumented unit was attempted. Seismic probes revealed an "impossible" 306 ips at 600 rpm.

Flux-probe waveforms showed a coil-to-coil short, with all the turns in one coil and half the turns in another being bypassed. The practical solution given time constraints: a rotor swap. Photos of initial findings when the unit was opened revealed deformed pole-to-pole connectors. Important to this discussion was that the normal pole crossover for a 7FH2 machine was not used when the generator was rewound previously by an alternative OEM and the replacement failed at about 700 starts and 11,500 hours.

Shop work included replacement of the two affected coils using pole-to-pole connectors of the generator OEM's design. Problem solved.

Conclusions and lessons learned included these:

- Things can change completely from one start to another.
- Confirmed that turn shorts can cause exceptionally high vibration during an LCI start.
- Reinforced the need to inspect other units in the power generator's flee with a similar pole-to-pole connector.
- If it's not broken, don't try to fix it—referring to the change from the OEM's hairpin pole-to-pole design which has worked well over the years.

SFRA study on generator stator re-wedging

The Sweep Frequency Response Analysis test generally is associated by plant personnel with the physical condition monitoring of transformer windings. It is an efficient way to detect displacement of the transformer core, deformation and displacement of the winding, faulty core grounds, collapse of partial winding, broken or loose clamp connections, shorted circuit turns, open winding conditions, etc.

In this presentation, the speaker presented three case histories and more than 50 slides to show the value of SFRA in determining when stator re-wedging is necessary. There's still more work to do but the message is clear.

Wonder why wedge tightness is showing up in SFRA data? The speaker explained thusly:

- A loose wedging system opens clearances.
- Clearances permit movement of coils/bars to release installation/migration stresses.
- Movement opens gaps and contact points affect capacitance and inductive coupling, and resistance to ground.

Things to keep in mind when trying to apply the SFRA data include the following:

- Fresh paint affects readings; make sure all paint is cured before gathering data.
- Meaningful data are limited.
- The analysis presented is global in nature; local issues may not show.
- Coil/bar displacement is a dependent variable.
- The test cases presented are for hydrogen-cooled machines. In-slot partial discharge damage may affect readings for air-cooled generators.
- The test cases also are for 2-pole machines. It's unknown at this time if the same patterns apply to 4-pole and hydro units.

AeroPac brushless-exciter flashover

It's 0800 and the subject unit is synchronized with the grid; power is increased to 110 MW within the hour. Load is raised to 140 MW and the unit trips at 0915 on a loss of generator exciter voltage. The operator's screen reads, "AVR fault." No obvious issues are identified and the operators decide to re-energize the unit figuring the trip was "false." But the unit trips again before it can be synched.

Inspection with assistance from a third-party services provider identified dust on the excitation generator, which was difficult to access. Molten metal was found in the diode wheel; it took three shifts to remove. Decision was made to remove the complete excitation generator housing.

The rotor shaft was damaged during the incident (very deep gouge) so it was pulled and sent to a shop for inspection, analysis, and repair. Electrical test results with the rotor out were satisfactory. Another observation: All six diodes failed but investigators were not able to determine how many failed before the incident. An alarm indicating diode failure was never received. Diodes had never before failed on any of the company's generators.

Repairs: The portion of the shaft with the deep gouge was removed and a new piece welded it its place. The excitation generator and diode wheel also were scrapped. Shop discovery: A socket head cap screw was found wedged in the diode wheel casing and the connection from the diode wheel to the radial lead was melted in half. Electrical tests received a passing grade; the AVR was eliminated as the root cause.

With the RCA still in progress at the time of the presentation, the plant took the following actions:

6. The outboard collector ring (at right in left photo) and associated brush-rigging components suffered severe arc damage. The outboard collector ring as viewed from the brush rigging is in the right-hand photo

- Planned to check the tightness of all bolts during every major outage.
- Purchased a handheld device to monitor diode condition; data would be collected monthly.
- Initiated work with the OEM on changing the type of filters for the air-cooled excitation generator.
- Planned to clean the excitation generator every four years and to replace the diodes and their hardware every 10 to 12 years.

7FH2 collector flashover event

This presentation affords the rare opportunity to experience a collector flashover event, which lasted less than an hour, virtually. The generator damaged was a 239-MVA, 18-kV, hydrogen-cooled machine. Data, details in words, graphs of operating data, a dozen photos, etc, are provided.

The outboard collector ring and associated brush-rigging components suffered severe arc damage (Fig 6 left, outboard collector ring is at right in the photo): eight brushes detached completely, seven still attached by their pigtails were free of their holders, nine brushes remained stuck in their holders—attesting to the level of detail provided by the speaker. All 24 brush holders showed arc damage (Fig 6 right).

Repair scope included replacement of the following components:

- Entire brush rigging, including new holders and brushes.
- Both collector rings (the inboard ring could have been reused, however).
- Outboard collector terminal stud (the existing one had to be drilled out).
- Seal assemblies on both terminal studs.

Plus, shaft grinding was required to remove harden metal created by arcing.

Identification of the exact root cause of this flashover event was complicated because most of the evidence was vaporized during the incident. Insights gained during the inspection allowed elimination of the following possible causes as unlikely: short brushes, high brush vibration levels, inadequate ventilation, and ambient air contamination.

Among the contributors to this specific collector flashover were believed to be generally low current densities in the brushes, ineffective periodic cleaning of brush holders by contract personnel, poor contact between brush terminals (pigtails) and the outboard collector yoke assembly, and improper orientation of brush holders relative to the collector ring. In brief, the speaker believed the brush holders had outlived their useful lives.

The speaker offered the following characteristics of good collector assembly performance:

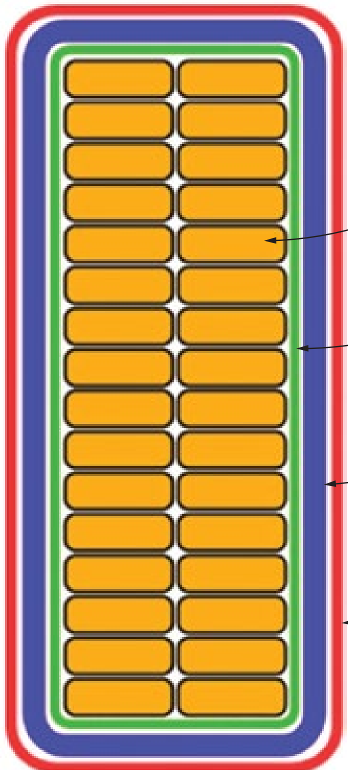
- Continuous contact of brush to collector ring.
- Proper brush-to-collector ring contact pressure.
- Good collector-ring surface film condition.
- Limited selectivity.

A proven maintenance approach to assure good collector assembly performance focuses on these points:

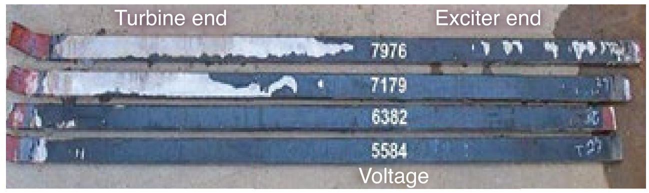
- Routine checks of collector assemblies with rounds on each shift.
- Weekly checks with the enclosure covers removed—including visual inspection, verification of no abnormal brush vibration, and confirmation of brush freedom of movement within the holders.
- Monthly, measure brush currents. Compare these to those from the preceding month to identify any obvious current selectivity.
- Identify and log specific deficiencies, if any, identified with the prescribed maintenance approach.

Special technical presentations

Presentations made by National Electric Coil, MD&A, AGT Services, and Siemens Energy to owner/operators participating in Weeks Three and



7. Stator-bar cross section shows inner and outer corona protection



8. Voltage is an integral factor for corona as the photo indicates. Elevated temperature acts to further promote the phenomenon. The higher the voltage and the closer corona attack is to the turbine end of the generator, the greater the damage, as evidenced by the amount of "bleaching" in the photo

Four of the virtual GUG2020 conference are summarized below. You can access the PowerPoints submitted by the first three vendors on the Power Users website at www.powerusers.org. The Siemens presentations are posted on the company's Customer Extranet Portal (CEP). For help in locating them, contact your plant's service representative.

Corona in HV stator coils: Theory, causes, repair, laboratory prognosis

W Howard Moudy, director of operations for National Electric Coil, is a frequent presenter at user group meetings. His goal here was to help plant personnel better understand what corona is, the damage it does, how to identify its presence, and the need to repair the damage it causes early, to avoid the possible need for a coil replacement.

But first, a brief backgrounder on the terminology, extracted from an article written for CCJ by Donald Selkirk, PE, of SaskPower several years ago. The terms corona and partial discharge (PD) are commonly used interchangeably in the electric power industry, he wrote. However, this is not correct.

Both corona and PD are electrical discharges that occur in high-voltage rotating machines (HVRM) when the strength of the applied electric field is great enough to cause ionization.

The IEEE Standards define corona as a "luminous discharge due to ionization of the air surrounding a conductor caused by a voltage gradient exceeding a certain critical value."

PD is not necessarily luminous or visible. Further, PD may not occur adjacent to an energized conductor and need not occur in air or gas. Additionally, a corona discharge may bridge the entire gap between energized conductors.

Moudy continued: Corona is a surface phenomenon (a "glow"), he said, that leaves its distinguishable mark on winding surfaces, both in the cell and end-winding portions of HVRMs. It is often caused by insufficient clearances between surfaces having different electrical potentials.

Corona also may be attributed to inadequate functioning of the gradient portion of the outer corona protection (OCP) wrap encapsulating stator bars (Fig 7). Erosion of the OCP, he continued, can develop from inside the coil when the ground-wall insulation near the OCP is of poor quality. Mica is a material that may best inhibit corona attack on ground-wall insulation.

The insulation binder is attacked first, followed by the conductive fillers of the OCP material, which may be destroyed. This allows the corona to reach the OCP surface, where it is easy to recognize (Fig 8). Moudy noted that OCP repairs made prior to deterioration deep into the ground-wall insulation are most successful. Given reasonable access, he said, future deterioration in the area of repair can be prevented. Then the prognosis for long-term reliability is very good.

HV generator stator ground insulation repairs

This presentation by National Electric Coil's W Howard Moudy, director operations, and Gary Slovisky, director of field service, discusses in meaningful detail two case histories—one concerned with the repair of ground-wall insulation, the other with OCP (outer corona protection) repair. The second is a sequel to Moudy's first presentation (immediately above).

Before committing to a repair, the speakers began, there are things you should know—including the following:

- Understand the cause of the failure.
- Determine the full extent of damage and the suitability of undamaged components.
- Identify the repair options.
- Consider the practicality of the repair options identified and their associated risks, and the prognosis in terms of reliability.

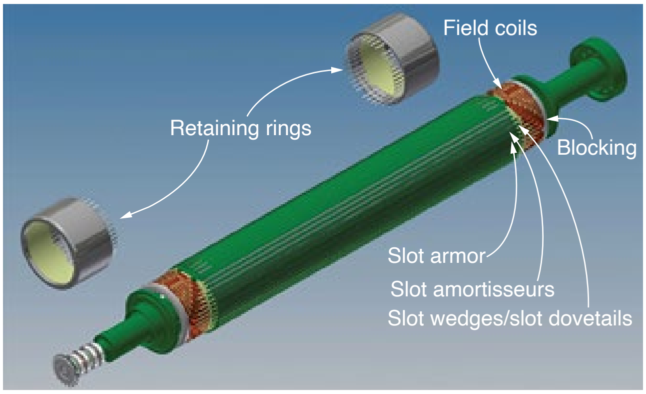
Participation and guidance by experienced personnel with a bit of wisdom is essential for a successful outcome, Moudy and Slovisky said. Keep in mind that access and space often are the greatest obstacles in making repairs in the field. Creativity, patience, and experience are essential to overcoming these obstacles.

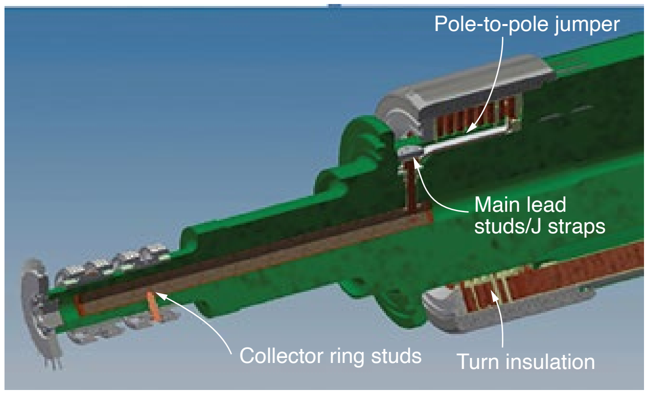
The root cause of damage to ground-wall insulation in the first case history was a rotor fan blade failure attributed to high-cycle fatigue. One of the 16 fan blades failed near its base but not at the weld joint. The liberated fan tip ring damaged the stator. The generator was relatively small, rated just under 22 MVA. The incident was characterized as a generic OEM design problem. The replacement 13-blade fan was machined from one block of ASTM 4340 alloy steel (no fan tip ring).

Interestingly, some owner/operators of air-cooled condensers equipped with fans having an even number of blades, identified with this problem. Their issues were resolved as well by transitioning to a fan with an odd number of blades.

These three repair options were considered:

- Repair failed and damaged coils in-situ and onsite. This offered the shortest delivery time and lowest price, but the lowest evaluated reliability.
- Factory repair and reinsulate the two failed coils; repair other damaged coils onsite. This option was penalized by a slightly longer delivery time than repair and about twice the cost of repair. However, it was less than one-third the rewind





9, 10. Know your field. These companion illustrations identify key rotor components to help you follow the accompanying discussion without hesitation

cost and offered a good evaluated reliability.

- A complete stator rewind was characterized by longest delivery time, highest price, and highest evaluated reliability.

The first option was selected. Presentation illustrates how the groundwall insulation was repaired successfully, step by step.

The second case history reviews OCP field repairs to a pumped-storage hydro generator and to a generator for an F-class gas turbine. Critical to achieving a successful OCP repair are the following:

- Expertise and skilled labor.
- Use of materials of the highest quality and of proven engineered processes.
- Assuring an appropriate interface with the ground plane (core).
- Thorough mixing of semi-conductive and gradient coating treatment materials.
- Application of the gradient coating in a manner to assure proper/adequate overlap with semi-con coating.
- Ensure adequate cure time.

Preparing generator rotors for cyclic duty

James Joyce, manager of generator repair operations at MD&A, set the scene with his opening statement: "The impact of cyclic operation on ac generators is significant. As more units transition from baseload to cyclic duty, the thinking behind generator maintenance and repairs needs to adapt."

Keep in mind that baseload units operate under creep conditions—that is, constant stress—while cyclic units are challenged by the fluctuating stresses consistent with fatigue conditions.

Major contributors to increased wear on generator rotors in cyclic service, he continued, are these:

- Different rates of expansion and contraction of rotor components in close proximity to each other that are made from different materials. Examples include copper coils, insulation, and steel forging (Figs 3 and 4).
- Expansion and contraction of the retaining rings caused by centrifugal force.

Recall that heating of the rotor winding generally is the limiting feature in generator design. Thus, generators cooled by hydrogen, a more-efficient coolant than air, and are smaller than air-cooled units of similar output and issues related to the expansion and contraction of components are not as severe.

Important to note, Joyce said, that generator manufacturers are under increasing pressure to reduce costs and necessary decisions on conductor cross section, insulation thickness, the amount of steel in the core, etc, negatively impact a generator's ability to absorb the increased mechanical and electrical stresses of cyclic duty. This puts pressure on O&M personnel to operate their machines within limits suggested by designers to assure the desired levels of reliability and availability can be achieved.

Joyce's presentation focused on case histories illustrating the effects of cycle duty on the generator fields for a 450-MW hydrogen-cooled unit, a 200-MW hydrogen-cooled unit, a 300-MW air-cooled unit, and an 80-MW air-cooled unit. You can learn a great deal from the PowerPoint because the speaker shares the planned work scope for the shop visit, what was found during the inspection, emergent work required, solutions selected, etc.

Highlights include the following:

- Cracked blocking required replacement with an enhanced design to prevent crushing and delamination.
- Replacement of original Nomex turn insulation with a glass laminate material which does not absorb moisture to the extent that Nomex does.
- Modification of a full-length slot amortisseur, springs, and creepage blocks to accept a top hat pin which locks all three components together, thereby preventing the springs under the slot amortisseurs from migrating during operation.
- Replacement of original slot armor with Teflon-coated Nomex. Note that the relative movement of the copper coils during load cycling can lead to abrasive damage to the slot armor. The Teflon coating provides a slip plane to mitigate this.
- The original pole-to-pole connectors were susceptible to low-cycle fatigue as the copper coils expanded and contracted during cyclic operation. They were replaced with an improved design more capable of handling the additional stresses associated with cyclic duty.
- Copper deformation from cycling dictated coil replacement. Plus, there were broken main leads not normally seen in situations involving high cycles; they too were replaced. New retaining-ring insulation also was installed, the replacement with a Teflon slip plane to prevent the end-winding top turns from deforming while expanding and contracting axially as they heat up and cool down.

Generator findings and case studies

James Joyce's second presentation provides valuable information for all involved in generator-maintenance decision-making. You've heard at user-group meetings about outage extensions to deal with emergent work and may be wondering just how often such incidents occur. Joyce shares MD&A's experience from the 18 months preceding his presentation Dec 3, 2020 to illustrate how important it is for you to operate your generator within the bounds of the OEM's recommended practice, review operating data with a keen eye, conduct appropriate tests periodically, and to continually plan for the outage ahead—all this to minimize the number of surprises at the next overhaul.

The manager of generator repair operations said that most fields that come into MD&A's shop fall into two categories: rewind, or rings-off inspection with a defined scope that does not involve a rewind—such as blocking mods, deep cleaning, or simple testing and inspection.

In the last 18 months, he said, 70% of the units that came into the shop were scheduled ahead of time. The rest were the result of a forced outage. In that latter group, about 12% participated in a field-swap program to minimize outage time. Roughly one-quarter of the scheduled visits required an outage extension because of emergent work (expansion of the original work scope).

Analyzing the root causes of field rewinds, Joyce said 46% of the generators had to be rewound because of a shorted turn or ground fault, 38% because of a main lead or mechanical failure (the latter category includes failed blocking, copper mushrooming, etc), and 12% because of contamination (such as foreign material blocking ventilation passages) that could not be removed. The remaining rewinds were age related.

Joyce concluded his presentation with two case studies, one involving a collector-ring failure, the other damage attributed to loss of lube oil. The first resulted from a flashover between the brush rigging and field forging. Once the flashover occurred the collector-ring insulation was compromised, allowing a ground fault from the collector rings to the field forging. Many photos illustrate the extensive damage incurred.

The field winding was unaffected by the flashover. This allowed removal of the damaged section at the end of the rotor and installation of a stub-shaft in its place. Machining of the turbine end journal and oil-deflector surfaces was part of the rework required. Successful inspections and high-speed balance confirmed the field was fit for duty.

The lube-oil failure experienced during startup after a maintenance outage did considerable damage. It occurred because the lube oil to the generator bearings was inadvertently shut off. The incident screamed for attention to detail on the deck plates, the use of checklists, and multiple pairs of eyes on everything.

The resulting bearing failure caused the shaft to drop about 200 mils. The rotating blower hub blades then contacted the stationary housing and shredded, sending the stainless-steel blades throughout the unit. Repair work included machining and weld restoration of journal and seal areas to eliminate hardness, installation of a stub shaft, a rewind and replacement of all insulation components, and blower replacement.

GE GT- and ST-driven generator field repair needs

AGT Services' Jamie Clark has been on a mission for the last couple of years, presenting at the annual meetings of all major users groups to alert owner/operators about the significant increase in generator failures his company and other service firms are seeing. Clark's thoughts echoed those of MD&A's James Joyce in his presentation a week earlier, "Generator findings and case studies" (see above).

Both Clark and Joyce share the view that the failures experienced today are related in large part to unit cycling (in particular, those machines designed for baseload service) and age, with lapses in attention to detail during inspection and maintenance contributing.

Clark began his presentation with a chart illustrating the dramatic increase in the number of starts experienced by a combined-cycle plant in Maine over the last decade compared to the start stats for the facility's first eight years of service. An informal survey that he conducted at a recent meeting revealed a 50% increase in the number of starts among 7F owner/operators. That was an interesting factoid because about half of "planned" projects that AGT Services has been involved in lately have resulted in emergent work. Another 14% of the surveyed users said their starts had doubled, or more than doubled, over the last 10 years.

AGT is seeing more unplanned stator rewinds than ever, Clark continued. Same is true for field rewinds, he added, with some of those resulting from stator failures.

Clark then highlighted the primary areas of the stator affected by cycling, including the following:

- End-winding vibration/loosening, noting the higher risk for strand-to-strand series connections.
- Core-looseness impacts—such as keybar rattle/belly bands and loss of core compression.
- Slot support system—including wedge system and side packing/ripple springs.

The speaker stressed that all stator parts are designed to work together as a system. Example: Bellybands restrain keybars and when loose allow keybars to "rattle" producing particles of iron oxide. Add in some oil and you have greasing that lubricates the connections, further compromising tightness.

Clark's extensively illustrated presentation next walks you through the primary field components affected by age/cycling (or design), focusing primarily on GE 7FH2 and 324 generators. Below is a list of the topics he covers. One or more has to be of sufficient interest to warrant a review of slides on the Power Users website.

Slot component migration
- Creepage block
- Amortisseur springs
- Slot armor deterioration (birth or prior repair defects)
- Turn insulation

Distance blocking movement
- Axial blocks
- Radial blocks

End turn insulation migration

Copper distortion
- Main leads, crossovers
- Elongation/foreshortening
- Fat copper in the slots

Braze design/failure

Cracked brazes at corners and on crossovers and leads

Collector systems
- Leaking stud seals
- Collector ring/brush life
- Field ground detector inoperative

Case studies: Cycling impacts on generators

Alejandro Felix, manager of generator service engineering, focuses in large part on the effects of flexible operation on stator end windings and then discusses the OEM's innovative technologies to address flex-operation needs. For rotor components these include new designs for J straps and pole crossovers. For the stator, new rewind designs are more capable of absorbing axial thermal expansion of the coils. The presentation concludes with a look at Siemens' service solutions to support flex operation.

Third-harmonic stator ground protection

Tony Cararano, solutions engineer, digs into the details of third-harmonic voltage and how to assure 100% stator ground protection not assured by adhering to IEEE standards. Readers may recall that Consultant Clyde V Maughan sounded the alarm on this oversight in the standards in the pages of CCJ several years ago (2Q/2013) after it had cost the industry hundreds of millions of dollars. Topics discussed include 59N neutral over-voltage, 27TN third-harmonic neutral under-voltage, and 64S subharmonic voltage injection. Three case studies provide valuable insights.

Hi-pot testing approach

Jim Lau, expert engineer and one of the industry's most highly regarded electrical engineers, provided a backgrounder on high-voltage testing, covering both ac and dc tests. Dielectric evaluation, preparations to test insulation resistance and polarization index, the value of pass/fail dc hi-pot testing, partial-discharge testing, low-voltage power-factor testing are among the topics reviewed. CCJ

STEAM TURBINE USERS GROUP

STUG2020

Concluding coverage

The 2021 conference of the Steam Turbine Users Group (STUG) will be an in-person event at the Marriott St. Louis Grand, August 23-27, and co-located with the annual conferences for the 7F, 7EA, and Power Plant Controls user organizations—all organized and managed under the Power Users umbrella. Visit www.powerusers.org for program details and to register.

If you have never participated in a STUG event, the summaries of user and sponsor presentations from Weeks Three and Four of the 2020 virtual meeting that follow will encourage your attendance this year. This information, vital to your professional development and your plant's success, is not available anywhere else.

Registered owner/operators also can access the user experiences and presentations made by third-party products/services providers during Week One of STUG2020 (November 11) on the Power Users website. For technical presentations made by the OEM during Week Two (November 18), visit GE's MyDashboard website.

Week Three

User presentations

Alstom MI with IP blade replacement and L-0 replacement

Reviews the planning and execution challenges associated with a recent steam-turbine major inspection, incorporating lessons learned. Background: The 282-MW Alstom steam turbine serving a 2 × 1 F-class combined cycle began commercial operation in 2003 and had a service history spanning 100k operating hours and nearly 600 starts. HP and IP steam conditions were 1050F/1975 psig and 1050F/483 psig, respectively.

Scope of work for the full-train (HP/IP/LP/Gen) major inspection included the following:

- Inspect HP turbine stop/control valve inspections, replace Radax blade row, and provide new rotor and casing seals.
- Inspect IP turbine intercept stop/control valves, replace Radax blade row and first- and second-stage rotating blades, install new rotor and casing seals.
- Replace LP turbine L-0 blades and refurbish LP gland housing.

Speaker shares with colleagues IP rotor findings and the two blading replacement options considered: restore to original design or leave as is. For the LP section, L-0 blades were removed and replaced onsite with mix-tuned blades (Fig 1); no balancing was performed. Unit was returned to service with no vibration or operational issues.

GE D11 casing cracks and repairs (2013-2020)

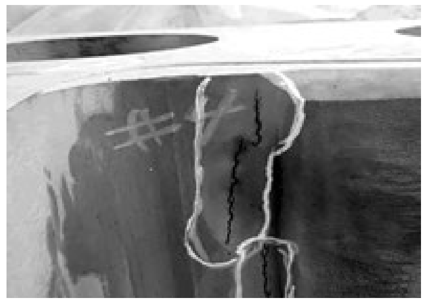
This presentation affords the opportunity to learn about the casing cracks and repairs made to a D11 steam turbine over the unit's life from COD in 2002 through its second major in 2020. The first major, conducted in 2013 after nearly 45,000 operating hours and

STUG steering committee for 2021

Chairman: Seth Story, Luminant
Eddie Argo, Southern Company
Jess Bills, Salt River Project
Jake English, Duke Energy
Jay Hoffman, Tenaska
John McQuerry, Calpine
Matt Radcliff, Dominion
Lonny Simon, OxyChem

Founding members of STUG who recently retired from the committee are Bert Norfleet (2019) and Gary Crisp (2020)

1. L-0 blades were removed and replaced onsite



2. Cracks of significant length and depth at this turbine's HP inlet were ground out and weld-repaired

3. Portable mill set-up on the horizontal joint helped to correct casing distortion nearly 1700 starts, was planned for 49 days but took 95. Operating hours at the start of the second major numbered about 98,000, but there were only about 120 starts in the second interval.

Inspection of the HP casing at the first major revealed cracks of significant length and depth in the inlet area (Fig 2). GE's recommended welding procedure was reviewed by owner and plant personnel. It included a post-weld heat treatment of about 1200F for the entire HP/IP casing. However, during this process the casing was humped, requiring another repair. It involved removing about 200 mils of material from the horizontal joint in the HP inlet area to correct the distortion (Fig 3). Plus, machining of the diaphragm fits/steam seal faces and casing reliefs with a boring bar.

With the turbine gods smiling, the unit was reassembled and restarted with no vibration issues or rubs in January 2014. No issues were in evidence prior to the second major. But staff was apprehensive as the unit was opened for inspection. One crack was found on both the upper and lower halves that required attention. It was ground out and weld-repaired.

Creep and diaphragm dishing were in evidence and the experts conducting the investigation said they expected a casing replacement might be required at the next major. In sum, personnel believe that heavy cyclic duty prior to the first major contributed to the severe cracking corrected in 2013. Baseload service in the second interval mitigated the underlying issue. But the lingering question was the following: At what point does the plant quit trying to repair and evaluate retrofit options?

GE rotor indication recovery

This analysis and repair of the rotor for a 523-MW GE G2 turbine is based on experience gained at the gas-fired steam plant since COD in 1973. Steam conditions for the unit, designed for baseload operation: 2270 psig/950F/950F. The first clue something was amiss was vibration identified in 2019—especially on the T1 and T2 IP bearings on coast down.

The unit was operated in the partial-arc mode and vibration occurred at certain valve settings. Going to full-arc admission eliminated the vibration. The unit tripped on high vibration in summer 2019. Upon disassembly, a 360-deg circumferential crack was found on the discharge side of the first-stage wheel transition area.

The rotor was shipped to the shop for additional inspection and evaluation. Cracking was found in other areas as well. Excavation of the first-stage crack was initiated, experts believing it to be at least 3 in. deep; it was 8 in. (Fig 4). Some details of the effort are shared in the presentation.

4. A 360-deg, deep rotor crack was excavated and weld-repaired allowing a return to service

Outage duration was approximately 230 days. Since returning to service for the summer 2020 run, the unit has behaved well. However, the extensive weld repair reduced the rotor's remaining life. A new like-kind rotor, in manufacture, is planned for installation early in 2022.

Post mortem: A review of vibration data from 2010 revealed clues regarding rotor cracking. The unit had operated for years outside the service parameters for which it was designed. The fast start/fast-ramp paradigm adopted, with 500-deg-F thermal ramps and a dispatchable load range of from 50 to 500 MW, took a toll. The replacement rotor in manufacture has design enhancements to better accommodate today's challenging operation requirements.

Special technical presentations

MD&A: Using turbine performance to improve your maintenance strategy

This presentation by James G Miller, PE, manager of performance services for MD&A, is a valuable primer for plant personnel participating in their first steam-turbine outage and equally valuable as a refresher for more experienced engineers and technicians. Miller's message: Use the results of (1) recent performance tests conducted with the unit in service, and (2) steam-path audits made in the early stages of the outage, to reduce both outage cost and duration.

Miller reminded attendees that performance losses are a sign of degrading conditions that adversely impact the plant's bottom line. The outage affords the opportunity to use this information for pursuing repairs and upgrades of greatest economic value.

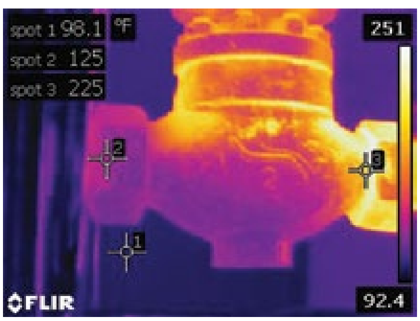
The speaker covered the basics of performance testing, and how to conduct the all-important steam-path audit, in his presentation, which is available on the Power Users website complete with formulas, calculation examples, a comparison of as-tested performance to reference data, etc.

Best practices in performance testing—such a making sure there's at least 25 deg F of superheat when calculating turbine efficiency—are included in the PowerPoint, together with a list of diagnostic parameters or additional tests that can be used to further characterize the sources of loss—such as solid particle erosion (SPE), casing leakage, and valve leakage. Thermal scans are particularly valuable for identifying the locations of leakage (Fig 5).

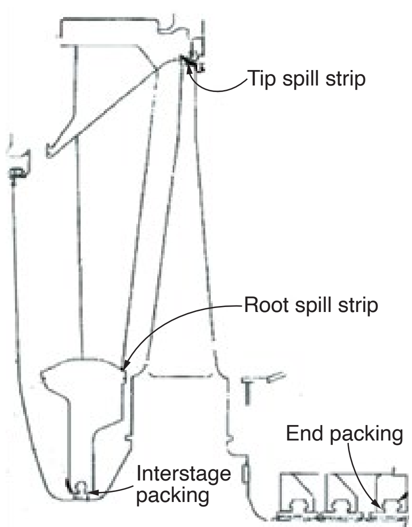
Examples of typical sources of performance loss identified during the steam-path audit include the following:

- Seal leakage (Fig 6).
- Surface roughness.
- Change in trailing-edge blade profile.
- Deposits.

Case studies identifying the rea-



5. Thermal scans are valuable for identifying where performance-robbing leakage is occurring



6. A steam-path audit can pinpoint locations of performance loss, such as those shown above sons for performance loss in a reheat turbine at a combined-cycle plant, in a reheat turbine for a conventional steam plant, and in an industrial double-extraction condensing turbine are highly informative. For the first unit, performance testing revealed gross output had decreased by 2.3%. Excessive surface roughness, worn end packing, rubbed tip spill strips, and leakage by startup vents and HRSG drains were among the primary contributors to the loss.

A checklist of information to review in overhaul planning concluded the presentation.

Shell Lubricants: Choosing your lubricant not a one-size-fits-all

Lubricant selection is one of those subjects you might not think about for years, but when needed it's good to have a backgrounder like this at your fingertips—or only a couple of mouse clicks away on the Power Users website.

Key discussion topics include these:

- Base-stock evolution (Groups I through V).
- Varnish.
- Mitigation methods for varnish—including top-off fluids, filtration units, and fluid solutions (polyalkylene glycol, gas to liquid—lubricants made from natural gas).
- Field experience.

Varnish elimination with polyalkylene glycol (PAG) was a focal point of the presentation, which included a review of experience since 2001 at two units that switched to PAG to eliminate servo valve issues caused by varnish. Since then there have been no servo failures or trips while on PAG.

Recall that the stress experienced by a turbine lubricant contributes significantly to the ageing of petroleum oil, causing the *non-polar* fluid to oxidize. However, the resulting byproducts of decomposition are *polar* and insoluble in the base oil; they come out of the solution as varnish. Polyalkylene glycol, by contrast, is a *polar* fluid and, while it too oxidizes, the byproducts of decomposition are *polar* and infinitely soluble in the base stock. No varnish is produced.

Week Four
User presentations

Maintenance of D11 stop valves and lessons learned

This is a fleet-wide perspective on valve maintenance based on operating-hour intervals and managed by the utility's program called Optim. Focus is solid-particle erosion of valve stems (Fig 7) and seat erosion. Shearing of main stop/control valve strainer anti-rotation pin, LVDT nut looseness, and implementation of GE's "Digital Valve" upgrade (Fig 8) are other topics—all well illustrated.

Three of the steam turbines addressed in the presentation rely on 32k operating-hour intervals for maintenance of their main stop/control, reheat stop/intercept, and LP admission stop/control valves. Another unit's maintenance is based on 24k because it has experienced excessive scale buildup on the main and reheat valves. Findings and lessons learned are summarized in the slide deck available to registered users on the Power Users website.

Upgrading D11 valves

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, and operating experience to date with the "Digital Valve."

Lessons learned in the transition to GE's digital valve (Fig 9):

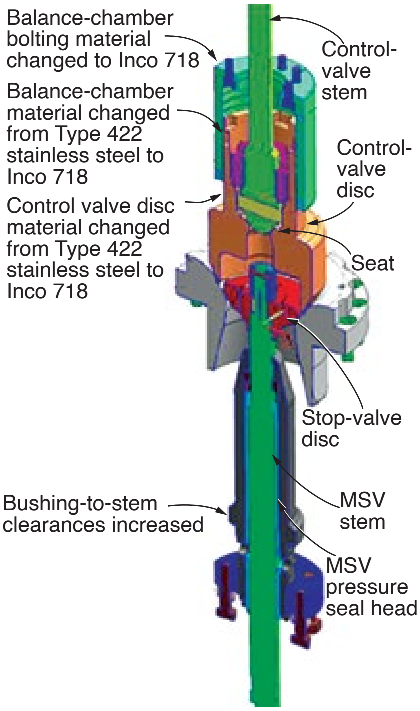
- Obtain drawings early to resolve any discrepancies prior to the outage.
- Ensure all parts and components associated with the new valve are onsite prior to the outage.
- Order spare-parts kit along with the valve to assure availability of critical spares.
- Ensure all specialty tooling for shell-arm load checks are available with spare parts.
- Plan for new junction boxes and cable pulls to support below-seat drain relocations.
- Contractor hired for electrohydraulic line mods must be trained on how to bend stainless-steel tubing.
- Verify hardware on new valves is torqued and locking tabs are in place.

Benefits of the digital valve package include daily online testing, ability to monitor performance, and the promise of extended maintenance intervals. Operations personnel verified the digital valves operate quietly and smoothly.

Valve O&M considerations for steam turbines and auxiliaries

Eric Prescott, EPRI's program manager for valves, discussed maintenance strategies for valves—including condition-, fleet-, value-, and time-based programs. His slides on maintenance workflow, system maintenance approaches, and valve condition monitoring are excellent primers

7. Main-stop-valve stem wear, attributed to solid-particle erosion, occurred over run of seven and a half years



8. GE's digital valve upgrade was implemented to reduce stem erosion

9. Digital valve replacement at right eliminates the need for upgrades to internal parts and the valve casing at left made necessary by solid particle erosion for personnel new to your O&M team.

Prescott digs into the details of valve damages and operational stressors. For example, on the all-important subject of solid-particle erosion he examines the sources of particles, plus the importance of particle incident angle, steam velocity, and erosion-resistant materials for minimizing damage.

Coverage also includes fasteners and sealing elements, the spindle-guide bushing interface, Stellite hardfacing, and monitoring of valve castings for service fitness.

Special technical presentations

ARNOLD Group: Advanced steam-turbine warming for increased startup flexibility

Pierre Ansmann opened his presentation on "the most advanced turbine insulation combined with a high-performance heating system to improve startup flexibility," by summarizing its value proposition thusly:

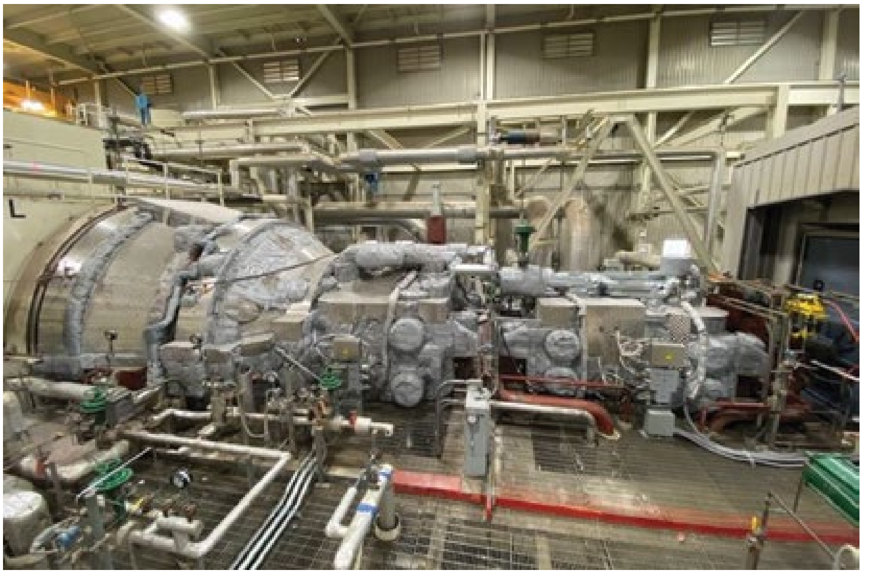
- Increased in-market availability.
- Lower startup costs.
- Reduced thermal fatigue and longer mean time to repair for critical components.
- Increased operating flexibility.

He reviewed alternative warming-system arrangements, rejecting those integrating the 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 heater on metal mesh baffle, for the lower casing, permanent mounting of heating cable below the split line.

The ARNOLD system features interlocking high-performance blankets which conform perfectly to the turbine surface (Fig 10). 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.

Dozens of 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.

Ansmann said a properly maintained ARNOLD insulation 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 start within this time period, reducing startup fuel consumption and auxiliary power.



10. Upgraded insulation system mitigates the thermal fatigue of steam turbine's critical parts and enables longer intervals between maintenance outages

Combining high-quality insulation and warming systems enables tight control of casing-to-casing and rotor-to-casing expansion during shutdowns. A goal for operations personnel to aim for, Ansmann said, is a homogeneous cooldown to maintain the temperature difference between the upper and lower casings to less than about 100 deg F.

EthosEnergy Group: Multiple upgrades improve D11 reliability

Owner/operators of the popular D11 steam turbine are sure to benefit from a review of this illustration-rich, 50+ slide presentation, easy to access in the Power Users archives. It covers the repair of 40-in. L-0 blades, and upgrades of Smart seals and the N2 packing box, among other things. The subject plant was a 4 × 2, 1240-MW combined cycle. COD for the unit upgraded was 2011; first major inspection in 2020.

Two rows of the damage-prone L-0 blades were weld-repaired prior to the outage to correct excessive leading-edge erosion (Fig 11). Cracking in the blade pin-finger dovetail roots also was addressed. Presentation provides details likely of value to anyone facing the same issues. Photos illustrate key steps in the process, including re-blading of the L-0 row.

The Smart seal upgrade was done to address rotor vibration caused by seal rubs. Experienced users know the HP/IP rotor is very flexible and sensitive to mid-span rubs. Detailed measurements of packing and tip-seal wear (average horizontal, top, and bottom) are presented. Heaviest rubs are identified with the lower-half horizontal joint. The speaker noted that although clearances generally are larger on the bottom, wear is substantial at all locations.

11. Excessive leading-edge erosion often is identified with 40-in. L-0 titanium blades installed in many steam turbines

A seal developed to upgrade OEM seals to avoid rubs and wear during startup and shutdown, by way of additional clearance, is illustrated. Reduced vibration during startup is one benefit. Another is increased revenue, said to be upwards of $17-million for a typical 300-MW steamer over an eight-year run time. Information on estimated savings in fuel and carbon emissions also are presented.

N2 packing heads, which contain shaft seals between the HP and IP steam paths, have a history of horizontal joint leakage. This impacts performance because HP inlet steam leaks into the IP section. Plus, steam cutting occurs across the horizontal joint. The presenter highlights what his company's experts say are design issues that prevent maintaining a closed joint. Described modifications are said to mitigate the problem. CCJ

Chevron VARTECH industrial cleaner helps restore gas turbine to maximum power

Chevron's San Joaquin Valley Business Unit (SJV) operates more than 16,000 wells in the Kern County area of California, where summertime temperatures frequently are in the triple digits. Yet the state's top oil and gas producer has thrived in this severe environment for more than a century, today producing 159,000 barrels of crude and 53 million cubic feet of natural gas daily.

In an oilfield located in McKittrick, west of Bakersfield, SJV operates a Solar Taurus 60 gas turbine in a cogeneration configuration—simultaneously producing steam and electricity. The steam facilitates the recovery of heavy crude oil; electricity is sold to the local utility.

Chevron is recognized for its world-class expertise in oil recovery by way of steam-flooding—a method in which saturated steam is injected into the oil reservoir to reduce crude viscosity and assist in pumping it to the surface.

During last summer, the gas turbine was running too hot to operate at its full design capacity of 5.5 MW. Even when operating just below the lube-oil and bearing alarm temperatures, the turbine could produce only 3.3 MW, causing an annual revenue shortfall of about $350,000, in round numbers.

While high ambient temperatures might be a contributor to the problem, the SJV operations team also suspected that varnish could be insulating heat-transfer surfaces and reducing oil-cooler efficiency. Visual inspection of the lube-oil reservoir revealed varnish bathtub rings, supporting the suspicion that varnish was the culprit.

To address the varnish issue, the SJV team did the following:

- Changed the oil filters.
- Replaced 15% of the used in-service oil with Chevron VARTECH™ Industrial System Cleaner (ISC).
- Restarted the system.

As the gas turbine approached full capacity, it was apparent that something had changed radically: All system temperatures remained within the acceptable range and no alarms were triggered. Specifically, the lube-oil header temperature dropped to 154F from 159F after the addition of VARTECH ISC, while the bearing temperature went from 206F to 194F. Perhaps more importantly, unit output increased from 3.3 MW to 5.5 MW.

The gas turbine continued to operate at full capacity for two weeks with no high-temperature alarms. Then the mixture of used in-service turbine oil and VARTECH ISC was drained. The system was flushed, filters replaced, and the system refilled with Chevron GST® turbine oil.

Andrew Gerlings, lead power solutions operations engineer, noted that "VARTECH Industrial System Cleaner did its job perfectly, and we can now run the unit at its full design capacity. The operators are very happy because they don't have to constantly monitor temperatures and juggle the output."

Chevron

The bottom line: VARTECH ISC allows SJV to operate its cogeneration system at full capacity year-round, even during the hottest summer days, to ensure maximum revenue from the sale of electricity.

To learn more about Chevron's premium lubricants and targeted programs for powerplant applications, please visit www.chevronlubricants.com.

POWER PLANT CONTROLS USERS GROUP™

The Power Plant Controls Users Group (PPCUG) returns to in-person conferencing August 23-27 when it joins owner/operators of steam turbines (all OEMs) and GE Frame 7 gas turbines (models A through F) at the Power Users 2021 Conference in the Marriott St. Louis Grand. More than 200 users and 100 exhibitors are expected to participate, despite federal, state, and local rules tightly controlling the conduct of meetings during the pandemic.

Recall that the 2020 conference of the PPCUG was conducted online. A summary report on that meeting is included in this article.

2021 conference overview

The technical program for the 2021 meeting is directed by an all-volunteer steering committee of industry engineers with deep controls experience (photo). Here's an overview of the speakers and events for the week beginning August 23:

Monday, August 23. The conference opens in the morning with tours of MD&A's Turbine/Generator Repair Facility, a short bus ride from the hotel. RSVP is required for participation, as is a Covid-19 temperature check and a mask.

The afternoon "classroom" session, sponsored by MD&A, begins at 2 p.m. Eastern US time and includes presentations on the company's approaches to/solutions for rotor assessment, 1-2 spacer cracking, gas-turbine alignment, component life extension, and thermodynamic analysis and performance testing. A welcome reception and dinner follow.

Steering committee, 2021

Brian Hall, TECO Energy; Bryan Eddins, Duke Energy; Peter So, Calpine; David Martorana, Tenaska; Clift Pompee, Duke Energy; Jason Justice, Southern Company (l to r). Camera shy: Adam McCool, Tenaska

Tuesday, August 24. Introductory remarks begin at 8 a.m., including a Power Users update by Chairman Sam Graham. Suppliers make half-hour presentations beginning at 8:30 and ending at the noon lunch break. The lineup:

- *IEEE C37.23-2015: New standard for metal-enclosed bus—what you need to know and why,* Electrical Builders.
- *The GTC quick solutions package,* GTC Control Solutions.
- *Using digital twin technologies to improve plant operations,* Emerson.
- *Hydraulic to electric gas valve and IGV actuator replacement,* Young & Franklin and TC&E.
- *Gas turbine operability challenges in an unstable grid environment,* EthosEnergy.
- *Predictive ignitor wear diagnostics,* Chentronics.

The afternoon program kicks off at 1 p.m. with an interactive 90-min panel discussion on 7F performance and controls. Half-hour presentations by Siemens and users fill the remainder of the afternoon until the vendor fair at 5:30. The details:

- *The evolution of gas turbine controls,* Siemens.
- *Navigating the challenges of modernizing controls for non-US-OEM steam turbine/generators,* Siemens.
- *HRSG flexibility through controls,* Duke Energy.
- *GE 7FA anti icing (events, issues, resolutions),* Southern Company.

Wednesday, August 25. The morning program features an eclectic mix of half-hour presentations from 8 a.m. to lunch at noon. The program:

- *Turbine lubricant analysis and new technologies,* Shell Lubricant Solutions.
- *Electromagnetic interference monitoring for motors and generators,* Cutsforth.
- *Remote initiated operator purge,* Environment One.
- *Optimizing your existing GT controller and plant DCS,* PSM.
- *Alarm management, historian updates, turbine controller temperature,* Southern Company.
- *Communication link failure, virtual HMIs,* TECO Energy.
- *Oil leak detection via Mark VIe, other enhancements,* Southern Company.

Following lunch and time at the vendor fair from noon to 2 p.m., GE takes center stage with the following program, plus an open discussion session after the prepared presentations:

- *Starting reliability: Exciter and static starter.*
- *Understanding/unlocking capability with MBC/ETS.*
- *Non-optical (virtual) flame detector.*
- *Controls hardware and HMI/networks.*
- *Controls services.*

The day concludes with a fun-filled evening at the ballpark until 9 pm.

Thursday, August 26. GE's interactive breakout program begins at 10 a.m., following a general session with access to the OEM's technical experts. The lineup of breakout sessions follows:

- Session 1, 11 a.m. Your options: Compressor, accessories, flexibility enhancements for simple- and combined-cycle units.

- Session 2, 1 p.m. Your options: Turbine, controls, performance troubleshooting.
- Session 3, 2:15. Your options: Rotor, repairs, "beyond the GT."
- Session 4, 3:30, Your options: Controls and combustion, Generator 101, ageing fleet strategies.

The day concludes with a GE social and open house from 6 to 9.

Friday, August 27. GE and the FieldCore team focus on outage conduct from 8 a.m. until 11:30, when the conference concludes. Topics include "Live Outage," making your outage better with LEAN, and outage planning.

2020 conference overview

Presentations made at last year's virtual meeting, focusing on user experiences and vendor products and services, were conducted Nov 10-12, 2020. 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. The 2020 meeting 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.

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 presented on the 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. 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 P2 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.

Cemtek KVB-Enertec's Gary Caccciatore 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.

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 PPCUG, 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 startups 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

Five reasons why you should upgrade your fuel train

Gas turbine fuel control has become more important than ever. Whether due to emissions mandates, maintaining efficiency, plant profitability or increasing the lifespan of a facility, operators and owners are looking for ways to achieve a tighter rein on fuel usage. Here are the top five reasons why now is a good time to upgrade your fuel system.

1. Aging parts are unreliable. There are a great many gas turbines that have been in operation for ten, twenty, thirty or more years. Machines that have been in heavy use are likely to have worn fuel valves, unreliable shutoffs, or systems that aren't responsive enough to operator instructions. But even peaking turbines that have seen infrequent use can suffer badly due to faulty fuel control systems or components.

As these units age, component wear can lead to problems in starting up the machine as well as unscheduled outages and maintenance personnel continually having to babysit the fuel controls.

In the past fuel control valves have been upgraded along with control system upgrades. Many times, the existing (old) fuel manifold and shut-off valves have been reused. As these components age, they may stick or hang up during a start causing unscheduled maintenance. Worst case: In an emergency will they close quickly and reliably? The shut-off valve and associated check valves, vent valves and actuators need to be replaced after years of service.

Additionally, there are many turbines with fuel control systems that are either poorly supported or have been made obsolete by the OEM. There comes a point when it becomes too much of a burden to continually scramble to find components or keep aging controls running.

2. Lack of speed of response. Today, speed is everything. Operators demand turbomachinery that is going to start up rapidly on demand, and shut down instantly should problems arise. The fuel control system must match these expectations. This means valves that provide the precise fuel mix and fuel shutoffs that do the job rapidly and reliably.

Yet fuel controls don't always measure up. In some cases, aging facilities have installed manual ball valves to keep their fuel control systems running. There is no place for such technology in a modern gas turbine plant.

Even standard fuel control systems may not be good enough for current conditions. Response times of half a second to a second (and as much as two seconds for a slow motor) are commonplace. Such systems are operating at risk.

What is required is pneumatically actuated valves with response times of 200 milliseconds or less. Only then, can the operator have peace of mind that shutoffs will occur fast enough to avoid damage. Furthermore, pneumatic systems are available that only need 1 amp at 24 volts DC.

Fuel metering valves must also be able to function at the right pace. Gains are set and adjusted to allow the valve to work in coordination with the control system. Fuel control valves must offer real-time flow control to dispense the right amount of fuel at the right time, as requested by the turbomachinery control system. This has everything to do with achieving performance objectives, while avoiding the possibility of falling out of emissions compliance.

3. Skills shortage. Not so long ago, plants operated with large teams of skilled operations and maintenance personnel. But the demand to do a lot more with far fewer personnel has drastically shifted the skills picture in facilities. Couple that with an aging workforce and a steady parade of retirements and there is no place for finicky or unreliable turbine systems.

Fuel controls must not be the weak link. Instead of being composed of multiple components cobbled together over the years that require constant attention, they must be unified into one comprehensive, automated fuel metering, shutoff and control system. Ideally, such pre-assembled systems would include low power actuation in order to eliminate the need for additional high-powered electrical lines to be fed into them to operate motor-driven valves.

Such systems ease the burden on less-experienced plant personnel by offering them an engineered solution that is tested, integrated and can be dropped in place. Veteran staff may be able to purchase the various components and competently tie everything together—if they have the time. But the generation entering the workforce demands fit-and-forget, leak-free systems. They want to spend their time on the big picture—overall performance, plant economics and emissions compliance—not in the routine of adjusting valves, checking for leaks and troubleshooting fuel controls issues.

4. Meeting the latest standards. Standards are continually evolving. Safety standards have changed markedly over the last twenty years. These days SIL 2 or 3 safety levels are the norm for new valves. Fast shutoff of fuel to the gas turbine is another aspect of safety. The flow of gas must cease immediately as dictated by plant control systems or whenever there is a loss of pilot pressure.

Older systems lack the safety capabilities of the latest fuel control systems, including redundant pneumatic shutoff valves, and a block-and-bleed architecture to prevent leaks. Additionally, they offer pilot valves. These feature a spring-loaded piston, activated by system pressure, to open the valve. When pressure is released, for any reason, the valve closes at once. This safety feature is an important fail-safe mechanism. Those relying on all-electric systems, however, can experience shutdown delays in the event of a power outage.

Many standards and regulations apply to the fuel train. Older fuel controls often are found lacking when it comes to complying with some of these rules. For example, they may struggle to remain in emissions compliance because their control systems do not have the flexibility to respond in timely fashion to shifts in fuel heating value. By contrast, the latest systems are available with complete fuel control assemblies fully certified and tested to meet the latest requirements.

5. Poor economics. Inefficient fuel systems can have a significant negative impact on plant performance and profitability. Older systems often lack the degree of responsiveness necessary to maintain a healthy balance sheet.

Component or system unreliability opens the door to unexpected shutdowns. Investment in modern end-to-end fuel controls reduces operational risk and increases the likelihood of a more predictable economic outcome.

The Gas Fuel Shutoff and Control System from Continental Controls is a complete fuel train inclusive of fuel metering, redundant pneumatic shutoff valves that meet safety and other industry standards, pilot valves, flow measurement, NO_x feedback, fuel heating-value measurement, and gas leakage elimination via a coaxial valve. This integrated system includes a controller with sensors for temperature, pressure and other parameters. All components are pre-assembled, welded, tested, certified and delivered on one manifold.

For more information, visit www.continentalcontrols.com.

Rick Fisher, VP
Continental Controls Corp
rfisher@continentalcontrols.com

GE's Frame 7 turns 50

The 7EA Users Group returns to in-person conferencing August 23 - 27 when owner/operators of GE Frame 7B-EA gas turbines gather at the Marriott St. Louis Grand for the organization's 2021 conference. Several score users and more than a hundred exhibitors are expected despite federal, state, and local rules tightly controlling the conduct of meetings during the pandemic.

Recall that the 2020 conference, originally planned for October 19 - 22 at the J W Marriott Houston Galleria, was conducted online October 20 - 22. A summary report on that meeting is included this article.

The technical program for the 2021 meeting is directed by an all-volunteer steering committee of industry engineers with deep 7E experience (Sidebar). Note that the OEM aggregates the model designations 7A, 7B, 7C, 7E, 7EA (a/k/a 7E.03 in GE lingo) under the 7E banner. Users typically refer to this group of units as 7EA. Puzzled by the naming convention? Industry sources promise clarity before the 2022 meeting.

> **Steering committee, 2021**
>
> Dale Anderson, *East Kentucky Power Co-op*
> Joshua Coots, *Duke Energy*
> Tracy Dreymala, *EthosEnergy Group, San Jacinto Peakers*
> Jeff Hansen, *Old Dominion Electric Co-op*
> Guy LeBlanc, *IHI Power Services Corp*
> Tony Ostlund, *Puget Sound Energy*
> Mike Vonallmen, *Clarksdale Public Utilities*
> Lane Watson, *FM Global Chemical Operations*

Golden Anniversary. The first two GE Frame 7 (Model A) package power plants (PPP) were ordered by Long Island Lighting Co in 1970 and installed 50 years ago this summer—one at the utility's West Babylon plant in July 1971, the other at Lilco's Shoreham Plant (a/k/a Wading River) in August 1971. The nominal 52-MW, distillate-fired units, still equipped with their original Speedtronic™ Mark I control systems, are in standby service.

From two, many: The OEM reported during the 2020 meeting that now there are nearly 1200 7Es operating at more than 300 plants in over two-dozen countries. In round numbers, 60% of the fleet is located in North America, 25% in Saudi Arabia. Over the last half century the output of this frame has almost doubled to 91 MW. Sales continue, with expectations that about two-dozen 7E.03s will ship from Greenville within the 2020-2022 window.

More facts about the 7E that help characterize the fleet:

- Simple-cycle efficiency is now 33.9%.
- The 7E.03 is the dominant model with nearly 900 units operating.
- That nearly 200 7Bs are still in service testifies to the value of this model. Even more surprising, perhaps, is that the OEM was preparing to ship two new 7B rotors to a customer as 2020 drew to a close. Those were the first new 7B rotors made by GE in 45 years.
- In round numbers, the fleet includes 150 cogen units, 100 in LNG production, 200 hours-based generating units, and more than 700 starts-based engines. Total fleet operating hours are north of 70 million.
- Ambient temperatures at sites with units in service range from about -40F (above the Arctic Circle) to 130F (some desert regions in Saudi Arabia).
- One of the highlights of the 7E's history is that this frame hosted the company's first DLN combustion

system. Today, 45% of the fleet is equipped with DLN1 and DLN1+ systems. Other fleet firsts include axial fuel staging and sub-5-ppm NO_x.

2021 Conference overview

Monday, August 23. The conference opens in the morning with tours of MD&A's Turbine/Generator Repair Facility, a short trip by bus from the hotel. RSVP is required for participation, as is a Covid temperature check and a mask. The afternoon "classroom" session, beginning at 2 p.m. Eastern US time, is sponsored by MD&A and includes presentations on the company's solution for 1-2 spacer cracking, gas-turbine alignment, component life extension, and thermodynamic analysis and performance testing. A welcome reception and dinner follow.

Tuesday, August 24. Introductory remarks begin at 8 a.m. with Tony Ostlund, 7EA steering committee co-chair at the podium, followed by a Power Users update from Vice Chairman Ben Meissner. The meat of the program gets underway at 8:30 with Mike Hoogsteden presenting his annual report on what Gas Turbine Support is seeing across the fleet during its borescope inspections.

Remainder of the morning's program has a compressor focus and features the following 30-min presentations:

- *Compressor Vane Looseness: What to Look for and What to Do,* CTTS (a/k/a Core Tech).
- *Emergency Rotor Support Services Case Study*, Sulzer.
- *Analysis of Inspection Protocols for S-1 Clashing,* Veracity Technology Solutions.
- *Getting Your 7EA Ready for Increased Run Time,* Emerson.

The afternoon session starts at 1 p.m. with an open discussion forum. A series of half-hour vendor presentations follows until the Vendor Fair starts at 5:30. The lineup includes the following:

- *Bus Maintenance in Action,* RMS Energy.
- *The GTC Quick Solutions Package,* GTC Control Solutions.
- *PGO Servo Valve Product Release,* Moog Industrial Group.
- *Gas-Turbine Operability Challenges in an Unstable Grid Environment,* EthosEnergy.
- *Fire Protection in Turbine Packages—CO_2 and Water Mist,* ORR Protection Systems.

Wednesday, August 25. Half-hour vendor presentations continue throughout the day. These are scheduled for the morning:

- *7EA Turndown Solutions: How Low Can We Go?* PSM.
- *Remote Operations for Simple-Cycle GT Sites,* Emerson.
- *Using Flow Net Modeling to Optimize Fuel-Nozzle Calibration and Flow Testing,* Trinity Turbine Technology.
- *Emergency Material and Design Support,* Schock Manufacturing.
- *Generator Testing: What the Tests Mean and How They are Resolved,* AGT Services.

The lunch break goes until 2 p.m., enabling a final visit to the vendor fair. An open discussion forum launches the afternoon program, followed by these 30-min vendor presentations beginning at 3:

- *Generator Maintenance Considerations,* National Electric Coil.
- *Considerations for the Fleet Management of Gas Turbine Lubricants,* EPT Clean Oil.
- *Predictive Analytics to Improve Gas Turbine Power Forecasting*

and Maintenance Practices, Camfil Power Systems.
- *Breaking Down the Run-to-Failure Strategy: Why Proactive Bus Duct Maintenance is Critical,* Electrical Builders.

Evening entertainment at the ball park (RSVP required) follows from 6 to 9.

Thursday, August 26. This is GE Day. The eclectic program generally follows the 30-min presentation format used Tuesday and Wednesday, except all the speakers are from the OEM. Here's the lineup of topics:
- *Re-Imagining the Mission.*
- *Things You Should Know.*
- *Hydrogen: What's My Capability and Things to Consider.*
- *Advanced SFN for DLN1/1+ and Combustion Flexibility.*
- *Asset Management.*
- *Reliability Ideas.*
- *7B-EA Parts Planning.*

The first presentation in the afternoon session, starting a 1 p.m., is *Part-Load Efficiency and Other "Small Ball" Ideas.* The breakout sessions are next, each offering two options:
- Session 1, 1:35 to 2:20: Cogen and peaker.
- Session 2, 2:30 to 3:15: Controls/accessories and generator.
- Session 3, 3:30 to 4:15: Repairs and field services.

GE's program wraps up with a short *Ask Me Anything* session hosted by the OEM.

Following a skull session with the 7EA steering committee, users are invited to GE's social and open house from 6 to 9 (RSVP required).

Friday, August 27. GE and the FieldCore team focus on outage conduct from 8 a.m. to 11:30, when the conference concludes. Topics include "Live Outage," making your outage better with LEAN, and outage planning.

2020 Virtual meeting synopsis

The 7EA Users Group's 2020 conference was conducted online October 20 – 22. The program arrangement for the first two days was the same: Mornings (9 a.m. to 1 p.m.) were reserved for 15-min one-on-one meetings with vendors. Appointments were made by the users at their convenience, using the virtual scheduling pages prepared for each of the sponsoring service providers.

Two presentations by owner/operators were made during the 1:15 to 2:15 session, followed by four 30-min live vendor presentations. A virtual vendor fair with chat rooms followed from 4 to 5 for service providers presenting earlier that day.

Thursday, October 22, was GE Day. It also started with one-on-one meetings from 9 a.m. to 1 p.m. with OEM experts, followed by 20-min presentations by GE subject matter experts until 3. Then a series of half-hour interactive breakout sessions began, running until end of day.

The eight live vendor presentations made during the first two days of the meeting (list below) were recorded and can be accessed on the Power Users website. Messages from other conference sponsors were pre-recorded and also are available on demand at www.powerusers.org. Most of the pre-recorded presentations also can be viewed at www.ccj-online.com/onscreen.

The GE presentations are available at https://mydashboard.gepower.com.

User presentations

7EA Stage 3 bucket shingling

An owner/operator with a fleet of more than 30 7EAs, all but one starts-based, was surprised by the damage to third-stage buckets on one of its machines found during an annual borescope inspection (access the presentation to see the photos). Bucket shingling was such that there would be a high risk of catastrophic damage were the machine—call it No. 1—to continue operating.

TIL 1313-2R2 (October 2003) states, "Bucket pairs with shroud overlap should be replaced at first opportunity. During replacement, buckets with less than 0.050-in. engagement should also be replaced." An outage was taken and the third-stage buckets were removed and sent for repair. The spec required 90 mils of engagement. However, Covid restrictions limited shop visits and the vendor determined engagement by calculation, not fixture fit. The old adage "trust but verify" is appropriate here.

S3B condition fleet-wide was assessed and a sister unit—call it No. 2—which had been serviced by the same repair vendor and outage team as No. 1, was found to have 10 buckets actively shingling, plus some with low engagement.

Plan was to replace No. 2's buckets with the repaired buckets from No. 1. Upon examination, the final repair report contained only three pictures, there were no NDE results, welds had porosity, the engagement requirement was met in some cases by weld build-up, some contact faces were not parallel. A flawed plan, obviously. Another set of buckets repaired by another vendor were installed in No. 2.

Lessons learned—some relearned—included the following:
- A capable witness would have identified concerns with welds before parts left the shop.
- Engagement by calculation is not adequate.
- When making similar repairs, require a fixture fit.
- Require engagement readings during installation.
- Having an owner's advocate during outages is important.

Generator breaker failure to open

This presentation focuses on the troubleshooting of a failed generator breaker and steps taken to repair the device and quickly return it to service.

The 15-kV GE Magne-Blast breaker supplied with a four-decades-old Frame 7E gas turbine/generator had become unreliable and was retrofitted economically with a new breaker from National Breaker Services mounted in an old Magne-Blast frame. About six months later, at approximately 290 operations, one of the generator poles didn't open when required and the incident cascaded to a unit trip.

NBS was notified immediately and an RCA (root cause analysis) was initiated. A loose part was found to have caused over-stress and failure. The breaker was repaired with an upgraded part, plus Q/C improvements were made in assembly. The unit was returned to service by a satisfied customer without incident.

Lube-oil system vacuum, post major maintenance

Oil sprayed from the mist eliminator vent piping for a 25-yr-old 7EA during the unit's first start following a major inspection that included installation of a life-extended rotor. Prior to the outage no issues had been reported with the mist eliminator or with oil bypassing it.

The speaker describes the instrumentation used to collect the data required for problem analysis and the inspection and troubleshooting associated with the bearings and mist eliminator. System vacuum was re-established after replacing the degraded butterfly valve on the mist eliminator and bearing oil seals, plus the addition of a fourth mist-eliminator filter to increase system throughput from 1500 to 2000 cfm. Bearing split lines also were resealed with a more effective product.

Covid-19 and what we do about it

With yet another strain of coronavirus to deal with today, some of the rules established to mitigate the effects of Covid-19 and later relaxed, are being re-enforced. While it might not have made much sense to dig into the details of this presentation a month or two ago, it likely does now. It reviews the steps taken by a major power producer to keep personnel safe during normal plant operations and outages.

Live vendor presentations

AGT Services. *7EA-driven generators: Stator rewind preparedness*

The service lives of generators driven by 7EAs are becoming more difficult in many cases—that is, increased stops/starts, faster ramp rates, etc. Since the average design life of any generator typically is from 20 to 30 years, having a plan in place for stator rewinds may be critical to the success of your plant. It can save months of outage time.

Several owners with a large number of these units in their fleets mitigate risk by having a set of replacement windings "on the shelf." This presentation highlights the key drivers for performing stator rewinds—including discussion of birth defects that may prevent some of these units from achieving their design lifetimes.

Allied Power Group. *Rotor repair and life management: What has and has not changed*

GTC Control Solutions. *(1) Two single-point of failure case studies; (2) Implementation of TILs 1524 and 1275—what you need to know; (3) Control hardware field updates*

Key takeaways for users include the following:

- A better understanding of the factors that determine a "single point of failure" and how to identify them, plus the not-so-evident aspects of Technical Information Letters (TILs) that can be learned only by implementation.
- Mark VI: Attendees learned about previously unknown/undisclosed failure modes, how to determine if their Mark VI is potentially susceptible to it, and what their opinions are for avoiding future occurrences.
- Mark V: Become familiar with two new critical cards from GTC capable of extending Mark V panel lives.

Liburdi. *7EA nozzle repair: Proven LMP® technology for cycling units*

Key takeaways for users are these:

- Liburdi Powder Metallurgy, LMP®, a patented high-strength metal replacement process used in both the manufacture and repair of gas-turbine superalloy components, is a practical alternative to weld and braze techniques, which may not achieve expectations.
- LMP repairs maintain dimensional fidelity, allowing swift and accurate reassembly. Plus they exhibit excellent durability in service.

ORR Protection Systems. *Improving the life safety of CO_2 fire extinguishing systems*

PSM. *Targeted upgrades using digital logic and combustor hardware solutions to improve flexibility and reliability*

Presentation covers combustor and digital solutions—from small investments to large—that help owner/operators maximize asset life. Example: LEC-NextGen, drop-in compatible with the OEM's DLN1 combustor, is said to offer increased hardware reliability, fuel flexibility, and even lower emissions. In many cases, structured upgrades can be used in combination with the DLN system in place without having to invest in total hardware or control replacements to benefit from the upgraded features.

Shell Lubricants. *Choosing and maintaining lubricants*

What you'll learn from this presentation:

- Mitigating varnish is not a one size fits all.
- Basic understanding of the various options—including filtration units, cleaning/high-velocity flushing, and the top-tier chemical treatments and the short/long-term solutions they provide.
- Replacement fluids.
- Chemical makeup, solvency, and benefits of different base stocks.
- Fluid maintenance.
- A better understanding of what's possible based on actual customer results.

Trinity Turbine Technology. *Upgrading original transition pieces to newly designed Barnes aft mounting*

Recorded webinars

AP+M. *Outage in a box*

AP+M. *Turbotect 2020*

Braden Filtration. *Functionalization of filter cartridges for air inlet systems*

Reviews historical pulse-filter performance for air inlet systems that use self-cleaning pulse cartridges. Learn about nanofiber processes that have allowed for a greater variety and application of varying nanofiber sizes. The customized lamination and adaption of these fibers can be used more efficiently to solve difficult atmospheric and operating conditions.

Cemtek KVB-Enertec. *TDL for NO_3 compliance*

Certrec. *Winning strategies for managing NERC regulatory requirements*

Chevron. *Case studies in varnish removal*

See "Chevron VARTECH industrial cleaner helps restore gas turbine to maximum power," p 87.

JASC. *Pitfalls to avoid for enhanced liquid-fuel-system reliability*

Gas-turbine fuel-delivery reliability depends on three systems performing equally: liquid fuel, purge air, and water injection. Each system has unique operational characteristics and challenges.

The presentation provides an overview of the various components and the design features developed for each. You'll come away with a roadmap for achieving fuel-system reliability which provides an ROI in 16 months or less.

Mee Industries. *Inlet fogging*

Moog. *PGO servo valve release*

National Electric Coil. *A comprehensive approach to 7A6 generator O&M*

Whether you have a fleet of 7A6 generators (the model typically married to the 7EA gas turbine) or just one, this presentation is of value to asset managers, maintenance planners, and plant engineers alike. Lifecycle management issues can impact budgets as well as outage planning and execution. Awareness of the specific issues and related failure modes discussed in the presentation can help guide preventive maintenance activities and long-term outage planning.

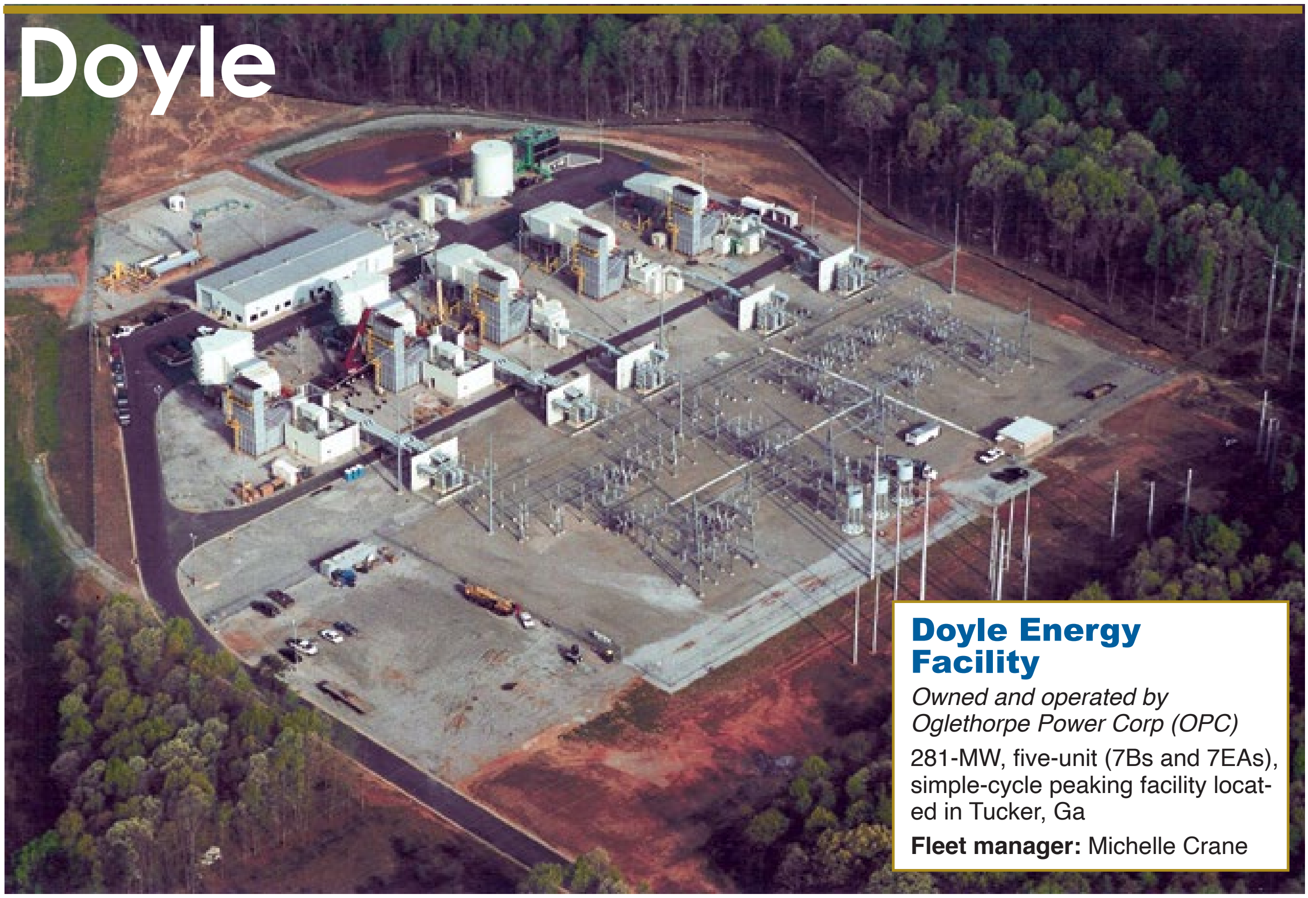
Parker, Energy Div. *Jet-pipe servo valves*

Parker, GT Div. *Gas-turbine filtration solutions*

SVI Industrial/SVI Dynamics. *Defining and implementing SCR emission system improvements for GT exhaust*

Presentation offers actionable strategies for detailed evaluation of existing SCR systems, low-cost methods for evaluation NH_3/NO distribution, CFD modeling, and fast-track retrofit capabilities.

Doyle



Doyle Energy Facility

Owned and operated by Oglethorpe Power Corp (OPC)

281-MW, five-unit (7Bs and 7EAs), simple-cycle peaking facility located in Tucker, Ga

Fleet manager: Michelle Crane

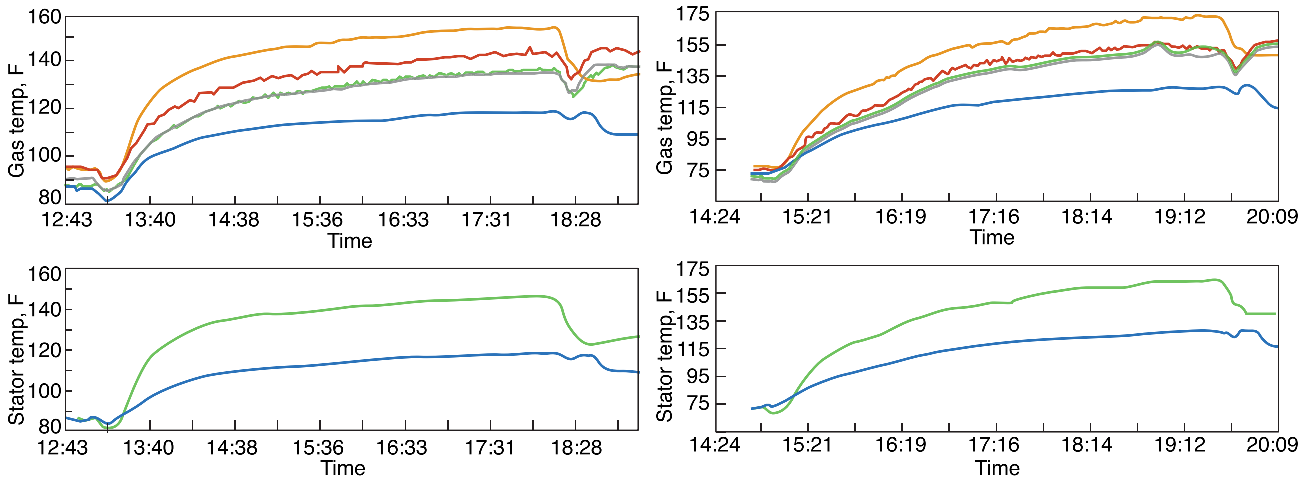
Converting generator cooling gas from hydrogen to helium

Background. Doyle Unit 1 is a 1968 GE 7B gas turbine with a 64-MVA/14.4-kV, 30-psig hydrogen-cooled generator. A thorough investigation of the engine by OPC engineers revealed degradation of its asphalt insulation and estimated remaining life at less than two years. Several equipment condition and operational performance gaps with the hydrogen cooling system also were identified during unit inspection and testing. Bringing the cooling system up to industry standards would require an estimated investment of $400,000 to $500,000.

Challenge. Find a safe alternative to the hydrogen cooling system for the predicted remaining life of the generator.

Solution. Oglethorpe Power personnel researched the practicability of using helium as the cooling medium in a hydrogen-cooled generator and in April 2018 the idea was tested and implemented on Unit 1.

A hydrogen-to-helium conversion was considered primarily because of condition issues with both the hydrogen cooling system and generator stator. Regarding the former, the original OEM control panel was 50 years old, the hydrogen scavenge system was in poor condition, there was no haz-gas



Tests using hydrogen coolant (left-hand charts) in August 2017 showed a maximum gas temperature of less than 155F and a maximum stator temperature of less than 150F. Temperatures using helium coolant in April 2018 tests (right-hand charts) were slightly higher with gas temperatures remaining below 175F and the maximum stator temperature also less than 175F detection for hydrogen and no emergency auto-purge functionality, etc.

Regarding the stator, a rewind was recommended because of its deteriorating condition, polarization index was less than 2 Mohms, debris from the degrading asphalt insulation was accumulating at both ends of the stator, glass tape was unraveling on series loops at the collector end, stator end basket was in a weakened condition, etc.

Results. The Doyle Unit 1 generator was tested successfully using helium as the cooling medium on Apr 13, 2018. For verification purposes the machine was operated from a minimum load of 52 MW to 60 MW while varying reactive power from +30 to -10 MVArs. Helium and field- and stator-winding temperatures were monitored and captured throughout the trial run, along with gas pressure (charts).

Generator temperatures were 20-25 deg F warmer with helium as the cooling medium than with hydrogen. The average gas temperature of 166F was well within the Class B insulation maximum temperature requirement of 266F. Helium purity, monitored with in-place calibrated instrumentation, was maintained without need for scavenging; no windage loss was observed. Testing proved the unit could operate with sufficient cooling to the generator, and without operating limitations, while using helium coolant.

During the 2018 summer season, Doyle Unit 1 was dispatched 12 times for peaking purposes, operating 57.2 hours. As predicted, a generator fault caused by age and insulation deterioration did occur as the summer was winding down; however, an inspection found not connection between helium cooling and the failure.

OPC identified the following benefits of using helium as the cooling medium in the Unit 1 hydrogen-cooled generator:

- Eliminated a flammable-gas hazard.
- Consumed less gas coolant.
- No operating restrictions.
- In-place instrumentation could be calibrated and used for purity monitoring.
- Minimal cost impact, plus the possibility of reclaiming helium when purged. Additionally, there could be a commodity cost reduction if bulk liquid helium is used and converted to gas onsite.

In sum, testing and operation of the Doyle Unit 1 generator verified the validity of helium as a possible alternative to hydrogen for generator cooling.

Project participants:
Michelle Crane, fleet manager
Greg Peeples, O&M supervisor
Also, site personnel Kenny Young, Bryan Kesler, Derek Crowley, and Brandon Luchner
Kashif Ahmed and Julio Trujillo, technical services

Mulberry

Mulberry Cogeneration

Owned by Northern Star Generation Services

Operated by CAMS

115-MW, dual-fuel, 7EA (DLN1)-powered 1 × 1 cogeneration plant located in Bartow, Fla. Power is exported to the local utility; steam to industrial facilities

Plant manager: Allen Czerkiewicz

Wireless camera keeps extra set of eyes on plant equipment as necessary

Challenge. In any fast-paced O&M environment, there are times when certain pieces of equipment require additional, temporary, periodic observation—such as valves, exposed tank levels, pumps and motors, or even areas of the plant grounds.

Generally, this function is performed by roving operators who must break away from their rounds to travel to the area requiring observation. This can be a challenge, especially if the item requiring enhanced monitoring is located on top of the HRSG or in some other hard-to-access location. It can be exhausting for the staff and only allows observation for as long as the operator can remain at the scene.

Solution. Most sites now have comprehensive security-camera systems. Mulberry acquired a simple wireless camera that can be positioned at whatever location requires enhanced monitoring (photos), with the wireless receiver plugged into the security-camera system on an unused channel. This offers the CRO a live look at the area of concern while he or she remains in the control room. The display can be viewed like any other camera on the system.

An added benefit is that the camera also records, allowing staff to look back on any event that occurred. After the temporary monitoring assignment is completed, the camera can be picked up and brought inside or moved to another location.

Results. The camera has been used extensively since it was purchased. Improvements have been to affix a magnet to the camera base, as well as to purchase a set of attachments that allow the camera to be installed practi-

Wireless camera, magnetically attached to piping (left) points to lube-oil flange guards (center). Screen view is at right cally anywhere—from round railings to flat metal surfaces. The camera and receiver are powered from 110-V ac outlets, although a battery-powered inverter can be used in remote locations.

Project participants:
Allen Czerkiewicz, plant manager
Jason Leverette, operations manager
Jason Wolfe, operations manager
Joe Shaffer, maintenance manager
Lee Bland, maintenance manager

Lincoln Generating Facility

Owned by Lincoln Generating Facility LLC

Operated by CAMS

600-MW, eight-unit (7EA DLN1), simple-cycle peaking facility located in Manhattan, Ill

Plant manager: Brad Keaton

Platform facilitates borescope access, improves safety, reduces outage cost

Challenge. The gas turbines installed at Lincoln Generating Facility were not equipped with platforms for accessing the power-turbine sections of the units (photo left). Reaching the borescope ports on the lower portion of the turbine required staff to place two planks across the open space as a temporary work platform. During the monthly VPP safety committee meeting this maintenance practice was discussed and participants agreed that a change was required.

Solution. The immediate solution was to hire qualified contractors to install temporary scaffolding to allow access to disassemble, inspect, and reassemble the turbine. However, the scheduling and coordination of temporary scaffolding installation during planned outages on eight units was challenging at times and the cost continued to increase each year.

Site personnel developed work scope and solicited quotes from qualified contractors to install OSHA-approved platforms. The project received approval from the owner and placed in the annual budget. Installation was coordinated with qualified contractor and new platforms were installed.

Results. During the spring outage, the OSHA-approved platforms were installed with the following results:

- A safer work area was provided for disassembly, inspection, and reassembly of the turbine during borescope inspections.
- Scheduling and coordinating the installation of temporary scaffolding during outages was no longer required.
- Technicians can safely perform additional PMs and major maintenance from the new platforms.
- The project has a three-year return on investment.

Project participants:
Brad Keaton, plant manager
Rick Stoltz, O&M tech II
Jeff Haun

Original platform (left), was inadequate and replaced by one offering much improved access and safety benefits (right)

What color is your hydrogen?

You can add another color to the burgeoning spectrum that is hydrogen as an energy stream: turquoise. According to Brad Bradshaw, speaking on the Hydrogen Energy Center's (HEC) Apr 23, 2021 webinar, "Decarbonizing the Gas Grid with Hydrogen," turquoise H_2 is methane subjected to pyrolysis to split it into hydrogen and solid carbon. Carbon dust is easier to deal with (and has valuable industrial uses) than CO_2, says Bradshaw, president of both HEC and Velerity, a Massachusetts-based research and consulting firm.

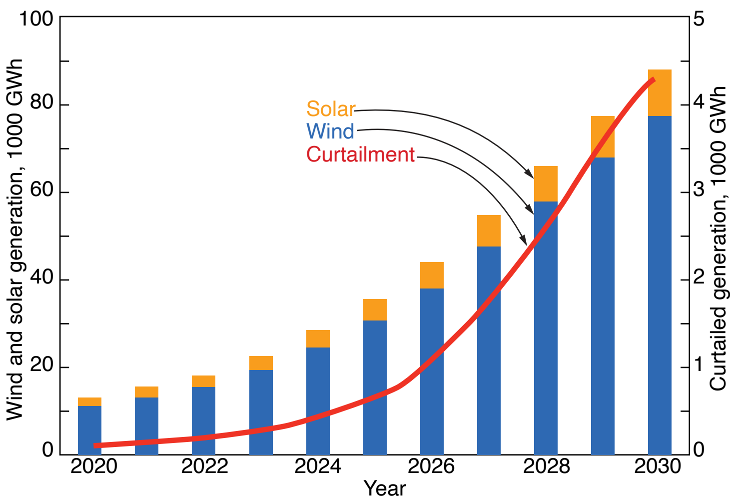
HEC describes itself as a "professional association focused on accelerating hydrogen as an enabling solution for renewable energy."

To review:

- *Green H_2* is produced using renewable electricity to split water in an electrolyzer.
- *Blue H_2* is produced from steam methane reforming with carbon capture and storage.
- *Gray H_2* is produced from steam methane reforming without CCS.

While you're at it, you can also add another squishy term to the industry's lexicon: *renewable gas*. This is natural gas that is processed to reduce the amount of carbon that will ultimately be discharged when it is burned or otherwise used. Processing can be as straightforward as blending H_2 in pipeline gas or as involved as gas pyrolysis.

Renewable gas echoes an earlier industry attempt to align a fossil fuel with environmental correctness: clean coal.



Projected wind and solar curtailments in the Northeast are on a sharply rising curve

The introduction of the HEC's Renewable Gas Consortium (RGC) is a direct counter to pressures the natural-gas industry faces—listed by Bradshaw as bans on new gas hookups at the local distribution company (LDC) level, pipeline permit reversals, and "calls to electrify everything." However, the call to electrify everything is not realistic, says Bradshaw, such as winter heating loads in the northern parts of the country and many industrial process heat applications—including district heating and cooling.

LDCs face a threat similar to that of electricity distribution utilities: As more gas customers leave the grid, the remaining customers have to pay more to maintain the infrastructure. Major cities in California, Massachusetts, Washington, and Colorado—including Berkeley, San Jose, Mountain View, Brookline, Denver, and Seattle—have banned new gas customer hookups. Others are seeking to displace gas with electricity.

While solar power purchase agreements have reached 1 cent/kWh, solar and wind curtailments are rising, notes, Bradshaw, because of the mismatch between renewable energy daily and seasonal availability and electricity demand curves (figure). If you can use this excess electricity to moderate natural gas' carbon footprint, then the phrase "renewable gas" isn't quite as squishy.

One example is adding H_2 to biogas which "sweetens" the methane content by up to 70% by converting CO_2 to methane. There's a net benefit here for biogas that would have been released to the atmosphere because methane's climate impact is, using the average of the range of figures reported, around 20-fold greater than CO_2.

One "turquoise H_2" company, C-Zero, Santa Barbara, Calif, employs an innovative thermocatalysis pyrolysis process to convert natural gas to carbon and H_2. It is described on the company's website as a "drop-in" system between the gas distribution infrastructure and gas customers. Bill Gates' clean energy investor group and Mitsubishi Heavy Industries are both investors in the company and technology. However, the notion that a pyrolysis process can be simply "dropped in" on the gas delivery system makes the phrase renewable gas look like it belongs in Webster's.

MHI also is invested in Monolith Materials, Lincoln, Neb, with a plasma-based pyrolysis technology.

The National Renewable Energy Laboratory (NREL) is leading a coalition of six national labs in an R&D program to "address the technology barriers to blending" H_2 in natural gas pipelines. Southern Company Gas, part of Southern Company, is a major private sector participant.

According to Bradshaw, renewable gas and H_2 can meet 60% of the non-power gas demand in the Northeast and the RGC is "driving $10-billion investment in renewable gas, hydrogen, and biomethane in the Northeastern US."

Expectations around H_2 should be tempered with the understanding that most of the current activity is positioning for the billions in expected government and venture capital investment. Enthusiasts will undoubtedly declare "this time is different," but the vast majority of technologies from the clean coal RD&D program—including integrated gasification combined cycle, pressurized fluidized combustion, slagging combustors, and back-end multi-pollutant removal processes—never reached commercial adoption beyond one or two full-scale demonstration units. In the meantime, solar, wind, and gas-fired gas turbines and combined cycles displaced coal-fired systems based on lifecycle economics.

H_2 has an added challenge: It is an energy *carrier* not an energy *source*, just like electricity. Ultimately, economic viability depends on whether the value of carbon, with respect to its threat to climate and social disruption, is priced high enough to counter the cost of extracting the hydrogen. CCJ

Mitsubishi Power atop the leader board in gas-turbine sales, energy storage

Mitsubishi Power (MP) finished 2020 with the highest market share for large frame gas turbines in the Americas, according to *McCoy Power Reports,* a power-industry market data service. The company's sales totaled 3288 MW, 54% of total orders in the region. More than half MP's 2020 orders include a hydrogen performance guarantee or have a joint development agreement for hydrogen in progress.

The company says among its orders are the industry's first combined-cycle gas turbines that will operate on 30% green hydrogen by their commercial operating dates. They will emit at least 11% less CO2, in pounds per megawatt-hour, than engines not so equipped.

Mitsubishi Power also claimed the No. 1 market-share position in the Americas last year with orders for 151,000-MWh of energy-storage capacity of all durations. The all-duration category covers utility-scale and behind-the-meter technologies—including battery, pumped hydro, and green hydrogen storage. The company provides both long-duration green hydrogen storage systems and short-duration battery energy-storage systems to meet the decarbonization needs of power-generation and grid customers.

An example of the former is the 840-MW Intermountain Power Project in Delta, Utah, which will have two JAC gas-turbine power islands guaranteed to burn a mixture of 70% natural gas and 30% green hydrogen when commercial service begins in 2025. The companion Advanced Clean Energy Storage Project in Delta will use renewable power and electrolysis to produce green hydrogen that will be retained in a salt cavern. It will store enough renewable fuel to produce 150,000 MWh.

Short-duration lithium-ion-based energy storage provides multiple services in power markets—including dispatchable peak capacity, firming of intermittent renewable resources, ancillary services, energy price arbitrage, and T&D congestion solutions. Mitsubishi Power received orders for 920 MWh of short-duration capacity in 2020—all scheduled for commercial service this year.

Recent gas-turbine project developments include the following:

- Entergy Texas Inc's 993-MW Montgomery County Power Station, powered by two Mitsubishi Power 501GAC engines, began commercial operation Jan 1, 2021, bringing the number of G-series units in service worldwide to 94.
- El Paso Electric orders a 228-MW Smart M501GAC enhanced-response gas turbine, allowing the company to triple its renewable-energy portfolio and reduce carbon emissions. The SmartER machine complements renewable-energy resources by starting up and shutting down rapidly to accommodate intermittent generation.
- Capital Power orders two M501JAC gas turbines to repower its Genesee Units 1 and 2 in Alberta, Canada, from coal to natural gas. The upgraded facility will produce 1360 MW (net), with carbon-emissions intensity decreasing by approximately 60%. Power producer's goal for Genesee is to be off coal in 2023.
- Alabama Power selects a Mitsubishi JAC power island for a 720-MW combined cycle being installed at its Barry Power Plant.
- Mitsubishi Power ships the first JAC gas turbine manufactured in the US to the 1200-MW Jackson Generation project in Elwood, Ill. Commercial operation is scheduled in 2022. The plant is designed with two 1 × 1 power trains to provide efficient, flexible generation to complement power production from renewables resources, in addition to reducing the state's dependence on coal. By the end of 2020, more than 80 J-series gas turbines had been ordered for service in nine countries.

Briefs

Emerson promotes Ram Krishnan to executive VP/COO and Mark Bulanda to executive president of Automation Solutions. Krishnan will oversee global supply-chain operations, IT, and M&A.

Conval, which manufactures high-performance severe-service valves often specified for HRSGs in combined-cycle and cogeneration plants, appoints Jeremiah J O'Callaghan, PE, manager of engineering.

ap+m acquires Turbine Controls & Excitation Group, well known to many users for its work in troubleshooting and upgrading control systems for turbines and generators.

NERC cybersecurity info sharing platform explained

During the Siemens Executive Cybersecurity Forum for Electric Power, held virtually June 17, 2021, Manny Cancel, senior VP, North American Electric Reliability Corp (NERC), encouraged electric-power industry stakeholders to share information on cybersecurity threats, vulnerabilities, and experiences through NERC's E-ISAC (Electricity Information Sharing and Analysis Center) platform.

Cybersecurity alphabet soup is thick enough, and it's often difficult to see what value many of these cyber organizations and initiatives offer. Nevertheless, it's good to at least be aware of them and their work on behalf of the industry. This report, available on the E-ISAC website (www.eisac.com), may help you figure that out.

Among other things, E-ISAC runs GridEx, an annual simulated attack scenario to which stakeholder leaders respond as a "play" exercise. The goal is to "engage senior industry and government leaders in a comprehensive discussion of the extraordinary operational measures needed to protect and restore the reliable operation of the bulk power system (BPS)."

On an on-going basis, E-ISAC members work with the relevant government agencies to find patterns and trends in vulnerabilities, threats, and incidences. This can only be done if stakeholders share data from which the patterns and trends can be discerned.

Current efforts are directed at supporting President Biden's "100-day plan" to shore up industrial control systems and operational technology (OT—the stuff that is inside your plant running things) by addressing global supply-chain vulnerabilities.

Among the factoids gleaned from Cancel's presentation:

- 43% of respondents to a recent survey said they were either "not confident in" or "not sure about" their company's emergency response plan to address physical and cybersecurity threats.
- Unpatched vulnerabilities are the cause of one-third of all breaches of Microsoft software.
- There has been a 48% increase in vulnerabilities between 2019 and 2020.

Fortunately, most problems can be addressed by paying attention to the basics of strong password usage, endpoint management (centrally and remotely monitoring servers, PCs, mobile devices, etc) and secure remote access. **CCJ**

Holland

Holland Energy Park

Owned and operated by Holland Board of Public Works

145-MW, gas-fired, SGT-800-powered 2 × 1 combined-cycle cogeneration plant located in Holland, Mich

Plant manager: Mike Radakovitz

LOTO command post

Challenge. Develop a consolidated area for everything related to lockout/tagout (LOTO), arc flash, confined space, and safety, to facilitate safe work practices and to further mitigate the potential for errors. The development of this command post started with the construction of the Holland Energy Park.

Solution. The LOTO room was designed and developed with the mindset of having one location for employees to muster, coordinate, and plan safety events (photos). The LOTO process is owned by the operations department, and having the LOTO room connected to the control room greatly aids the lockout/tagout process.

The room is equipped with a computer with a wall-mounted display screen to review drawings and procedures, and create and print out forms; a confined-space monitor charging and calibrating station; arc-flash suits; chemical suits; and all essential tools, lockboxes, and devices to safely perform LOTOs.

Results. Establishing a central area to store, manage, and facilitate all safety items, and incorporate excellent housekeeping skills to manage that equipment, resulted in increased employee safety and involvement in the plant's continuous-improvement effort. It also improved operational efficiency by reducing the time needed to implement LOTOs.

Having multiple reliable resources readily, available to implement correctly, and safely apply them in a timely manner, has established a foundation of trust and commitment to safety. This encouraged more employees to actively look for improvement areas. Post-outage reviews, near-miss reporting, and evaluation of routine activities improved and continues to provide areas of improvement.

Project participants:
Mark Richey, operations supervisor
Carl Thorwall, production engineer

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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 UScleanblast.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.

Taylor's Industrial Coatings

Distinguished in industrial painting, protective and specialty coatings, sandblasting, and foam services for inlet filterhouses, bellmouths, HRSGs, CCW piping/lining, and tanks.

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.