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COMBINED CYCLE Journal

Annual Meeting and Vendor Fair
February 4 – 8, Orlando, Fla
Contact: jacki@somp.co

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Contact: jacki@somp.co

Alstom Owners Group
Seventh Annual Meeting
Summer 2024, Savannah, Ga
Contact: ashley@aogusers.com

FT8 Users Group
First Annual Meeting
March 12 – 14, Washington, DC
Contact: FT8@FT8users.com

34th Anniversary Conference
March 24 – 27, Palm Springs, Calif
Contact: wkawamoto@wtui.com

FILMFORMINGSUBSTANCES.COM

Film Forming Substances
Seventh Intl Conference
March 26 – 28, Prato, Italy
Contact: bdooley@iapws.org

Best Practices Awards (p 55)

to plants powered by 501F, G, and D5 engines

Kings Mountain Energy Center • Athens Generating Plant • Kleen Energy Systems
Rolling Hills Generating • CPV Valley Energy Center • Milford Power

INDEPENDENT VOICE OF THE GAS-TURBINE-BASED GENERATION SECTOR

2024 meetings focusing on user information needs

February 4–8, 501F Users Group, Annual Meeting, Lake Buena Vista Fla, Coronado Springs Resort, Disney World. Details/registration at www.501fusers.org as they become available. Chairman: Ivan Kush, Cogentrix Energy Power Management. Contact: Jacki Bennis, jacki@somp.co.

February 4-8, 501G Users Group, Annual Meeting, Lake Buena Vista Fla, Coronado Springs Resort, Disney World. Meeting is co-located with the 501F Users Group conference. Details/registration at www.501fusers.org as they become available. Chairman: Jody Lumpkin, plant manager, Hillabee Generating Station, Constellation Energy. Contact: Jacki Bennis, jacki@somp.co.

Summer 2024, AOG (Alstom Owners Group) Users Conference, Seventh Annual Meeting, Savannah, Ga, Savannah Marriott Riverfront. Details/registration at https://aogusers.com. Contact: Ashley Potts, ashley@aogusers.com.

March 12-14, FT8 Users Group, First Annual Meeting, Washington, DC, EPRI offices and Westin Downtown. Details/registration at www.FT8users.com as they become available. Contact: Ashley Potts, FT8@FT8users.com.

March 24-27, Western Turbine Users Inc, 34th Anniversary Conference and Expo, Palm Springs, Calif, Palm Springs Convention Center. Details/registration at www.wtui.com first week of January. President: Ed Jackson, Missouri River Energy Services. Contacts: Charlene Raaker, conference registration coordinator, craaker@wtui.com; Wayne Kawamoto, conference executive director, wkawamoto@wtui.com.

March 26-28, Film Forming Substances, Seventh International Conference, Prato, Italy (about 20 minutes by car or train from Florence), Monash University. Details/registration at https://FilmFormingSubstances.com. Chairman: Barry Dooley, Structural Integrity Associates (UK). Contact: Rachel Washington, rachel@meccaconcepts.com.au.

April 7-11, CTOTF, 2024 Spring Conference, Savannah, Ga, Hyatt Regency Savannah. Details/registration at www.ctotf.org. Chairman: Dave Tummonds, LG&E/KU. Contact: Beth Doyle, executive vice chair for operations, beth@meetingplanningforyou.com.

May 20-24, 7F Users Group, 2024 Conference and Vendor Fair, St. Louis, Mo, Marriott St. Louis Grand. Details/registration at https://www.powerusers.org as they become available. Contact: Sheila Vashi, sheila.vashi@sv-events.net.

May 15-17, European HRSG Forum, 10th International Conference, Prato, Italy (about 20 minutes by car or train from Florence), Monash University. Details/registration at https://europeanHRSGforum.com. Chairman: Barry Dooley, Structural Integrity Associates (UK). Contact: Rachel Washington, rachel@meccaconcepts.com.au.

June 10-13, HRSG Forum, 2024 Conference and Vendor Fair, St. Louis, Mo, Marriott St. Louis Grand. Details/registration at https://www.powerusers.org as they become available. Chairman: Bob Anderson, Competitive Power Resources. Contact: Sheila Vashi, sheila.vashi@sv-events.net

July 15-18, Legacy Turbine Users Group, Third Annual Conference and Vendor Fair, The Woodlands Waterway Marriott Hotel, The Woodlands, Tex. The Frame 5, 6B, and 7EA Users Groups comprise LTUG and meet independently; some joint functions, including meals and vendor fair. Details/registration at https://www.powerusers.org as they become available. Contact: Sheila Vashi, sheila.vashi@sv-events.net.

August 26-29, Combined Cycle Users Group, 2024 Conference and Vendor Fair, Phoenix, Ariz, Arizona Grand Resort. Meeting is co-located with the Steam Turbine, Generator, and Power Plant Controls Users Groups, and the Low Carbon Peer Group; some joint functions, including meals and vendor fair. Details/registration at www.powerusers.org as they become available. Contact: Sheila Vashi, sheila.vashi@sv-events.net.

August 26-29, Steam Turbine Users Group, 2024 Conference and Vendor Fair, Phoenix, Ariz, Arizona Grand Resort. Meeting is co-located with the Combined Cycle, Generator, and Power Plant Controls Users Groups, and the Low Carbon Peer Group; some joint functions, including meals and vendor fair. Details/registration at www.powerusers.org as they become available. Contact: Sheila Vashi, sheila.vashi@sv-events.net.

August 26-29, Generator Users Group, 2024 Conference and Vendor Fair, Phoenix, Ariz, Arizona Grand Resort. Meeting is co-located with the Steam Turbine, Combined Cycle, and Power Plant Controls Users Groups, and the Low Carbon Peer Group; some joint functions, including meals and vendor fair. Details/registration at www.powerusers.org as they become available. Contact: Sheila Vashi, sheila.vashi@sv-events.net.

August 26-29, Power Plant Controls Users Group, 2024 Conference and Vendor Fair, Phoenix, Ariz, Arizona Grand Resort. Meeting is co-located with the Steam Turbine, Generator, and Combined Cycle Users Groups, and the Low Carbon Peer Group; some joint functions, including meals and vendor fair. Details/registration at www.powerusers.org as they become available. Contact: Sheila Vashi, sheila.vashi@sv-events.net.

August 26-29, Low Carbon Peer Group, 2024 Conference and Vendor Fair, Phoenix, Ariz, Arizona Grand Resort. Meeting is co-located with the Steam Turbine, Generator, Combined Cycle, and Power Plant Controls Users Groups; some joint functions, including meals and vendor fair. Details/registration at www.powerusers.org as they become available. Contact Sheila Vashi, sheila.vashi@sv-events.net.

September 15-20, CTOTF, 2024 Fall Conference, Las Vegas, Nev, M Resort Las Vegas. Details/registration at www.ctotf.org. Chairman: Dave Tummonds, LG&E/KU. Contact: Beth Doyle, executive vice chair for operations, beth@meetingplanningforyou.com.

COMBINED CYCLE Journal

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A quick guide to planning for GE rotor end-of-life

Excerpt from EthosEnergy's eGuide "How to keep your aging GE gas turbine running longer". To download the full eGuide, please visit ethosenergy.com/rotoreguide

Rotors are a critical part of a heavy-duty gas turbine. But they have a finite life. And failure to inspect increases the risk of defects, which can result in downtime, lack of availability, and even damage. All of which comes at a cost.

That's why GE issued a safety-critical technical information letter (TIL 1576) imposing limits on the operational life of its rotors. TIL 1576 was first released in 2007 and subsequently revised in 2011. Although it has been around for a while, there remains a high degree of uncertainty for owners and operators.

With the challenges associated with the TIL, how do you decide what works best for your assets?

Know your own roadmap

A critical first step is to look at the big picture for your plant(s). With the energy transition taking center stage, make sure you have a clear understanding of the minimum amount of time that your plant(s) will need to operate using your existing combustion turbines. For example, if your company or the area you are in has set aggressive net-zero targets, you may be looking at a shorter window of operation and thus need fewer fired hours and starts to get you there.

Identify when your rotor will reach the limit

Once you have an idea of a target date that you'd like to reach, you'll need to determine how long your existing rotor will run. Identify the date when your rotor will reach 200,000/144,000 FFH or when it will reach 5,000 FFS.

Understand your outage timing

Work out whether you can afford to take on a longer-term outage to extend the life of your current rotor, or whether you need a replacement rotor to keep the outage to a minimum.

This will help you narrow down to one of two options:

1. Extend the life of your current rotor via an LTA or CBLE – if you can afford a lengthy outage.

2. Replace the rotor with a CPO™ rotor with a known pedigree, a Phoenix Rotor™, or a new rotor – and perhaps consider an exchange program.

Understand the market

There are a growing number of options in the market, so due diligence is vital to ensure that the vendor and replacement option you choose is aligned to your goals.

In general, you have three options for purchasing a rotor from the marketplace:

- via a broker;
- purchasing from an independent service provider (ISP) that manufactures/refurbishes rotors; or
- purchasing a new rotor from the OEM.

Before we get into the pros and cons of each option, however, there is a critical issue to consider.

Compatibility

With GE Frame B-, E-, and F-class rotors, there are technical details that need to be considered before swapping out your rotor.

It is essential to have a qualified engineering team evaluate and assess your system to ensure full compatibility as there may be nuances between the rotor you have been using and the replacement rotor. In some cases, engineering customizations will need to be made – again, this is something a qualified team should assess. And all of this should be backed by a thorough quality management system.

SCAN ME

Download the full 19 page eGuide at ethosenergy.com/rotoreguide, or scan the QR code to have a copy delivered to your email

EthosEnergy

501F USERS GROUP

February 4 – 8, 2024 • Orlando, Fla
Coronado Springs Resort, Disney World

Owner/operators of 501F and 501G gas turbines co-located at the Peppermill Resort and Spa in Reno, Nev, for their 2023 conferences, Sunday February 19 through noon Thursday February 23. The last time these two groups shared the same in-person venue was in February 2020 at the Hilton West Palm Beach, about a month before the pandemic changed things.

Sunday's program featured social events for all attendees. The agenda for Monday—including a safety roundtable, vendor presentations, and vendor fair—also brought together the 501F and 501G Users Groups. The organizations met independently on Tuesday, Wednesday, and Thursday for technical presentations by users, services providers, and OEMs.

The technical meeting got underway after breakfast Monday with welcomes by the user-group chairs, steering-committee members (Sidebar 1), and conference sponsors (Sidebar 2). The contributions of Steve Bates, the long-time leader of the 501G Users Group, who died suddenly while on a family vacation Nov 30, 2022, were remembered with admiration and respect. The annual safety roundtable was next, focusing on human performance, led by a subject-matter expert.

The Vendorama program, an attendee favorite, began in mid-morning, following a tutorial describing the features of the 501F website. The half-hour Vendorama presentations were arranged in seven sessions, with five presentations conducted in parallel during each session (Sidebar 3).

A busy first day ended with a vendor fair and reception from 4 p.m. until 7:30, giving owner/operators the opportunity to peruse the products and services offered by 85 companies with interest in the 501F and 501G fleets (Sidebar 4).

Agenda highlights for the F frame's portion of the 2023 joint meeting are summarized below. The program, developed and moderated by the steering committee, focuses on the operation, maintenance, inspection, troubleshooting, repair, and optimization of equipment in generating plants powered by 501F, 701F, and SGT6-5000 gas turbines made by Siemens-Energy, Westinghouse, and Mitsubishi Power.

Tuesday, February 21: First half the morning session featured a closed user section and generator roundtable with associated presentations by owner/operators. Siemens-Energy's program followed the refreshments break and ran until lunch at noon.

PSM was at the podium for the entire afternoon.

Wednesday, February 22: Inlet and exhaust and compressor roundtables and their associated user presentations ran from the opening bell to the mid-morning break. The rotor and hot-gas-section roundtables completed the morning program.

Mitsubishi Power was at the podium for the entire afternoon.

Thursday, February 23: The morning-only program featured combustor and auxiliaries roundtables before refreshments and the outage roundtable following. Conference concluded at noon.

1. 501F Officers and Board of Directors

President and Chairman of the Board
Ivan Kush, *principal CT and controls engineer, Cogentrix Energy Power Management*

Vice Chairman
Carey Frost, *program manager, Duke Energy*

Vice Chairman and Treasurer
Brian Berkstresser, *plant director, Liberty Utilities*

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Board Members:
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John Burke, *O&M manager, Cottage Grove Power Plant, NAES Corp*
Greg Dolezal, *managing director, Klamath Energy LLC, Avangrid Renewables*

501G Steering Committee

Chairman
Jody Lumpkin, *plant manager, Hillabee Generating Station, Constellation Energy Corp*

Members:
Scott Wiley, *outage manager, Vistra Corp*
John Wolff, *technical support/compliance manager, Ironwood, EthosEnergy Group*
Kevin Robinson, *operations manager, Lakeland Electric*

2. Conference sponsors

AGT Services
Arnold Group
Badger Industries
Cutsforth
Doosan Turbomachinery Services
Falcon Crest Aviation Supply
Mitsubishi Power
Nord-Lock
PSM
Siemens-Energy
Tetra Engineering Group
TOPS Field Services
Trinity Turbine Technology



User presentations

A dozen presentations by owner/operators were incorporated into the 501F roundtables. Summaries follow. Get the details by accessing the PowerPoints on the group's website at https://forum.501Fusers.org. Find them in the "2023 Conference Materials" folder (click on the magnifying-glass symbol at the top right-hand side of the page). Only registered users are admitted to this portion of the website.

Aeropac I generator robotic inspection

Background: Unit commissioned in 2002, some drawings not available, first major inspection (MI) in 2012 included a stator rewind because of spark erosion, 501FD2/3 driver, static starter.

Speaker summarized key steps in FAST-Gen, the OEM's alternative MI procedure with rotor in place (refer to Service Bulletin 4-19-0001). Photos describe unit disassembly—roof panels, cooling ductwork, outer-end wall removal, blower-blade shroud removal, inspection instrumentation and its set-up, etc.

A second focus of the presentation: Inspection of the 18-18 retaining ring, suggested every 10 years or so and not done on this unit previously.

Next came experience in the installation of a keybar-stud-assembly capture device to protect against damage to endwindings should stator-core fastening hardware liberate.

Finally, a drip-pan inspection procedure is described. Cracks have been found in several drip pans fleetwide with the likely root cause being natural frequencies close to 60 Hz. Cracking typically is low-risk, but the installation of upgraded drip pans should be considered as part of an upcoming outage.

GT exhaust fire, explosion events

3. Vendorama presentations

- AGT Services, *Are you abusing your generators?*
- Arnold Group, *Advanced steam-turbine and HRSG warming for significant startup improvement*
- Braden Filtration, *Pulse versus non-pulse filters—when and how to choose*
- C C Jensen, *Oil maintenance in powerplants—What about transformer oil?*
- CECO Environmental/Peerless Mfg, *Top five most common issues affecting your SCR System*
- Cutsforth, *Case study on brush condition monitoring*
- Doosan Turbomachinery Services, *Manufacturing programs: Inquiries, production, and challenges*
- Environex, *Enhanced SCR and CO system management for today's operational challenges*
- Environment One Corp, *Automated gas-manifold and generator purging best practices*
- Frenzelit, *501F upgrades for legacy units*
- HRST, *Bigger HRSGs equal new problems*
- Hy-Pro Filtration, *Turbine oil tests and frequencies*
- Industrial Air Flow Dynamics, *HEP and covered piping systems under the jurisdiction of ASME B31.1 (Section VII) for power generation*
- Industrial Air Flow Dynamics, *Gas-turbine expansion joints*
- Marioff NA, *Protection of gas turbines using high-pressure water mist*
- Mee Fog, *Wet compression for 501Fs*
- Mitsubishi Power, *Modeling the best pathways to decarbonize while maximizing return on investment*
- Mitsubishi Power, *501F rotor technology*
- National Electric Coil, *Aging generator lifecycle planning and issue update*
- Nord-Lock, *501F four-way joint solution*
- NRG Faist Corp, *New ISO 29461-2 and gas-turbine air inlet filters*
- ORR Protection Systems, *Proper inspection and testing procedures*
- Powerflow Engineering, *Torque converters in starting packages: Long-term wear and failure modes*
- PSM, *Importance of tuning for dynamics and emissions: Manual or automated?*
- Shell Oil Products, *PAG-based EHC fluid—A sustainable alternative to phosphate ester for EHC application*
- Sulzer Turbo Services Houston, *Maintaining 501F rotors*
- SVI Dynamics/Bremco, *Case studies on turbine-exhaust-system gas-path upgrades to improve safety, reliability, and performance*
- Tetra Engineering Group, *Potential for hydrogen use in GT-CC duct burners under new USA H_2 production tax credit*
- Veracity Technology Solutions, *Advanced NDT testing methods for decreasing operational risk*
- Voith US, *Keeping your equipment available in the new normal*

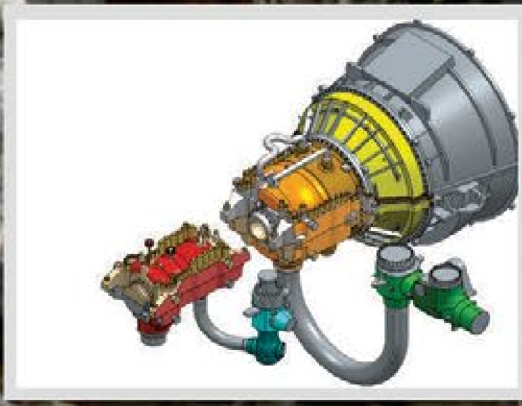
4. 501F exhibitors in 2023

- AAF International
- Accumetrics
- Advanced Turbine Support
- AGT Services Inc
- Allied Power Group
- Alta Solutions Inc
- American Thermal Solutions
- Arnold Group
- Badger Industries
- BBM-CPG Technology
- Bearings Plus
- BK Vibro America Inc
- Braden Filtration LLC
- C C Jensen
- Camfil Power Systems
- Catalytic Combustion Corp
- CECO Environmental/Peerless Mfg
- Columbia Water Technology
- Conax Technologies
- Conval Inc
- Cutsforth Inc
- Doble Engineering Co
- Donaldson Company
- Doosan Turbomachinery Services Inc
- Durr Universal Inc
- EagleBurgmann
- Environex Inc
- Environment One Corp
- Faist Filters
- Falcon Crest Aviation Supply Inc
- Fisher Improvement Technologies
- Frenzelit Inc
- Freudenberg Filtration
- Groome Industrial Service Group
- Hilco Filtration Systems
- HRST Inc
- Hy-Pro Filtration
- Industrial Air Flow Dynamics Inc
- Iris Power-Qualitrol
- Kingsbury Inc
- Koenig Engineering Inc
- Liburdi Turbine Services Inc
- LPG Industries Inc
- Macemore Inc
- Marioff NA
- Mee Industries Inc
- Millennium Power Services
- Mitsubishi Power
- Moog
- Munters Corp
- National Electric Coil
- Nederman Pneumafil
- Nord-Lock Inc
- ORR Protection
- Pal-Con Ltd
- Parker Hannifin Corp
- Powerflow Engineering Inc
- Precision Iceblast Corp
- PSM
- Rochem Technical Services
- ROMCO Manufacturing Inc
- Schock Manufacturing
- Shell Oil Products
- Siemens Energy
- Sulzer Turbo Services Houston Inc
- SVI Industrial (SVI Dynamics/Bremco)
- Tetra Engineering Group Inc
- TOPS Field Services LLC
- Trinity Turbine Technology LP
- TRS Services LLC
- Vector Systems Inc
- Veracity Technology Solutions
- Viking Turbine Services Inc
- Voith US

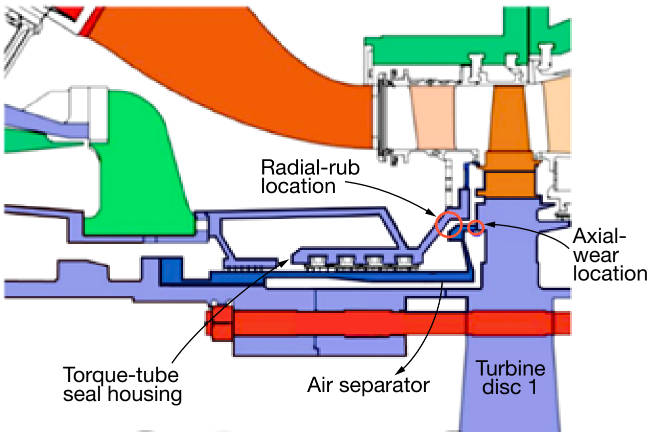
Turbine Shell Warming Systems

Advantages of the ARNOLD Steam Turbine Warming System

- Maintaining Hot Start Condition during Shutdown
- Increased IMA (In Market Availability)
- significantly reduced Startup Time
- significant Fuel & Emissions Savings during Startup
- Reduced thermal fatigue and longer component MTTR
- Reduction of Maintenance Intervals
- Equalized Delta T between Top and Bottom Casing
- Operational Flexibility
- Increased Monitoring and Diagnostics for CBM
- Insulation Warranty for complete Turbine Service Life



ARNOLD GROUP



Torque-tube, which joins the compressor and turbine sections of the rotor, is a recurring focal point of user discussions on the 501FD2/3 at annual meetings. The problematic air separator has been eliminated in the hybrid rotor

Generator retaining rings should undergo nondestructive examination at least once a decade, according to the OEM

Background, fire event: Unit completed a major inspection which included installation of a FlameSheet™ combustor. After two failed starts, the third attempt was successful but a bearing compartment fire resulted. Plastic instrumentation conduit was not rated for the temperatures encountered; insulation and cabling were replaced.

Unit was shut down following an explosion event (heard in the control room) triggered by the exhaust fire. Borescope inspection found outer exhaust finger seals deformed/displaced. Turbine cover was lifted, all upper-half finger seals were removed, repaired, reinstalled.

The why: Failed starts left unburned fuel which entered the exhaust system. Explosion resulted from rapid ignition of the unburned fuel when the fuel/air ratio reached the critical level.

Speaker provided some details on key findings/conclusions, plus illustrations.

Torque-tube failures

Presentation offers valuable technical background on torque-tube cracking experienced by 501F-FD3 engines of Siemens' design, as reported by owner/operators. According to the speaker, there had been 17 of these unplanned events among the 265 units fleetwide through the end of 2022, with 13 occurring since 2018. Recall that the torque tube is the rotor component that connects the compressor to the turbine.

What happens: Cracks grow radially outward and circumferentially from the downstream bolt retention groove of the turbine (see accompanying diagram). Propagation mode is through high-cycle fatigue from rotational bending. Two important points:

- All 17 cracking events experienced the same signature of increased vibration trends which exceeded allowable limits over a few days. Investigators reported a strong statistical correlation with units having high reserve shutdown hours, turning-gear time, and starts. Insightful illustrations. Access the slide deck on the 501F Users Group's website.
- No downstream damage, or damage to other components, occurred in any of the events reported.

Disc-cavity 2 issues following an HGPI outage

Background: 501FD2/3 commissioned in 2002, SPEX installed in 2012, torque-tube failure in 2017, 62,000 fired hours and 2000 starts (round numbers) lifetime, 22,000 fired hours and 300 starts (round numbers) since last overhaul.

Valuable presentation for plants experiencing disc-cavity cooling issues. Combustion and HGP hardware (including Row 4 blades and vanes) was replaced on this unit in 2022. There is a mixture of OEM and non-OEM hardware within the same row, plus a mixture of nickel- and cobalt-alloy vanes.

Non-OEM Row 2 vanes installed during the unit's 2018 major inspection exhibited significant degradation prior to the 2022 HGPI and component condition was monitored periodically by borescope. Photos show condition of vanes as found; blade-ring assembly drawing also provided.

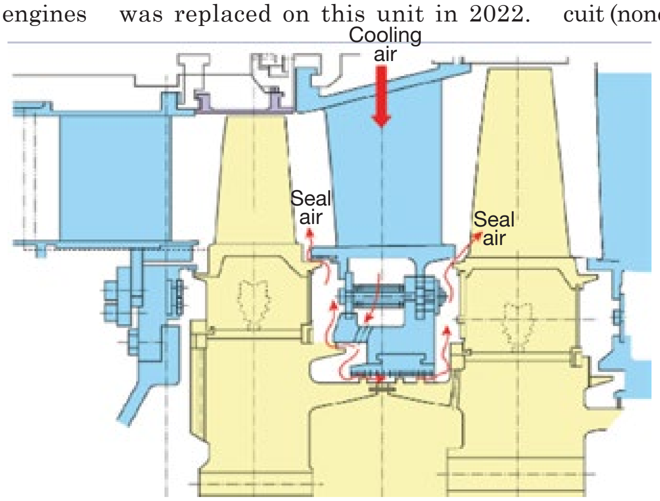
Unit tripped on vibration during the first start after the overhaul. Balance shot was installed and the machine was able to reach full-speed/no-load without issue.

However, the load ramp had to be stopped because the cooling valve for disc-cavity 2 was full open at 65 MW. DC 2 control valves typically operated at about 45% when at full load before the overhaul. The main cooling orifice had not been modified after the previous inspection.

The speaker next reviewed results of three increases in orifice size to correct the problem; the search for debris or blockage in the cooling circuit (none); thermocouple inspection to ensure they weren't rubbing on the rotor (not); and inspection of Row 2 vanes for signs of distress (none), etc.

Next came the challenge of adjusting pilot and C-stage splits to bring NO_x into compliance. Then, with cooling and emissions within spec, Peak 3 amplitude (100-500 Hz) became a problem. A reduction in firing temperature came next, along with tuning at part load. How combustion dynamics will be affected by winter operation is a lingering question.

This case history obviously is a good one for insom-



Disc-cavity cooling was improved by increasing orifice size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Catalysis
Smarter catalysts: two in one
Better emissions compliance
Clean air is our business. The GTC-802 (NOx/CO-VOC) "Dual Function" catalyst will help your plant meet stricter emission standards while improving performance and profitability. **GTC-802 combines two catalysts in one, delivering both superior NOx reduction and outstanding CO and VOC oxidation.** Lowest pressure drop, near zero SO_2 oxidation and reduced ammonia slip add up to improved heat rate, increased power output and fewer cold-end maintenance issues. GTC-802 is positioned downstream of the ammonia injection grid in the same location as the current SCR catalyst. As an added benefit, the catalyst allows direct injection of liquid ammonia or urea in place of the traditional vaporized ammonia.
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niacs to ponder. The speaker closes with guidance on suggested actions for avoiding a similar situation at your plant.

Off-cycle replacement of Rows 2 and 3 vanes on a W501F

Borescope photos of Row 2 vanes taken in November 2019 after 363 equivalent starts revealed no indications; 75% of the airfoils were inspected. A year and nearly 100 ES later a leading-edge crack was found in one vane. Over the next six months and 34 starts crack size increased marginally. By mid-May 2022, vane condition had deteriorated markedly, with significant erosion and material loss on both the suction and pressure sides of the airfoil at the leading edge.

Metallurgical evaluation of the adjacent vane that had not failed, confirming the original heat treat was good; TBC and MCrAlY were in good condition. At the failure location there was surface burn-up and the core plug had melted. The probable cause: Uneven oxidation/thermal stress on the leading edge attributed to poor distribution of cooling air.

Standard repair scope was reviewed, passing muster with some extra flow testing and process checks. Work was completed with no major surprises.

Major through-wall cracking was discovered in Row 3 vanes during the work on Row 2. Hookfits and air seals were restored, and outer-wall coverplate damage was repaired. Photos illustrate the degree of distress.

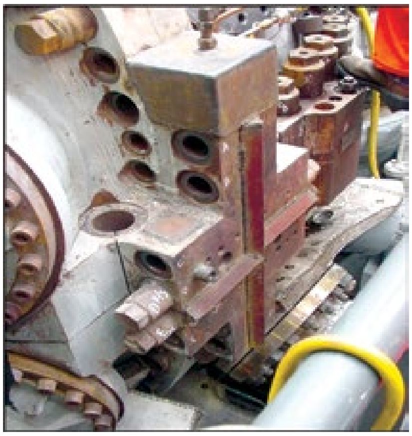
501F 4-way joint leakage solutions

A perennial discussion topic at 501F conferences is 4-way joint leakage. Its causes include one or more of the following—plus a few others: Improper torquing of bolts, case bowing, case bolt-hole outer ligament cracking, flange surface irregularities or mismatch, causing a step between any two mating flanges.

The OEM and others have spent years trying to solve this chronic issue. A permanent solution has been elusive. Partial success has been achieved in some instances by adopting one or more of the following procedures described in the presentation:

- Alternative bolt-tightening sequence.
- Sealants requiring a curing step.
- Seal welding.
- Shield enclosures.
- Mechanical "E" seals.
- Alternatives to standard bolting, such as SuperBolt™.
- Repair of outer bolt-hole ligament cracking.

The presenter focused on what might be the most promising perma-



Four-way joint leakage is a perennial discussion topic at 501F conferences. Here, leak boxes are used to protect against joint leakage

nent solution, one involving flatness and geometry measurement followed by machining of mating flanges. While flatness and geometry can be measured manually, recommended is the Faro laser technique. Following interpretation of results, a machining plan is developed to assure the flanges "square up" and all peaks and valleys will be removed. Laser mapping to determine flatness is described by way of drawings; photos of the machining set-up illustrate the complexity of the job.

DLN to ULN conversion update

Upgrades of the SCR systems incorporated in this 2 × 1 combined cycle's HRSGs were not viewed as adequate to comply with rules governing NO_x emissions and expected future limits on ammonia slip to meet the requirements of a new "regional haze" rulemaking by the state's DEQ.

Ultra-low NO_x (ULN) was selected as the preferred solution because of its demonstrated capability to reduce NO_x from the permitted 25 ppm to 9 to 12 ppm. ULN was installed on one of the plant's two gas turbines during a major inspection in 2021 and on the second unit the following year.

Here are the results described by the speaker:

- Plant output decreased by about 5 MW.
- Plant heat rate increased by about 290 Btu/kWh.
- Combustor dynamics were virtually zero.
- Plant is meeting its NO_x requirements, but struggling with CO until tuning.
- Ammonia consumption has been reduced by about half.

Dual-fuel challenges in cold weather

Presenter from a 501FD2-powered 3 × 0 plant equipped with DLN combustion hardware and gas/oil capability shared challenging operational experiences from a Christmastime 2022 storm defined by blizzard conditions. His motivation was to get attendees to share their experiences, if any, with frozen ignitors, frozen turbine drains, failure to ignite or accelerate, and other cold-weather problems.

Frozen ignitors. Fuel gas was curtailed because of the storm and a frozen ignitor was pulled from the unit after a failed start on oil. Important: The unit was cold and had not been run prior to the oil start attempt. The speaker asked attendees with success in starting on oil at low temperatures what was their minimum temperature.

The editors were not in the room for this presentation and suggested interested parties might ask colleagues so as not to be caught off-guard during a cold snap.

Frozen turbine drains. Plant was at below-zero temperatures for about two days with winds at 30-40 mph. Drains to the false-start drain tank were frozen. Speaker asked how others would address this situation. Would heat tracing be a viable solution?

Multiple failed-start attempts where ignition failed or the unit fired but failed to reach 1000 rpm, tripping on high spread. Important to know the minimum ambient temperature for a unit start on oil. Then consider operating the unit to warm the metal before arrival of the coldest temperatures. Another thought: Tune the diesel-oil system at the coldest temperatures normally expected.

Fuel-oil contamination of the hydraulic system was experienced, likely because fuel-valve leakage was forced into the hydraulic system during the two days of liquid-fuel operation when the drains were frozen.

Fuel-oil operations: Preparations and lessons learned

Background: 501FC+ powered 1 × 1 combined-cycle cogeneration plant commissioned in fall 1997. Peaking to intermediate service with 233 starts in 2022. WDPF control system migrated to Ovation in 2016.

Historically the unit started up and shut down on gas. Transfer to oil was done in the 18% to 22% load range. Transfers almost always resulted in a trip, typically because of a spread or variance issue. Note that the equivalent starts trip multiplier was 1.0 on gas, 1.3 on oil.

Causes of trips included the following:

- Leaks. A leak in 1999 caused a fire. Minor damage, however.
- Spread. Stuck check valves, water or oil. Another cause: Tubing

improperly terminated (going to wrong stage).

- Flame out. Water pushed through the pilot purge line. Piping was modified to install low-point drains.
- Coking. Implementation of a bidirectional purge corrected this.
- Fuel-oil quality. (1) Diesel oil can go bad. Change filters periodically (hourly if necessary) to reduce the pressure drop. (2) Sample and test oil in the storage tank semiannually for water and biological contamination. Drain any free water, eliminate the bugs with chemicals. (3) Turn over/refresh oil periodically.

Plant developed a fuel-oil readiness checklist, included in the slide deck, to identify possible trouble before it results in a full-blown problem. Issues still are experienced but most are encountered while running through the checklist. There has not been a trip on fuel oil since implementing the checklist.

W501FD2/3 upgrade to FD(6p) + hybrid rotor

Background: This is one of three presentations made by the owner/operator of a 1 × 1 combined cycle describing how the unit was modified to bring it up to today's requirements in terms of generating capability, efficiency, emissions control, safety,

- 2003. Commissioned as a 501FD2-powered 1 × 1 combined cycle.
- 2013. Upgraded to FD3 (at 49k equivalent baseload hours and 1250 equivalent starts) with single-piece exhaust (SPEX), plus conversion from TXP to T3000 controls, conversion of fire suppression from dry chemical to CO_2, new compressor Row 16 blades, new belly band.
- 2018. Hot-gas-path and rotor and casing inspection and evaluation (at 78k EBOH and 1930 ES) with 25k DLN 2.3 combustor upgrade, 33k-interval turbine hardware upgrade, torque-tube seal housing removal and inspection, conversion to PAG lubrication, insulation upgrade to Arnold, rotor-shaft mechanical limit increase to 192 MW, FASTGen inspection of generator.
- 2019. Combustion inspection (at 85k EBOH and 1937 ES), plus replacement of turbine Row 1 blades and ring segments.
- 2022. Second major inspection (at 108k EBOH and 1943 ES), plus hybrid rotor upgrade, rotor air-cooling-system upgrade, installation of a direct air injection system (DAIS) to allow faster restarts and to mitigate blade tip rubs during warm starts, and several other improvements to boost output, increase efficiency, and reduce emissions.

Hybrid rotor increases the shaft limit for the 501F to 227 MW

The presentation is highly recommended by the editors for anyone looking to get more from his or her legacy 501F units. It covers the drivers for change, planning needed, physical changes required, challenges and risks involved, pitfalls to avoid, and the performance improvements you can expect.

One important thing not included in the slide deck is cost. Obvious from the list of improvements above is that the cost/benefit analysis required to get management's attention is no simple task.

T3000, GT auxiliaries upgrades on a W501FD2/3(6p)

This is an extension of the work done on the unit described in the profile immediately above. It covers additional projects undertaken to promote safer operation and improved performance including the following:

- T3000. Software update from version 7.2 to 8.2. Hardware replaced included central servers, application stations, control-room workstations. New logic was configured, tested, and commissioned.
- Rotor air cooling (RAC) system mods were made consistent with the requirements for the FD6p and hybrid rotor upgrade (replaced piping, control valves, etc), replaced RAC separator, upgraded disc-cavity temperature control.
- Installed an active combustion-dynamics monitoring system, allowing an increase in the fuel fraction to the pilot and less air. This included the installation of new high-temperature, direct-mount pressure transducers.
- Added dewpoint temperature to the anti-icing system to help protect against icing in the bellmouth and on Row 1 vanes.
- Replaced the HRSG distribution-grid sidewall support system to accommodate load/stress increases consistent with the gas-turbine upgrade.
- Installed a Basler DECS 2100 AVR.
- Added a generator online monitoring system to track partial discharge, rotor flux, endwinding vibration, and shaft current and voltage.

Integrating a steam-turbine major into a W501FD2/3(6p)

The third presentation made by this plant's personnel reviews some of the work described in the two presentations immediately above with additional detail, and summarizes the work package for the major inspection on the 125-MW Fuji steam turbine (KN design)/generator.

Together the slide decks touch on most, if not all, the inspections/improvements/additions might consider in bringing their two-decades-old generating resources up to date—a valuable reference for others in this community of users.

This slide deck begins with a discussion of the drivers for using the hybrid rotor and the physical changes associated with upgrading to the new rotor and FD6 thermal performance—including: turbine Rows 1 and 2 nozzles and blades of new design, advanced DLN 3.0 combustor hardware (ULN technology was not implemented), plus new torque tube, pre-swirler, and shaft cover.

Outage planning for success was the next topic. It included discussion of the challenges and risks faced for a project of this magnitude. Steam-turbine activities followed the review of the gas turbine/generator work conducted, the RAC upgrade, DAIS installation, controls upgrade, etc.

Elements of the steam turbine/generator major were the following:

- HP/IP section. Casing cooling, insulation removal, lifting of the casing upper half, and NDE/analysis of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internals. The last included UT phased array, stress analysis and estimate of remaining life, and laser measurement of casing distortion. Components replaced and rotor indications were among the details shared.

- LP section. Visual and borescope inspection of L-0 and L-1 blades, condenser inspection and repair (plugging of damaged tubes, recoating of the waterbox).
- Steam valves. Overhaul of stop and control valves (main and reheat) with a focus on stems and bushings.
- Control oil. Replacement of the phosphate ester fluid to PAG.
- Generator. Retaining-ring inspections, electrical testing, pole-crossover inspection, repair of partial-discharge indications, cleaning of the water-cooling system, AVR replacement.

Completing the inspection and overhaul effort, the speaker covered the following:

- HRSG and high-energy piping (HEP). Inspection and repair of drums, inspection for FAC, evaluation of the HP and IP attemperators, NDE of HEP, overhaul and testing of pressure control valves.
- Balance of plant. Inspection and testing of transformers and breakers, evaluation of cooling-tower structural components and fans, check-out of boiler-feed and condensate pumps.

Access the slide deck on the 501F Users Group for the details (data and charts) on performance improvement.

Regarding outage duration, breaker open to breaker close was scheduled for 42 days and achieved in 45.5.

Blade-path thermocouple 6 failure case history

Sharing of experiences at user-group conferences does not necessarily entail deep detail and a major effort in presentation development. Sometimes it only takes a couple of photos and a few words to help a colleague. Perhaps only five minutes in total. This one of those "presentations." Informational might be a better descriptor. Only seven photos and a slide summarizing plant history: Commercial start, 1997. Through Feb 1, 2023: 71,498 fired hours, 4728 normal starts, 6286 equivalent starts.

The slide deck doesn't make much sense to review unless you're familiar with thermocouple failures and have a particular interest in T/C 6. Photos show the T/C, the thermowell, no exhaust damage, bushing, thermowell wear from bushing, close-up of wear, and the "wiggle" test to show why the failure occurred.

Of course, had you attended the meeting (the editors were not in the room for this presentation) you would have learned something useful from the speaker's commentary even if you didn't know anything about T/C 6. Plus, you could have asked questions to fill the gaps in your knowledge.

Register for the 2024 conference of the 501F Users Group—now's a good time—to take advantage of the knowledge your colleagues have to share. Consider bringing along a memory stick to the meeting with a few photos of an issue you're dealing with, go to the podium, and ask attendees if they have experienced something similar and, if so, what they did to solve the problem you described. Think of this as "free consulting" and a good reason for management to support your travel orders.

Vendor presentations

Are you abusing your generators?

AGT Services

Generators sometimes are last in line for inspection and maintenance, a point made clear by Jamie Clark on the title page of his presentation.

Generators suffer abuse, just like other parts of the plant, caused by actions and events such as the following:

- Start/stops.
- Shifts in outage planning or scope.
- Grid events and influences.

Clark offered some ideas on how to cope with limited inspection and maintenance budgets, including these:

- Replace field-out majors with field-in minors.
- Use robotics and borescopes.

Both the stator and field are impacted by mechanical and thermal forces, he continued, urging attendees to keep in mind that most problems with generators are mechanical in nature. The generator is put together primarily by hand and problems often are found in bolted and brazed areas.

Clark made a point that "Around 75% of combined-cycle starts run less than 24 hours." Also, some generators are not well instrumented (monitored). He therefore suggested that plants have critical spares (field, stator bars, etc) available or know where to get them. Also have a plan for bushings, fuses, diodes, etc.

His conclusions:

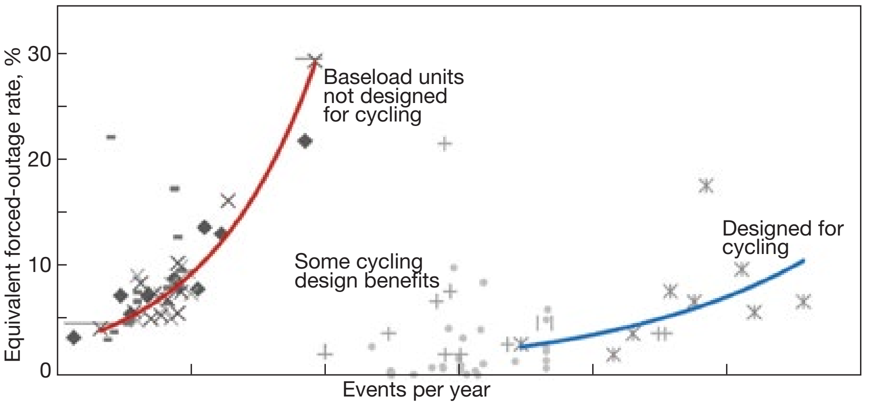
- Get your unit's baseline condition correct now, even if it means taking a Major Inspection to do it.
- Going forward, consider robotic inspections in lieu of field removal.
- Significant changes (increases) in operating duty warrant shorter outage intervals.
- Compared to prior outages, recent findings confirm that the most involved repairs are caused by cycling.
- All OEM bulletins are significantly more important when cycling.
- Some units are suffering common problems. Talk to people in the know. Most likely you'll find them at meetings of the various industry user organizations—like the 501F Users, 7F Users, Generator Users Group, etc—where sharing experiences is part of the attendee culture.

501F manufacturing programs: Inquiries, production, challenges

Doosan Turbomachinery Services (DTS)

Dr Scott Keller, director of engineering, started his presentation by noting that a majority of inquiries today are for outages within one year or less. However, the market reality is that supply-chain constraints are making just-in-time outage planning challenging and procuring long-lead items—rotor, exhaust, compressor components—difficult at best.

Keller focused on Doosan's work in compressor-blade development, not-



AGTServices. Risk chart compiled by Intertek shows baseload units forced into intermittent service are more prone to forced outages than those designed for cycling

ing that it is developing a complete replacement flow path for 501FD2/3 compressors. Access the slide deck to see the design differences between DTS airfoils and the OEM's and the steps Doosan has taken to verify the structural integrity and tuning/response of the new blades.

The second half of Keller's presentation concerned rotor overhauls and components. He reported that DTS provides overhaul services for the 501F family of rotors, from the AA to FD3. Offerings include disassembly/reassembly, repair and machining, and balancing. Mentioned was that Doosan was developing components to meet the needs of users in the supply of rotor bolting, FD2/3 torque tube, and FD2/3 air separator. Illustrations showed some of the issues identified in the company's work and repairs and component replacements made.

Advanced single-layer turbine warming system

ARNOLD Group

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. 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.

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

The speaker then described the company's new warming system for heat-recovery steam generators, citing its many advantages. Next came details on ARNOLD's balance-of-plant steam valve service, relatively new to the US market.

Think beyond the catalyst to improve emissions performance

CECO Peerless

The common root cause of several performance issues observed in powerplant SCR systems is not the fault of the catalyst, the speaker said, but rather one or more of the following:

- Poor reagent quality. Reagent grade aqueous ammonia is required; commercial- or technical- grade reagent is unsatisfactory. It was said that only one delivery of poor-quality ammonia could cause problems.
- Inadequate maintenance on existing equipment. This can cause vaporizer fouling, catalyst plugging, grid fouling, and other problems.
- Gas bypass of the SCR catalyst. Improperly designed/installed catalyst support frames contribute to gas bypass, as do gaps between catalyst elements, loss of packing between catalyst modules, etc.
- Ammonia-injection grid (AIG) maldistribution adversely impacts NO_x performance, increases ammonia slip, increases ammonia consumption, and reduces catalyst life.
- AIG fouling.

Several charts illustrate the importance of AIG design in SCR performance. The company's Edge® AIG is said to extend catalyst life and provide other benefits.

EASYchange® brush condition monitoring

Cutsforth

Monitoring the condition of generator collector brushes enables plant personnel to conduct maintenance based on actual condition rather than a calendar basis. Another benefit: This virtually eliminates the risk of having a ring fire because of short brushes.

Case study presented concerned the melting of brush health sensors on a steam turbine/generator. Side view of the brush holder showed the splatter pattern indicative of water on collector rings, which was confirmed by a review of historical data from the Cutsforth system. Data showed spikes in temperature and vibration.

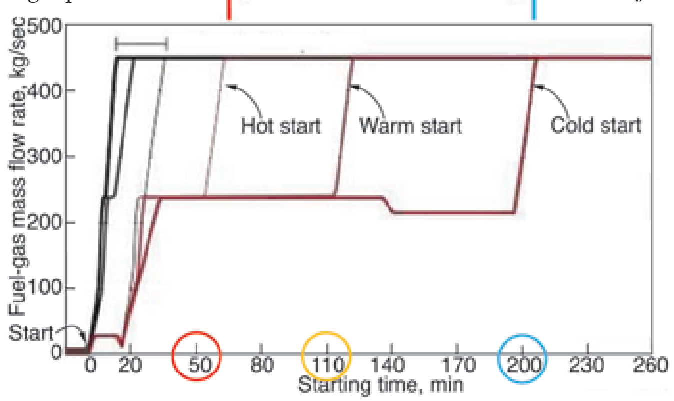
Physical inspection of the exciter revealed significant signs of water inside the housing. Note that water on collector rings washes away the lubricating carbon film on the ring surface, reducing the quality of the electrical connection between the brush and ring surface.

Automated gas manifold and generator purging best practices

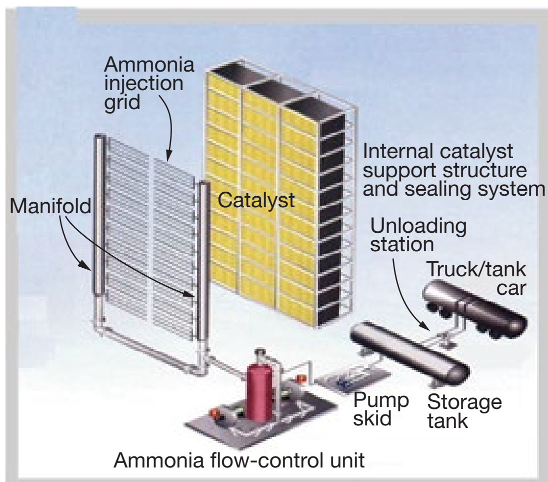
Environment One

Chris Breslin began by explaining the benefits of an automated purge system:

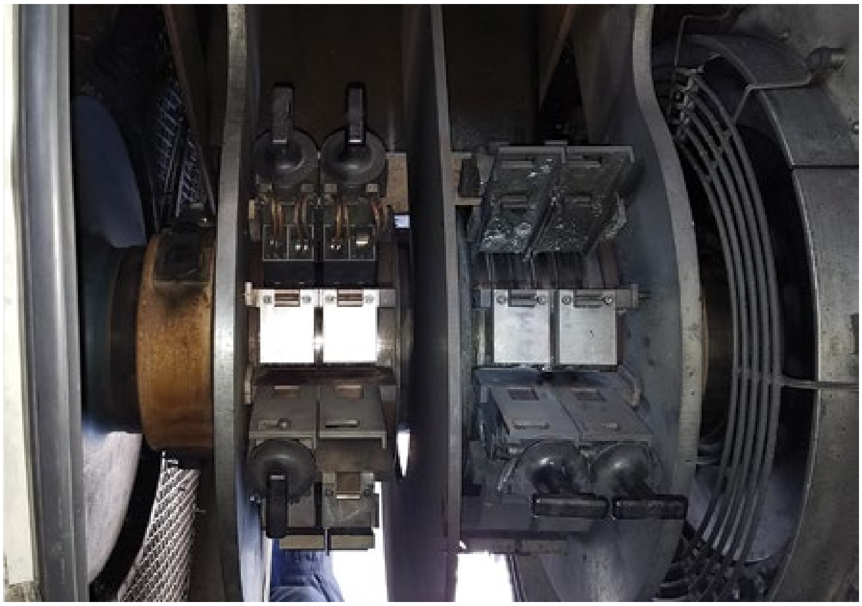
- Same process every time, no matter who's doing it.
- If there's an emergency, no need to



Arnold Group. Why to consider a warming system: Steam-turbine starting times differ dramatically for hot, warm, and cold starts



CECO Peerless. Common root causes of SCR performance loss include poor reagent quality, inadequate maintenance, catalyst bypass, fouling of the ammonia injection grid, and AIG maldistribution



Cutsforth. Brush condition monitoring provides early detection, mitigating the risk of ring fires and flashover events

Environment One. Automated gas manifold H_2 monitoring system with automated purge-system options

be in harm's way.

- Can speed up the time a purge takes with the correct equipment and process.

A current purge procedure and P&ID came next, along with automated purge-system and vaporizer options.

A helpful checklist: Things you should know to help determine if you're facing purge issues that you're not aware of include the following:

- Time it takes to purge your generator.
- How much CO_2 is consumed during a purge; what pressure and flow are you using?
- Can you confirm the amount of CO_2 that has flowed to the generator?
- Do you have CO_2-rated regulators and are they functional?
- Are operators confident they have a good understanding of the purge process and are well trained?

GT air intake systems

Faist

A good review of some things you may have forgotten about air intake systems; plus, an overview of the following relatively new filter standards specific to gas turbines:

- ISO 29461-1 (2021), designed to replace the other "dry dust" standards with a single uniform standard filter classification ranging from ISO T1 through T13, which includes EPA/HEPA filters.
- ISO 29461-2 (August 2022), designed to test filters against water penetration. Although the concept of hydrophobic filters or water-resistant filter media is not new, the speaker said there hasn't been a standard test or rating system until now. Bear in mind that water droplets have a major impact on pressure drop through the filter, efficiency, and reliability.

Two case histories are presented—one for a northern European coastal environment, the second for those same coastal conditions as influenced by incinerator operation.

Expansion-joint upgrades for legacy 501FD and 5000F units

Frenzelit

If your expansion joint is suffering a soft-goods or manifold failure, this presentation is worth reviewing for its many photos of damage and repairs. Benefits of Frenzelit's expansion-joint upgrade are said to include the following:

- Expansion-joint soft goods. Upgraded soft goods guard against internal moisture and pulsing during startup.
- Hard parts. Upgraded frame design helps protect against thermal cycling.
- External manifold insulation. Spring-loaded bands assure insulation will remain tightly wrapped around the manifold during thermal transients. Also, they mitigate sagging that would allow radiant heat to blow onto the bottom section of the expansion joint.

Bigger HRSGs equal new problems

HRST

Four case histories focus on HRSG auxiliary equipment or components sometimes found under-designed for 501F service:

- Improperly sized stack dampers. In this case study, flow-induced vibration caused the damper to vibrate and eventually fail. Damper blades were incorrectly mounted perpendicular to the flow direction; should have been parallel to the flow. The fix: Reinforced damper blades to increase stiffness at both support ends.
- Whirling tube instability. This refers to an operating condition whereby tubes tend to "whirl" in oval patterns when turbine exhaust gas flows by them. If tubes are in an array, when one is displaced, gas flow shifts, changing the forces on the other tubes. These forces induce instability when the "critical" velocity is exceeded.

Frenzelit. Installing an upgraded expansion joint

Spacing of tube supports exceeded best engineering practice and so-called J-bars (diagram is provided in the slide deck) were installed to reduce the spacing and prevent the whirling. Note that the tubes are not necessarily restrained by the J-bar, but it touches the tube surface and whirling is prevented.

- Inlet duct issues. Company's experience with inlet-duct liner systems is that they may not be sufficiently robust to overcome the effects of turbulent flow. More robust designs have met the challenge successfully.
- Steam-flow distribution issues. Flow stagnation caused overheating of a superheater tube and a subsequent leak. Flow distribution is impacted by the location of the inlet and outlet nozzles in the superheater panel. In this case, the nozzles were at the extreme ends of the headers. More even distribution would have been achieved by locating the nozzles at the middle of the panel.

High-energy-piping program overview

IAFD

If you have responsibility for inspection and/or maintenance of high-energy piping (HEP), you'll want to peruse the slide deck for this presentation. It's vintage Amy Sieben: Tons of valuable information packed into a couple of dozen slides on mandatory aspects of an HEP program, review of ASME B31.1 (Chapter VII), requirements for covered piping systems, creep, failure investigation, walkdown isometrics, hanger recordkeeping, restraint repair/redesign, pipe stress analysis, NDE, etc.

Water mist fire suppression for power generation

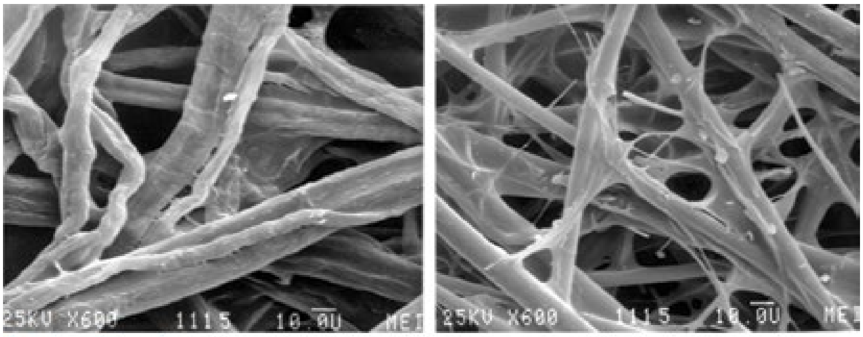
Marioff NA

This dissertation on water mist for fire suppression begins simply enough by answering the question, "What is water mist?" A chronology of the technology and its application shows water mist has been around for nearly 40 years, so there's plenty of experience to support the other 40 slides in the deck covering just about everything you'd want to know if you're considering the replacement of your CO_2 system.

Evaporative fogging and wet compression

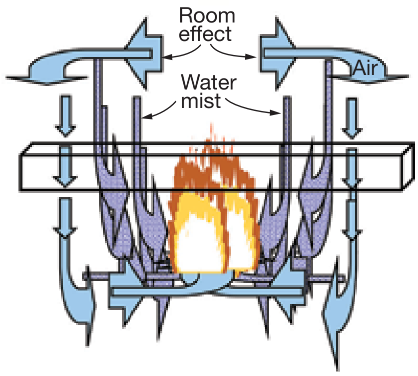
MeeFog

MeeFog may be home to the electric power industry's foremost experts on fogging/wet compression, having decades of analytical and plant-level experience on the technology. Derek Grayson encouraged attendees to consider this cost-effective method of power augmentation for delivering additional megawatts virtually instantly in time of need.



Braden Filtration. Natural (cellulose) fibers are a good choice in dry environments; they want to attract moisture, causing them to lose strength over time because of it (left). Synthetic fibers do not naturally attract moisture and recover faster when exposed to it (right)

IAFD. Piping downstream of the attemperators may be the most highly fatigued piping in the powerplant



Marioff. High water-droplet momentum is a key factor in fire suppression

Fogging/wet compression systems are easy to integrate with gas-turbine controls, he said, adding that his company typically can deliver the necessary equipment in three months or less and can connect the new system to existing equipment within a favorable outage window.

Erosion risk is reduced with small droplet size—a distinguishing characteristic of MeeFog's systems. Droplet size and its impact on equipment received significant air time.

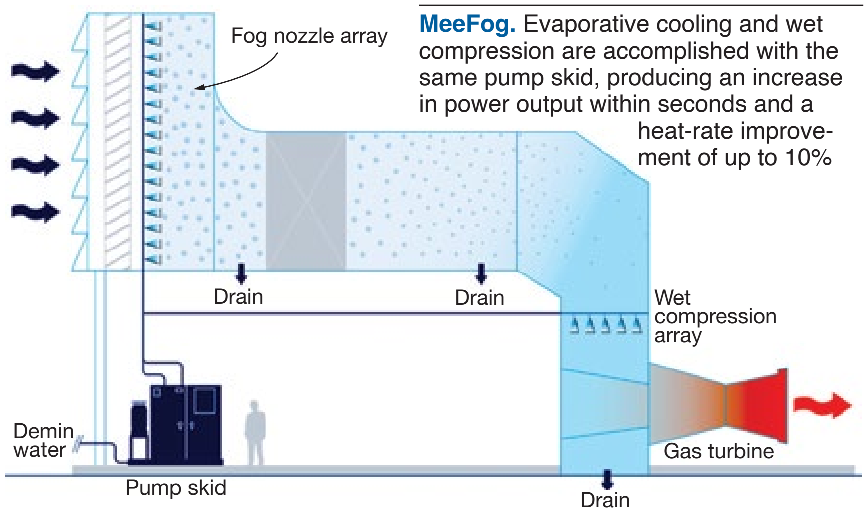
Pulse filters versus non-pulse filters

Braden Filtration

Mcleod Stephens began his presentation on why users should choose a pulse filter for their next plant by reminding attendees that self-cleaning filters, introduced in the 1970s, now account for 80% to 90% of all new-system sales. The reason, he said, is their ability to perform in the widest variety of conditions. Stephens covered the following topics:

- History of pulse-filter technology.
- Orientation of pulse filter houses.
- Composition of ambient dust.
- Filter efficiency.
- Pressure drop and pulse recovery.
- Filter media design and purpose.
- Selecting the optimal filter for your conditions.

If you haven't thought about pulse



MeeFog. Evaporative cooling and wet compression are accomplished with the same pump skid, producing an increase in power output within seconds and a heat-rate improvement of up to 10%

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Joseph Mitchell is the **Director of Operations** for the **Owner Engineer** group, **Gulf Turbine Specialists**. He is a **Gas and Steam Turbine Technical Specialist** and **Project/Outage Manager** with more than 30 years of power generation industry experience. His experience encompasses roles in the operations, maintenance and outage quality excellence of coal fired and simple/combined cycle power generation facilities, component repair sales and service and independent consultant.

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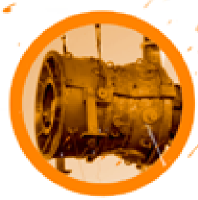

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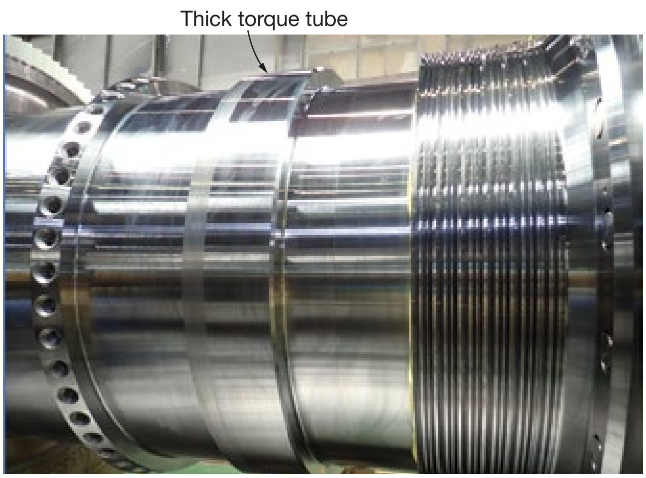
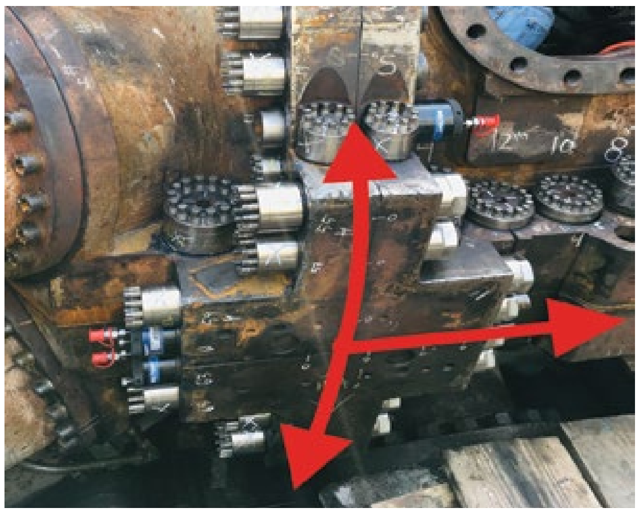
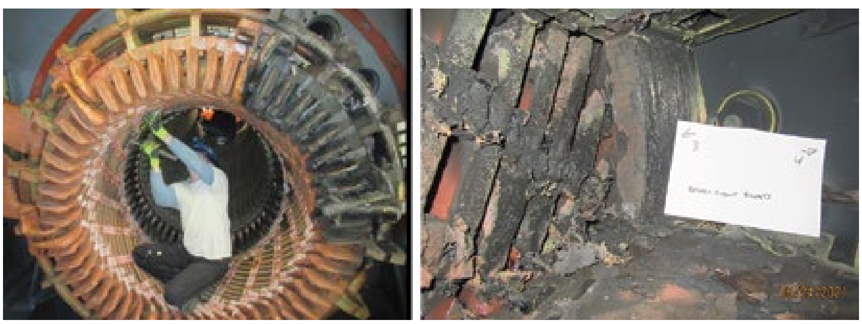


Mitsubishi Power's upgraded 501F rotor features a thick torque tube as a reliability improvement



Nord-Lock Group's superbolts are a multi-jackbolt tensioner that replaces the OEM's nuts on its studs. The MJTs are tensioned starting at the 4-way joint intersection of the turbine and combustion cylinders, with tensioning continued while moving away from the joint



National Electric Coil. Stator failure: T6 neutral connection ring, ring tab to inboard flex connector assembly plate. Close-up of damage is at right

filters recently, consider taking a few minutes to flip through Stephens' slide deck to see how this class of filters has evolved. Example: New nanofiber solutions and media substrates have improved performance and promoted longer life.

Lifecycle planning for aging generators

National Electric Coil

Howard Moudy, director of operations at National Electric Coil, explained that a typical generator lifespan for planning is 30 years, but there are other criteria: hours, cycles, bulletins, and model history.

Primary generator stator issues are:

- Endwinding resonance.
- Main lead failure.
- Endwinding support system looseness.
- Spark erosion.
- Partial discharge.

Primary rotor/field concerns are:

- Pole-to-pole crossover (TIL-2119).
- Collapse of top-turn hollow conductor and deformation.
- Slot liner cracking—top-cap interface (TIL-2256).
- Damper winding damage.
- Coil saddle connections/braze joints.

Moudy focused on Aeropac generators, beginning by directing attendees to over a dozen OEM documents—technical advisories, service bulletins, product bulletins—dating back to 2007 that demand your review. He advised on executing a life-extension solution before it's too late and becomes very expensive. Highlights of the presentation included a brief case history on a stator failure and T6 phase-ring repair. Plus, a checklist of Aeropac I life-extension rewind considerations.

W501F rotor technology

Mitsubishi Power

Greg Tomlinson, product line manager, described the company's options for assessing rotor condition, explained potential findings from a comprehensive rotor inspection, and reviewed the benefits of a rotor exchange. Next came details on the company's upgraded rotor to avoid the possibility of torque-tube cracking. Final portion of the presentation focused on Mitsubishi Power's concerns regarding rotor-in Major Inspections.

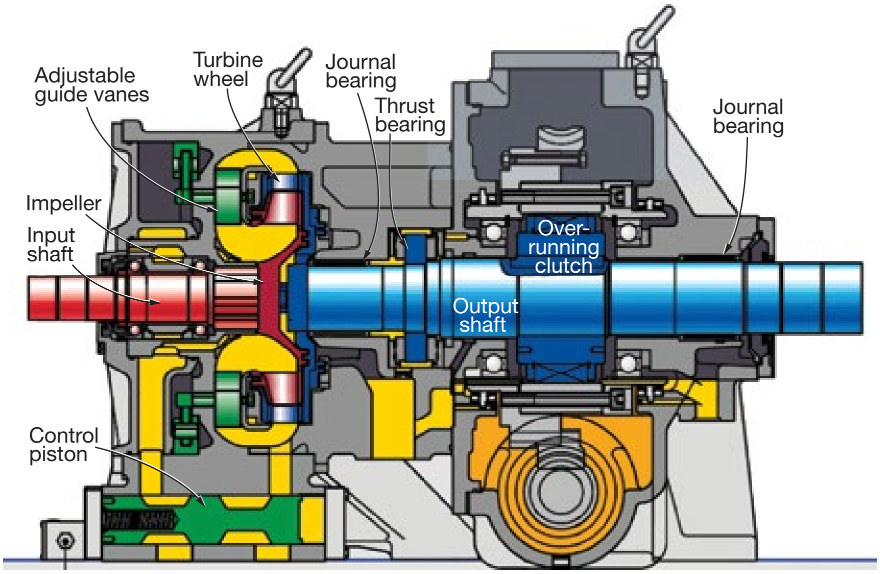
501F four-way joint solution installation

Nord-Lock Group

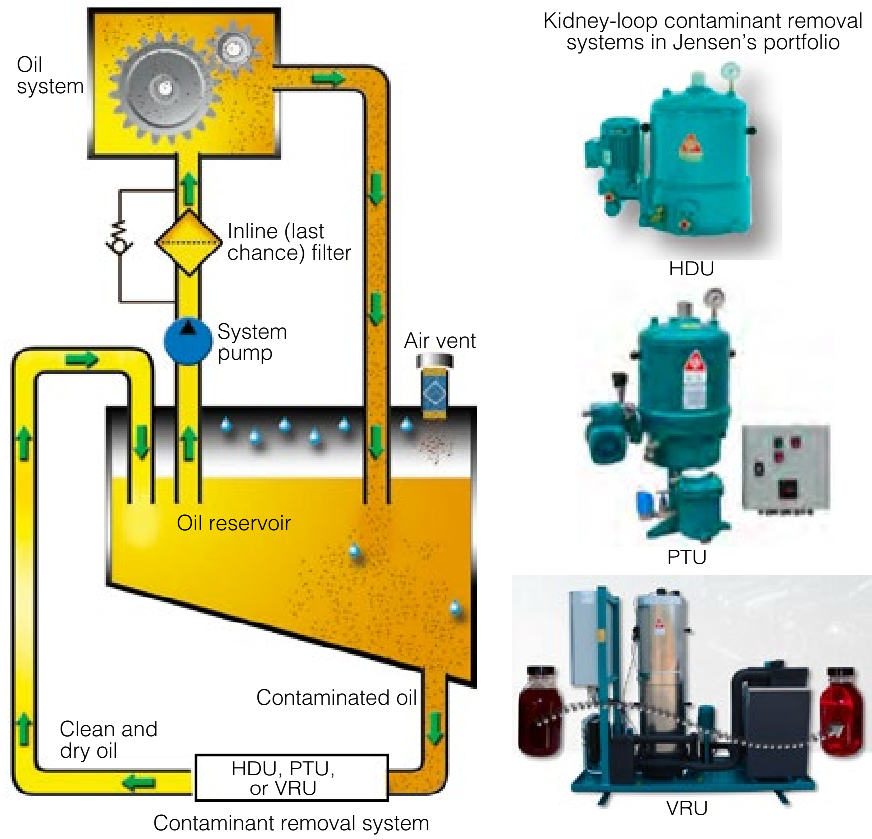
Nord-Lock partnered with a Siemens 501F user on an R&D project to investigate 4-way-joint leak issues with the goal of finding a fleet-wide solution. The partners consider remedying leakage issues important to the protection of both personnel and critical equipment. A comprehensive testing program identified, then validated on several units, an effective solution—one that combined multiple Nord-Lock products and technologies.

Given the multiple contributing causes of 4-way joint leakage, the most effective solution identified combines a specific mix of products and technologies. The combination works in concert to address multiple potential failures and provides the following advantages:

- To quickly assess and manipulate cylinder alignment, the solution includes a Boltight™ hydraulic closure system (HCS). This ensures the 4-way joint is tensioned, temporarily, to conduct a proper alignment check of the cylinder—one similar to a tops-on/tops-off alignment check performed on steam turbines.
- If the bolt hole or flange is misaligned, a proprietary CamAlign tensioner system is used to realign the cylinder. System can close an internal gap by 10 to 15 mils after the cylinder has been "squeezed" by the HCS—to ensure the smallest possible gap is achieved.
- The HCS is pressured up to simultaneously and uniformly squeeze the turbine cylinder around the 4-way joint—thereby isolating the area. Multiple hydraulic tensioners remain pressured up while internal and external gap readings are recorded, and cylinder alignment is checked.



PowerFlow Engineering's torque converters are used to multiply torque during gas-turbine startup. They may have integrated gears and clutches to turn the shaft during engine cooldown



C C Jensen. Kidney-loop contaminant removal systems rely on a stack of filter disks to eliminate particulates, water, acidity, and degradation products from lube, hydraulic, gear, transformer, diesel, and other oils

- Once adjustments are complete and the 4-way joint is aligned properly, the joint is squeezed again using the HCS, which allows load transfer to the Superbolt™ mechanical multi-jackbolt tensioners—to permanently tension the joint—without losing tension on the joint.
- Rather than tensioning one bolt at a time, which can continually create movement of the load, the HCS immobilizes the entire joint.
- An internal seal is installed to reduce leakage at the 4-way joint area where the cylinders for the combustion and turbine sections meet. The seal functions to eliminate any leakage paths that cannot be corrected by realigning the cylinders.

Nord-Lock reported completing two-dozen new installs of its 4-way-joint solution in 2021 and 2022.

Fire-protection inspections and maintenance

ORR® Protection

ORR promotes itself as a one-stop shop for things having to do with fire protection—including alarm, detection, notification, and suppression. It provides testing, inspection, and maintenance services for all types of fire protection systems offered by the major manufacturers of that equipment.

This presentation included a discussion on the most recent emergency dispatches, proposed corrective actions, recommendations, and performance assurance—something virtually everyone could learn something from. A series of slides on technology updates, code updates, and case studies concluded the session.

Torque converters in starting packages: Long-term wear and failure modes

PowerFlow Engineering

Torque converters, used to multiply torque during startup procedures, can have integrated gears and clutches to turn the shaft during engine cooldown. Good diagrams and photos help the reader navigate the slide deck to better understand what to look for during inspections. Problems covered include the following: leaks caused by wear of gaskets and seals, bearing failures, effects of long-term storage, corrosion, clutch failures, labyrinth ring wear, piston wear, cavitation, etc.

PAG, a sustainable alternative to phosphate ester for EHC applications

Shell Lubricant Solutions

Presentation begins by classifying turbine fluids in terms of their resistance to fire. Pros and cons of phosphate esters come next, followed by the pros and cons of polyalkylene glycols (PAGs).

The latter are considered by some owner/operators as having superior oxidation resistance as well as excellent lubrication qualities.

If you're in the market for a turbine fluid, consider reviewing this slide deck before making a decision.

Demystifying varnish

C C Jensen

Technical Manager Axel Wegner presented on the following three methods to remove varnish only a few weeks before his untimely passing:

- Physical filtration, including absorption and adsorption. In use are depth or surface filters with and

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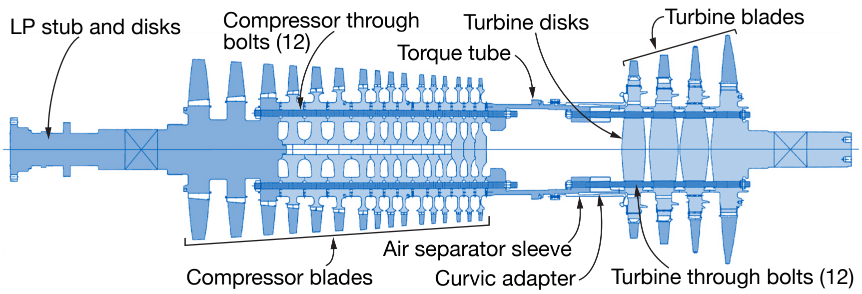
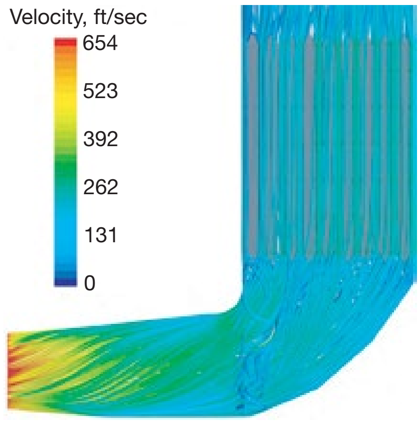


Sulzer. Rotor arrangement for a W501FD2 shows location of the torque tube and air separator



SVI Dynamics. Gas-path upgrades for the 501F exhaust system can improve safety, reliability, performance. System modeling using CFD is critical to success

without preconditioning: electrostatic and balanced-charge agglomeration.

- Chemical filtration. In use are cartridges with chemical bead compositions of varying mixtures that can be adjusted to accommodate different brands of lube oil and machine types.
- Depth-filter absorption/adsorption with advanced agglomeration, called VRU in C C Jensen speak. These systems precondition the oil in a way that all soft contaminants fall out of solution, agglomerate, and are removed by depth-filter inserts with high dirt-holding capacity.

Wegner answered the question, "Which of these methods should you use to remove varnish?" this way: It depends. . .on the efficiency of the system in different applications. More specifically:

- Systems operating at oil temperatures of around 100F and below can be treated with any of the methods identified above; many brands are available.
- Systems operating at oil temperatures above 100F are more difficult to be treated as solubility and varnish formation increase.

Another factor affecting varnish removal, he said, is run time versus downtime. As oil cools and the filter remains in service, it will collect anything coming out of solution.

W501F advancements in reliability

Sulzer Turbo Services Houston

Billy Bottera, manager, gas-turbine rotors, presented a detailed review of Sulzer's shop and service capabilities—including a laundry list of repair techniques; stocked and manufactured parts; coatings; rotor-lifetime inspections, assessments, and NDE; blade manufacturing services, including reverse engineering and modeling plus FEA and failure analysis; and the shop's large-rotor lifting and machining equipment.

Excellent drawings and photos make this slide deck a keeper for anyone responsible for overhauls.

501F exhaust-system gas-path upgrades to improve safety, reliability, performance

SVI Dynamics

This case history "checks all the boxes" as the most comprehensive plan for upgrades to a simple-cycle exhaust system that the editors can remember at a user group meeting. Here's what you'll learn by reviewing the slide deck:

- Problem definition—including customer inputs and expectations and site-inspection results.
- Site engineering study to verify the owner/operator's observations—including acoustic survey, vibration testing, and thermographic imaging.
- One-dimensional analyses and computer-aided engineering—factoring in both the current design and an alternative. This includes boundary-element-method (BEM) modeling, CFD modeling, and an acoustic model to project near-field and far-field noise emissions.
- Details of refined exhaust-system elements—including turning-vane optimization, vertical silencer optimization to reduce low-frequency noise and overall sound pressure level, and exhaust-flow distribution enhancements to increase flow uniformity.
- Design, fabrication, installation, and verification of the optimal solution—including confirmation of acoustic performance, alignment with prediction methods, and site review after an extended period of operation.

Potential for hydrogen use in combined-cycle duct burners under the new US H_2 production tax credit

Tetra Engineering

If hydrogen possibly is in your near-term future, this is a slide deck you'll want to review. Here are the key points made by Tetra's well-respected engineering team:

- Hydrogen storage and transport are the key bottlenecks to the use of this fuel.
- Early deployment of hydrogen in combined-cycle plants will be on a small scale and widespread. This allows use of existing plants and pipeline systems without large changes in operation. Use as a fuel for duct burners does not preclude use in the gas turbine as H_2 supplies increase.
- Operators gain experience in real plant markets.
- The US H_2 production tax credit effectively results in low total fuel cost for the hydrogen produced.
- Spark spreads for the portion of power dedicated to green hydrogen can be good and should cover CAPEX/OPEX costs for a real-time application. CCJ

HRSG FORUM

2023 Conference Workshops

Steven C Stultz, Consulting Editor

Editor's note: Access the presentations cited in this report to dig deeper into subject matter of interest. Go to www.powerusers.org; click the HRSG Forum logo; find the slide decks used by presenters by clicking the "Conference Archives" button at the top of the page.

Cycle chemistry

Barry Dooley, Structural Integrity Associates (UK), opened the Cycle Chemistry Workshop on Day One of the HRSG Forum's 2023 Conference and Vendor Fair, June 12 – 15, at the Renaissance Atlanta Waverly, with *Film-forming substances for combined-cycle/HRSG plants: History, background, and needs.*

He first presented IAPWS nomenclature background for film-forming substances (FFS), made up of two categories:

- Film-forming amines/amine products (FFA/FFAP).
- Proprietary non-amine-based film-forming products (FFP).

Most experience to date, he explained, is with the first category. Dooley then gave clear visual representations on FFA chemical structure (Fig 1) and the common topic of hydrophobicity.

One overall caution came early: "Dancing water balls," he explained, "are thought to indicate protection, but we now know that hydrophobicity does not necessarily mean protection" (Fig 2). This would be explained further with examples, such as Fig 3. In these conventional subcritical-plant reheater tubes, the example on the left was dosed with a non-amine FFP. The example on the right was never dosed with any FFS.

Dooley clarified that "It is unclear if hydrophobicity is a key aspect of corrosion control. In solution, some FFAs can actually be hydrophilic and increase surface wetting."

This message reinforces the complicated nature of simple visual assumptions.

Detailed FFS background is available in *Film-forming substances: Sixth International Conference,* CCJ No. 75, p 75, and *A wakeup call on film-forming substances,* CCJ No. 60, p 12.

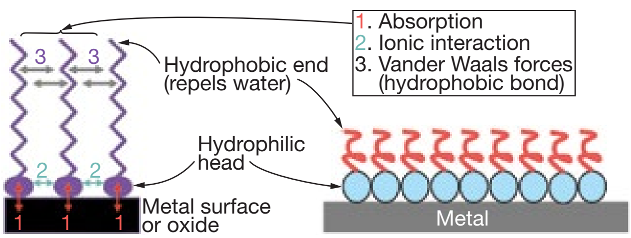
One important presentation takeaway was the list below of "Key highlights from fossil and combined-cycle/HRSG FFS applications":

1. There are universal reductions (measured) in feedwater Fe and Cu transport, but "no equivalent understanding" of the mechanisms of oxide growth reductions.
2. There are general (visual) observations of hydrophobic films on water-touched surfaces, but "it is underlined that hydrophobicity does not prove presence of a film or any protection." Refer back to the sketch of control angle in Fig 2.
3. There is generally good shutdown protection of water-touched surfaces.
4. Film formation remains "very questionable" on steam-touched surfaces.
5. Studies of adsorption of film onto metal surfaces as a function of FFS hopefully will provide information for changing the FFS applied.
6. Arresting flow-accelerated corrosion (FAC) is difficult to "see" other than by reduction of iron. Air-cooled-condenser corrosion/FAC is the exception. See report ACC.02: *Guidelines for internal inspection of air-cooled condensers,* available at no cost on https://accc-usersgroup.org
7. There are FFS application problems reported in some plants worldwide: internal deposits, tube failures especially under-deposit corrosion, formation of "gunk" (gel-like) deposits in drums and on heat-transfer surfaces, in steam turbines, and strainers/filters. Dooley offered detailed examples.

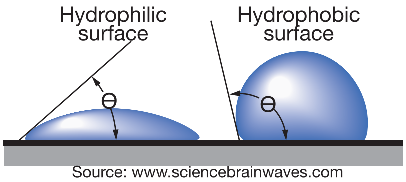
Looking forward, Dooley outlined the "path to needed research." Clarifying first that most work to date has been with metal surfaces rather than oxide surfaces in operating plants, Dooley highlighted the need for fundamental work on the "effect of FFS on growth mechanisms of Fe, Cu, and Cr oxides in water and steam."

Similarly, "much work is needed in the future on the effect of a wide range of FFS additions to allow more rugged and permanent advantages such as the ability to change from one FFS to another."

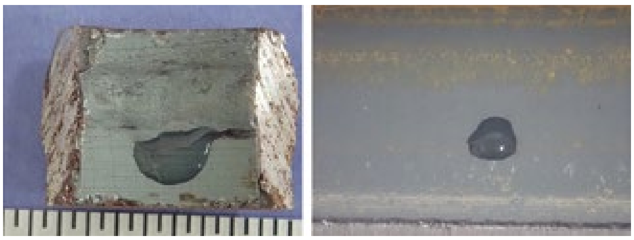
Current activity and discussion are the pathway to an IAPWS Certified Research Need (CRN) by the International Association for the Proper-



1. Background on FFA chemical structure. Hydrophobic film has been thought to "protect" the steel by decreasing contact between water and metal



2. Background on hydrophobicity



3. Conventional subcritical reheater tube dosed with a non-amine FFP (left); never dosed with any FFS (right)

4. Snow-white Millipore filter confirms optimized corrosion rate

5. Iron concentration is measured with an online laser nephelometer

ties of Water and Steam Power Cycle Chemistry Group.

In summary, he stressed application of two key rules, as the industry awaits a more complete understanding:

Rule 1, Make sure plant chemistry is optimized before application of an FFS.

Rule 2, Conduct a comprehensive review before any FFS application. Refer to IAPWS TGD8-16 (2019), *Application of film-forming substances in fossil, combined cycle, and biomass powerplants*, in particular Section 8, available gratis at https://iapws.org.

Doug Hubbard, retired manager of Chemical Engineering at American Electric Power, followed Dooley with *Do you need a film-forming substance? How do you know?*

He discussed corrosion protection during layup conditions, outlining AEP's guidelines to stop offline corrosion. Principal AEP options are:

1. Dry layup: Completely remove and keep all water and moisture off metal surfaces (ideal relative humidity: below 40%).
2. Use FFS to keep water from coming in contact with metal surfaces.
3. Wet layup: Remove and keep all oxygen out of water. Use nitrogen blanket.
4. Keep fluid moving.

These are in order from best to worst, but "any one of them is better than doing nothing," stated Hubbard. He also reviewed "layup stumbling blocks," such as online schedule uncertainties. He then covered standard "corrosion protection during operation," citing the IAPWS limits for total feedwater iron:

- Economizer inlet OT < 1 ppb (actual, optimized < 0.5 ppb).
- Economizer inlet AVT (O) < 2 ppb (actual, optimized < 0.5 ppb).
- Economizer inlet AVT (R) < 2 ppb (actual, optimized < 2 ppb).

One basic test shown for iron is the Millipore: snow white should indicate optimized corrosion protection (Fig 4). Said Hubbard, "I have never seen Millipores snow white and total iron not meeting IAPWS limit."

So, the question on need for FFS remains.

He then offered some "experienced-based opinions:"

1. Layup protection:

- If capacity factor is below 15%, FFS will not have time to "film cycle."
- If capacity factor is above 60%, FFS could be too expensive to feed.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- If unit runs hard and is then down for a long period of rime, this could be an ideal use of FFS.

2. In-service corrosion protection:

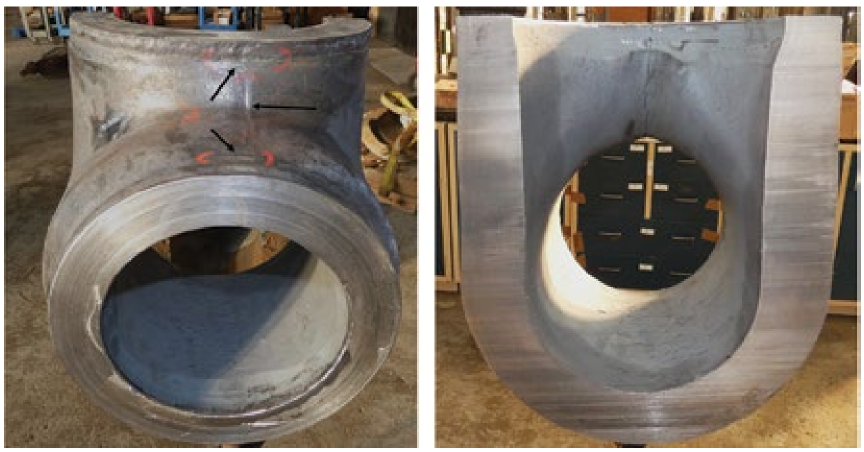
- FFS is not needed for AVT O/OT units.
- If there is significant two-phase FAC, FFS could be part of the solution once cycle chemistry is optimized.

3. Failure mitigation with FFS:

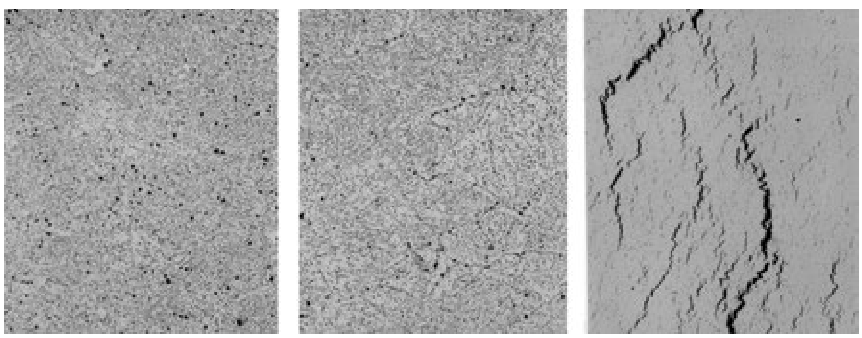
- Good option for pitting attributed to oxygenated stagnant water.
- Unclear for pitting due to chloride/sulfates.
- Unclear for under-deposit corrosion.
- No known value for existing corrosion fatigue (driven by strain).
- However, if you are trying to prevent corrosion fatigue, FFS may be of value by slowing down the corrosion part of corrosion fatigue.

Hubbard ended with important guidance: "Make sure you define clearly with your FFS manufacturer the goals expected while feeding FFS, with very specific measurables to determine if goals are being met. The FFS manufacturer needs to sign off on these goals and measurables," he emphasized.

David Little and Bruce Opsahl, Nalco Water, were next with *HRSG protection with Powerfilm™ 10000, a non-amine FFS.* While outlining the various reasons for considering filming technology, Little emphasized that FFS applications are "not a substitute for a good base steam-cycle chemistry program."



6. Tee suffered a through-wall crack at the crotch position on one side and another partially through-wall crack on the other



7. Stages in the evolution of creep damage

Nalco introduced Powerfilm 10000 as "a non-amine filming corrosion inhibitor designed to protect powerplant boiler systems from offline corrosion and stresses caused by cycling."

Little and Opsahl offered a case study of a 2 × 1 combined cycle in north Texas where market-driven layup practices had raised concerns about asset longevity. The plant faced wet layup of the HRSGs for long periods of time. A program was launched to reduce corrosion product transport, measured as total iron, to 5.0 ppb (EPRI action level).

Powerfilm was injected at the condensate-pump discharge. A low continuous dose (0.4 to 2.0 ppm based on feedwater flow rate) was applied during baseload operation, cycling load, and two–shifting on/off with hot standby. A high continuous dose (5 to 10 ppm) was applied for several days prior to shutdown and wet layup (1 month or less) or dry layup.

Using an online laser nephelometer, 3000 iron concentration data points were collected over a four-month period (Fig 5). Filter pad (Millipore) grab samples also were used.

Their summary of results showed that the nephelometer gave economic, portable, real-time collection of iron transport data, and concentrations

8. Creep-related failures may require full excavation of the damage (above)

9. Access limitations may require trolley systems and lifting/turning frames (right) remained below the target. Also, "iron reduction continued despite increased cycle events of the steam turbine."

Dale Stuart, ChemTreat, then presented *The use of FFA to mitigate corrosion in HRSG units* and offered various examples in the US.

He said the purpose is to "provide a passive layer when conventional chemistry fails."

Based on the examples shown, Stuart summarized that:

1. The FFAs used formed a bonded layer of persistent film.
2. The FFAs were volatile and traveled through the system.
3. Treatment was thermally stable, but required increased dosage at higher temperatures because of its higher volatility and desorption coefficient.

Eric Zubovic, Veolia, then discussed the *Impact of film forming amines on condenser efficiency* concluding that use improves condenser performance by promoting dropwise condensation on the tubes. He concluded that polyamine (FFA) increases heat-transfer efficiency, noting that a continuous feed (at the proper feed rate) is needed to maintain dropwise condensation. He also concluded that "turbine backpressure can be improved between 0.42 and 0.60 in. Hg with dropwise condensation."

Chris Dumas, Kurita, presented *Cetamine® treatment of an HRSG in Spain*, a presentation also made at the 2023 IAPWS International Conference on Film Forming Substances. His conclusions: (1) Cetamine G85X is offering beneficial protection during cycling operation and preservation periods. (2) It can be used as an additional treatment to conventional AVT or AVT+PT. (3) It has reduced startup times and use of blowdown. For more detail, see our report *Film-forming substances: Sixth International Conference,* CCJ No. 75, p 75.

Many interesting questions and discussions followed these presentations. Topics included good chemistry versus FFS in a new baseload plant, FFS selection for cycling units, iron sampling processes including filters, methods of pH control, and FFS versus changes to materials.

Dooley's Q&A summary: "Excellent questions; we know that many plants do not do their homework before application of an FFS. The pre-application process is the most important, and it is critical to first review IAPWS Technical Guidance Document TGD8-16 (2019)," freely available at www.iapws.org.

Contact Dooley (bdooley@structint.com or bdooley@IAPWS.org) for further information on FFS and the IAPWS FFS conferences.

Welding and metallurgy

The afternoon workshop on Day One of the HRSG Forum's 2023 Conference and Vendor Fair, June 12 – 15, at the Renaissance Atlanta Waverly, focused on welding and metallurgy. It was a combined effort among Jeff Henry and Kevin Hayes, Applied Thermal Coatings, and Amy Sieben, Industrial Air Flow Dynamics (IAFD) and had the official title *Powerplant materials, welding, and welding engineering support: What the industry-wide loss of expertise means for plant owners and operators.*

Henry began with *What a recent failure suggests about the state of our industry*. It concerned the failure of a 10-in.-diam tee after 80,000 hours of service (Fig 6). The component, from a 635-MW coal-fired boiler producing steam at 3700 psig/1050F, suffered a through-wall crack at the crotch position on one side of the tee, and another partially through-wall crack on the other side, both ID-initiated.

Also, cracks at the toe of both the

run and branch girth welds were OD-initiated. Multiple tees on other units suffered similar creep-related damage.

The material specified was Grade 91. Units were built "to Code," but analysis found that the materials did not match the plant's RFQ specifications, although they "came from a reputable OEM."

Other materials discrepancies were found at the plant.

This is just one example of multiple tee failures in multiple units in the US, and "EPRI has estimated the number of tees potentially at risk could be in the thousands," Henry said.

Historical perspective

Years ago, the US electric power industry was seen as a vital component of the economy. "To that end, the industry was regulated to control the risk to which utilities could be exposed and to provide a level of financial security that would encourage investment in the resources (people, equipment, etc) necessary to ensure an ample supply of power," explained Henry.

This arrangement, he said, "benefited not only the utilities but also the companies that supplied the major plant components—including the steam generators and the turbine/generator equipment."

OEMs became comprehensive service organizations capable of addressing all aspects including design, manufacturing, erection, commissioning, operations, and materials expertise. OEMs also provided detailed supplier oversight, and direct participation to ensure quality.

"With deregulation, the OEMs' service capabilities were gradually dismantled," he said.

Henry then reviewed the *ASME Boiler & Pressure Vessel Code,* stating that "from the beginning, the focus was on safety. Code was not intended as a design handbook or manual for best manufacturing practices. Design and manufacturing for efficiency and reliability were the OEM's responsibility," he explained. The OEMs also provided extensive support to, and participation on, the Code technical committees.

Henry further explained that the ASME Code is for new materials (that is, construction). Repair is in accordance with the National Board Inspection Code (NBIC) and the National Board of Boiler & Pressure Vessel Inspectors.

Today, plant operators are looking for assistance and are often left to choose from a "small pool of technical resources with more narrowly focused capabilities," particularly regarding materials, welding, and welding engineering. University programs, he further suggested, are also becoming more specialized.

"Plant operators themselves are already stretched to the breaking point," he added.

Pressure-part materials

Henry turned to a comprehensive overview of some of the more important metallurgy issues encountered in today's powerplants. He focused on:

- Principles of ferrous metallurgy.
- Pressure-part life and creep (Fig 7).
- Creep damage in welds.

He entitled his presentation *Pressure part materials—the basics*, but it was quite detailed and comprehensive in the areas of ferrous metallurgy (crystal structures, etc), martensite/pearlite/bainite, microstructures and properties, defects ("all materials contain defects"), hardenability, alloying of steels, common pressure part materials (carbon/low-alloy/CSEF and austenitic stainless steels plus "unwanted but tolerated residual elements in the ore that came along for the ride," pressure-part life and creep, and the structure of welds.

This was all what he called "an overview of some of the more important materials issues faced by plants today."

Kevin Hayes followed with a discussion on welding and welding engineering support, specifically *What industry-*

wide loss of expertise means for plant owners and operators.

"There is currently a shortage of welders in the US, and the potential shortfall of welders needed by 2027 will be 360,000, according to work-force data provided by the American Welding Society. Potential negative effects of a reduced labor pool include the following:

- Increased potential for weld-related defects.
- Competition by employers for limited resources.
- Use of automation, resulting in less hands-on skilled welders.
- Potential impacts on outage schedules.

He offered an interesting sidebar caution: "Temporary repairs tend to become permanent."

Hayes also had several suggestions on the path forward, stating that one competitive advantage will be to have multi-skilled team members (print reading, multiple welding and heat treatment processes, weld machine programming, multiple weld repair processes, etc).

"With the welding and welding engineering support shortage," he said, "tomorrow's team members will not be the same as the previous generation's team members."

Hayes then turned to detailed looks at potential welding defects, and the best methodology for executing an effective weld repair, including but not limited to:

- Understand the root cause of the damage or failure and base-material composition.
- "Sample, sample, sample"—boat samples, in-situ replication, visual, and other testing.
- Evaluate previous repairs.
- Consider original design, fabrication, and current operating conditions.
- Define the proper repair method, work scope, and resources required. Creep-related damage, for example, may require full excavation of damage (Fig 8).
- Execute the plan, then document what was performed and lessons learned.

Another key point: "Be prepared to expand the repair scope to address unexpected conditions." And most important: "Verify personnel have received proper safety training."

He then reviewed "NBIC Repair and Alterations, Part 3, Welding Method 6 and Supplement 8 Requirements."

Pressure-part replacements

Amy Sieben followed with *HRSG pressure-part replacements.* Citing the age of many units today, she addressed the increasing need for component replacements.

Sieben listed the following as the primary common mechanisms for pressure-part failures:

- Flow-accelerated corrosion.
- Under-deposit corrosion.
- Fatigue cracking.
- Corrosion fatigue/chemical attack.
- Creep/fatigue interaction.
- Dew point corrosion.

This led to discussions on replacements versus chemical cleaning, and the opportunities for material upgrades.

Case studies offered interesting looks at access, trolley systems and lifting/turning frames (Fig 9). Many examples are shared in the presentation.

Other case studies were given on tube and header replacements, NDE and post-weld heat treatment, tube plugging and repair methods, types of tube-to-header welds and weld preparation, and tube restraints.

Sieben then reviewed "the other 10% of failures"—such as baffle/casing systems, desuperheaters and drains, duct liner and expansion joint failures, GT exhaust frames, blowdown piping, etc.

She ended with advanced NDE detection methods, removal and inspection, thermal imaging, radiography, and use of drones. CCJ

Alstom Owners Group Seventh Annual Meeting

Summer 2024

The Alstom Owners Group (AOG) began in 2018 as a private user organization, enabling owners and operators of Alstom equipment to communicate directly with each other, collectively with the OEM, and with third-party service providers in a secure setting. The group meets annually.

AOG has grown dramatically since its founding. There were 41 members representing eight countries the first year. By the 2023 meeting, those numbers had increased to more than 200 members in three-dozen countries. Membership is limited to individuals directly involved in the construction, operation, and/or maintenance of Alstom gas and steam turbines and who are employed by companies with ownership and/or operational interest in those turbines.

Arnold Group, Hughes Technical Services (HTS), and Liburdi Turbine Services have supported the organization since its beginning, sponsoring each of the first six meetings.

The 2024 conference agenda, in development as CCJ goes to press, will be posted by year-end at www.aogusers.com, where you'll also find registration, lodging, and other pertinent information. Contact ashley@aogusers.com with any questions.

Content for, and conduct of, AOG conferences is organized by a steering

committee which has the following members for 2024:

- Brian Vokal, senior VP O&M and engineering for Midland Cogeneration Venture.
- Pierre Ansmann, global marketing director for Arnold Group.
- Robert Bell, plant manager of Tenaska Berkshire Power.
- Jeff Chapin, AOG founder; manager of business development for Liburdi Turbine Services.
- Ross Goessl, PE, senior engineer for We Energies.

CCJ's report on the sixth annual meeting follows.

Jeff Chapin welcomed the group to EPRI's offices and training facility in Charlotte (NC), Monday, Mar 20, 2023. Sessions would end on Thursday with a tour of the research organization's labs and four concurrent training workshops.

Attendance on the first day was limited to owners and operators of Alstom equipment, with GE, the OEM of record, joining in the afternoon. Service providers were invited to participate for the remainder of the conference.

Chapin launched the meeting with one paramount appeal: "Network! We all struggle to find parts and services. Let's work together and share information. We need to know our service providers, and they need to know us."

This initiated a long discussion on personnel—not just GE's or the service providers', but the owners' employees as well. And not just people as contacts; people who are willing to dig in and get things done.

With that, the meeting moved on to questions compiled during registration. Some were general: "Is there any successful peer/user repair experience on GT11 rotating blades using non-OEM shops?" Various responses followed with mention of Liburdi, TRS, and Doosan Turbomachinery Services—among others.

Some were more specific: "Any experience with GE-suggested borescope inspections on GT11N/GT11D Row 4 blades to address TIL-2376?" One response: These blades are difficult to see and assess. Side note by one: "We've had issues with parts repaired in Dubai shops, and it would be nice to know where replacement parts are coming from."

The key parts decision that comes up, all agreed: Repair, or replace?

The dialog continued.Next: Supply scheduling for new parts, even if the order is placed 18 months before the need. All agreed that such timing can work, but there are still delays. Owners agreed that the best strategy would be 24 months for GE parts.

One owner noted that even paying a 25% expediting premium gives no timing guarantee. "Even our long-term service agreements (LTSAs) aren't always helping us," said more than one.

All concurred that supply-chain concerns are not new, nor have they improved. The consensus was to "maintain capital spares at site if you can," but many reported restrictions with financial approvals (management) to do so. Many plants also have new or even multiple owners to complicate and delay the processes.

The consensus: Owners must be their own expediters into the supply chain, wherever the hold-up seems to occur.

An interesting point was made by one owner here: Check your parts warranties. Some carry one year after install, but some also state one and a half years from delivery. This is not consistent with the recommendation to carry critical spares in inventory.

Long-term planning has another obstacle. Operating profiles can change quickly, and when they do, unexpected pressures could be put on equipment.

For Alstom-specific issues, a few of the favorite non-OEM suppliers have good background within their management, but at times still need to look for specific experts for help. Many are also light on what the group called "bench strength."

Consensus again: Finding the right person, and having bench strength, are

1. Your original safety railings may no longer conform to OSHA regulations

concerns common to everyone, even GE. This raised two additional topics: First, owner/operators knowing the right people to call, and second, all companies in the industry needing to grow (or initiate) their apprentice programs for the longer term. "Succession planning is big for everyone," was a key takeaway.

An owner noted that during a recent C-inspection, the OEM had worked into its QA/QC plan three-point alignment checks based on fleet incidents. What do others recommend? One answer: Three points is just a check. Six points is better.

Another interesting find: "We have found a problem with the original, OEM-installed combustion-enclosure roof hatch (Fig 1). The protection violates today's OHSA code. It's not something you look at often. We discovered it during a roofing project."

Keep in mind that many of these discussions also occurred one-on-one or in smaller ad-hoc groups throughout the conference, and during the breaks and evenings. The posed questions acted as catalysts, and some came up during the presentations. To get the full benefit of the discussions, and to offer your input, the editors recommend being there in 2024—and beyond.

The AOG User Group Forum was mentioned often. For those interested, this online discussion feature is available to all registered members of AOG. This forum is a private online community of Alstom turbine owners to communicate directly and securely with each other. It is the online extension of the annual conference.

As noted earlier, membership is limited to individuals directly involved in the construction, operation, and/or maintenance of Alstom turbines and who are employed by companies with direct ownership and/or operational interest in those turbines. An account is required and can be obtained at https://forum.aogusers.com/login. Final slide decks for this conference are available to registered users through the Forum website.

General Electric

GE purchased Alstom's gas and steam turbine/generator operations in 2015 and has had a scheduled session with owners at the annual conference, serving as OEM.

Stefano Tartoni, platform manager base fleet; Tom Stroud, GT24 product manager; and others from GE addressed the group on the afternoon of Day One, beginning with a breakdown of the current and changing GE structure.

Said GE to begin, "As a fleet equipment overview, the GT11N machine is seen as rugged, reliable, and relevant. With 30 years of operating experience, 80 out of 87 units remain in service."

The GT11N2 fleet also has a 30-year history, an average age of 21 years, with 57 of 58 remaining in service globally, GE participants said.

For the GT24 fleet, said Stroud, 52 units have been installed globally since the mid-1990s, mostly in North America (including Mexico), averaging 5000 operating hours annually.

GE has issued and maintains Technical Information Letters (TILs) and Field Service Bulletins (SBs) on these fleets.

This led to brief technical updates on 11N Row 4 turbine-blade liberation (TIL-2376 issued), 11NM Row 3 blade liberation (SB issued), 11N2 TVC inset-ring improvements, and other specifics.

GT24

For the GT24, updates followed on Row 11 compressor-blade tip cracking, specific MXL2 upgrades, and others, including pulsation protection systems.

Rotor lifecycle management should focus on two areas, said GE: creep life and cycle life. A remaining-life program is available from GE that monitors operating hours (creep life) and fired starts (cycle life). The presenter dove into the details of each, ending with the thought that, with proper care, units should reach 200,000 EOH. Stressed was the need for "safety-critical inspections."

After a short break, GE returned to discuss replacement parts and outage planning. A strong GE suggestion: "Outage planning should start 30 to 36 months before the outage," recognizing that parts cycle times include material delivery, which itself can take up to 24 months.

GE does, however, carry an "emergency inventory" for forced outages. In fact, GE holds two inventories, new and refurbished, in Switzerland, they said.

Recognizing all global influences, the suggestion was: "Build your own inventory, and use GE to help." (Note owner comment above on inventories and warranties.)

One important add-on: Parts from GE will include the "latest and greatest" design improvements which might not be available from other suppliers, the presenters suggested.

Josh Pryor gave an informative presentation on repairs in general, stressing that GE's repair processes incorporate results of the company's "continuous investment and improvement" programs, including in-depth research. "There is investment and development within GE for the fleets," he said.

Another interesting point: Outage planning should include the latest tools developed for replacing the parts. Emergency repair cases handled by GE get passed through the company, he said, and become background for both current and future work—including the best tooling.

Then came an area where "GE is starting to pivot." Seeing that more and more of the repair work is "condition based" (that is, stop/start), GE is focusing on how to help with "short return-to-service intervals."

For generator support, GE is trying to qualify more American component suppliers to reduce import transportation and customs issues. But one difficult problem remains: There are relatively few "professional winders" and other skilled personnel within the industry pool.

For controls issues, GE has launched a program to help with Mark VIe systems.

Time was provided at the end for questions that included the items above plus the skills gap in field service teams (GE has a new mentorship program), concerns about current TILs and legacy SBs, a new generation of exciters, and benefits/drawbacks of three-point alignment.

Users, solutions providers

Day Two began with the steering committee's Brian Vokal welcoming service providers to the conference. The first keynote address followed. EPRI's Bobby Noble, program manager for gas-turbine R&D spoke to "How gas-turbine maintenance has changed."

Explaining that EPRI is funded 40% internationally, Noble focused on two programs and covered products for the GT8, GT11N/N1/N2, GT13, and GT24/26. The specific programs:

- Program 216, Gas-turbine lifecycle management.

2. The UK's Rocksavage Power Station, near Liverpool, required a complete EV combustor rebuild on its GT26

3. Damage to the Rocksavage combustor forced the unit out of service for six and a half months

- Program 217, Gas-turbine advanced components and technologies.

Stressing that the industry must adapt to constant change, he first discussed innovation in combustion technologies, advanced manufacturing and repair, and use of digital twins.

One specific innovation is a GT24 combustion tuning guide and training program developed by EPRI. Another is GT26 firing-temperature verification, addressing the "pain points" of shortened intervals, advanced hot-gas-path degradation, and premature replacement of parts.

Talking about outage management and oversight, Noble highlighted the big issue faced by the industry: Personnel retirements and the need for knowledge capture. This was in line with the opening discussions by owners.

For the personnel issues, he saw three strategies: Emphasize knowledge capture, focus on documentation (and archives), and create a strong culture of collaboration.

Noble also offered a detail taken from the 7FA fleet. At one unit, outages had been performed for decades, but only recently did the site include mechanical cleaning of the turbine wheel serrations. Lack of this cleaning led to rotor replacement in another unit.

The second keynote, by Dave Hetherington of McCoy Power Reports, Richmond, Va, covered "Alstom GT fleet behavior: GT24 and GT11."

He looked at data for units above 20-MW capacity, listing the Alstom USA fleet as:

- GT11 combined cycle, 24 units; simple cycle, 65.
- GT24 combined cycle, 24 units; simple cycle, 3.

Hetherington's long-term trends looked at fired-unit count, gross load, operating time, fleet heat rates and starts/stops for 2003 through 2022, and starts/stops for 2015 through 2022. For the last, GT24 has had the largest continuous trend in load and start/stop increases.

He then reviewed this within the context of ongoing global generation mixes and trends.

User presentation: Rocksavage

Alstom equipment owner, InterGen UK, described a significant GT8 EV combustor failure in May 2022 that shut down Rocksavage Power Station's gas-turbine B. Speaker Paul Swire labeled this a "rebuild project" with a "truly pragmatic solution."

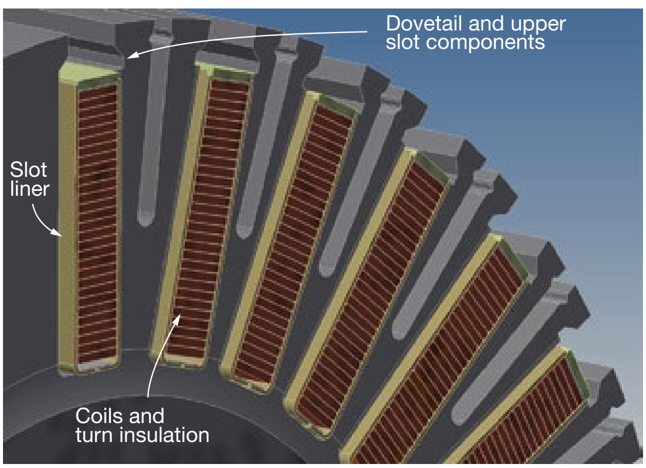
Rocksavage is a 2 × 1 800-MW, fully merchant combined cycle firing natural gas. It is located in the northwest of England near Liverpool. Commercial operation of the GT26 A/B version machines began in 1998 (Fig 2).

There are no OEM service agreements in place.

Gas-turbine B's failure, calling for a complete EV combustor rebuild, occurred on May 21. The plant's dedicated service provider was contacted and disassembly began on July 25. The GT was disassembled and assessments completed by August 25. Initial findings showed severe damage to the EV combustion chamber, lance trumpet, hood rear wall, and burners (Fig 3).

The unit was back online for the high-market-value winter months.

Challenges. There are very few GT26 A/B units operating worldwide and InterGen owns the majority—four.



4. Slot liners are designed to isolate the excited copper coils from the grounded field forging. Component fails only when the unit goes to ground (left)

5. Failed/cracked slot liner was identified during borescope inspection (below)

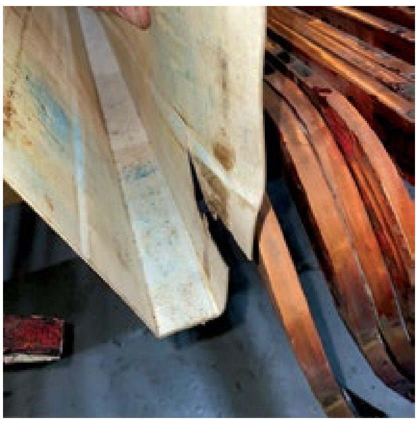
The OEM's stock of EV combustor parts for the A/B model is very limited.

To replace the EV combustor structure with new equipment from the OEM a 46-week lead time (to April 2023) was quoted. It was outage season and OEM resources were said to be stretched because of prior commitments. With that schedule, a return to service would be June 2023.

Solution. InterGen engaged with independent power-generation owners, GT consultants, and various service companies. They contacted the engineering teams of other GT26 A/B owner/operators worldwide and worked with the OEM to explore options.

Through this collection of resources, parts began arriving at site October 4 and the EV combustor rebuild began October 6. Some original pre-owned parts, critical to the project, were located at a GT26 A/B site in Argentina. Others were made by third-party providers, as well as the OEM.

The GT rebuild was completed in November with first synch November 24, and return to commercial service December 6. InterGen has "confidence" in running through to the 2024 Major Inspection. This rebuild approach beat the assumed OEM schedule by six months.



6. Damaged slot liner was removed in a single-coil rewind

Mechanical Dynamics and Analysis

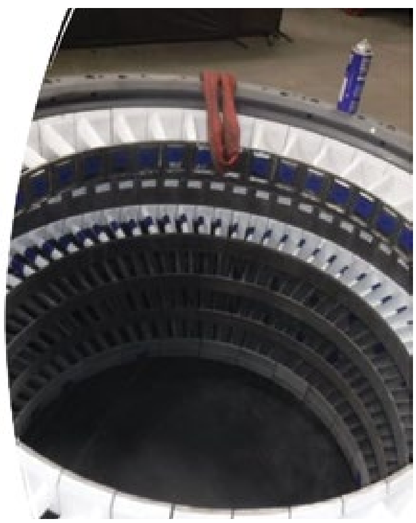
Next, James Joyce, MD&A's generator services operations manager, launched the service-provider's portion of the program with his presentation on "Slot liner cracking," focusing on Alstom generator fields.

Slot liners, which fail only when the unit goes to ground, are designed to isolate the excited copper coils from the grounded field forging. There are both U- and L-style liners.

The U-style in this example was experiencing pin holes and cracking. Explained Joyce, the U-style hugs the coil very tightly, and "does not have any tangential relief." The L-style on other units has a centerline break and can move slightly. The U-style has no centerline break causing all tangential forces to be applied to both sides of the U channel (Fig 4).

Liners can be inspected by borescope during a minor outage (Fig 5).

In the case study presented, the



7. HTS, in cooperation with TRS, refurbishes turbine parts, including those in the hot gas path

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unit had passed electrical testing. But inspection found a problem and potential for grounding. The owner/operator chose replacement. These liners can be replaced after removing the upper slot components in a single-coil rewind (Fig 6).

Joyce concluded by describing a high-speed balance and heat run by MD&A in its St. Louis shop.

K-Machine

K-Machine Industrial Services presented its profile of turbine services for utilities. This is a family-owned company in Savannah (Ga) that focuses on portable machining and welding, component manufacturing, and valve parts and refurbishment. Its gas-turbine focus includes exhaust frames and diffusers, diaphragm manufacture and repair, casing crack repair, and thermal re-rounding (shell and casing distortion correction).

K-Machine also manufactures selected OEM replacement parts.

Hughes Technical Services

A division of the expanding AP4 Group, which includes AP+M, Turbine Controls and Excitation Group, and Gas Turbine Controls Corp, HTS contributes expertise on powerplant commissioning and maintenance. It was founded in 2014 by former ABB/Alstom engineers and others in the industry, including GE.

HTS is "the primary third-party provider of Alstom parts refurbishment service in North America" in close cooperation with TRS (see profile below) and others, said Gary Hughes (Fig 7).

For gas turbine A, B, and C inspections the focus is turnkey—including tools, craft, technical advisors, and commissioning. Inspection and maintenance capabilities make for a long list, together with steam-turbine services and upgrades.

HTS also listed its in-house controls expertise and upgrades—including an ABB Value Provider Program. Add to that, the company's flame monitoring systems, pulsations monitoring, and balance-of-plant capabilities.

Arnold Group

The company's Pierre Ansmann focused on industry response to changing market conditions—including:

- Improved dispatch appeal.
- Reduced startup times.
- Reduced plant cycling stresses on single-point-of-failure assets.

Ansmann then explained the company's three key targets:

- Steam turbine warming.
- HRSG warming.
- Steam valve maintenance.

Steam-turbine warming systems can significantly reduce startup time. In a D11 case study, total plant optimization was reduced from 266 to 149 min, and the HP rotor life-consumption factor was reduced by approximately 25%. There were also lower overall steam-turbine stresses because temperatures never dropped below 300F. Upper-to-lower casing temperature differentials were also reduced.

The D11 example given includes direct permanent fixing of heating wires below the split line (Fig 8). The unit has removable heating panels on the split line and upper casing.

Ansmann explained the "single layer insulation and turbine warming system" that offers "the most advanced turbine insulation combined with a high-performance heating system." To dig deeper, see CCJ No. 72, p 34.

Liburdi Turbine Services

Dave Nagy, discussed "Gas turbine supply-chain challenges: Component repair to reduce waste and improve turn time."

"Materials are finite," he said, "and there is high global competition for raw materials used to make gas-turbine

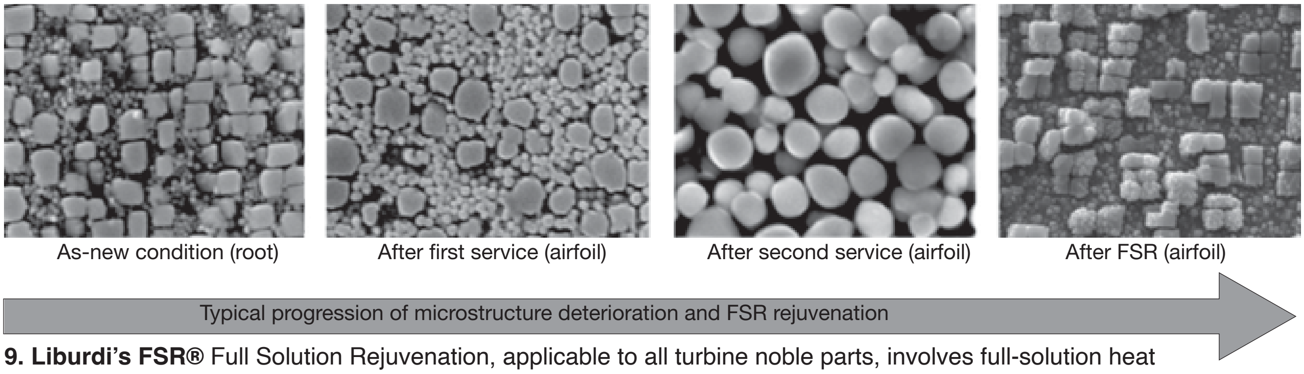
8. **Permanent placement** of redundant sets of heating wires on the turbine casing below the split line, plus the use of a heat-reflecting shield over the wires,

creep strength.
- Applicability to all turbine noble parts.

Two points about FSR:
1. The processed part must meet or exceed new-part strength requirements, and
2. The process can be repeated at each service interval.

Nagy offered a mechanical proof test (Fig 9) showing stress-rupture test results to make the point.

The fifth "R" is *reconstruction*. His example: Impact-damaged nozzle guide vanes with leading-edge damage (Fig 10). The leading edge was repaired using Liburdi's LPM metal replacement technique—a powdered metallurgy technology. The part was returned to service for a full 24,000-hr interval. Post-service inspection found no indications or material loss.



9. **Liburdi's FSR®** Full Solution Rejuvenation, applicable to all turbine noble parts, involves full-solution heat treatment and proprietary vacuum heat treatments to restore microstructure and creep strength

components." Most components have up to 60% nickel and 10% cobalt, although these numbers vary.

Nickel is in high demand for electric vehicles. Cobalt is another limited resource, and demand is about to outpace supply as some gas-turbine components have moved to around 60% cobalt.

The outcomes: Longer lead times and increased replacement-part costs, leading to "operational uncertainty."

There is also increasing use of the term "yield." For example, can someone repair a component to *yield* a 75% chance of making it to the next major outage (or similar milestone)?

Suppliers are no longer stocking spares, and global supply chains are subject to disruptions (nature, politics, economy, cyber attacks). Ongoing forced outages also contribute to inventory reduction.

Nagy offered a brief history of *"R"* terms. In the mid and late 1990s, many corporations turned to the Three Rs of *"reuse, reduce, and recycle."* These are in play today. But now we are adding *rejuvenate.*

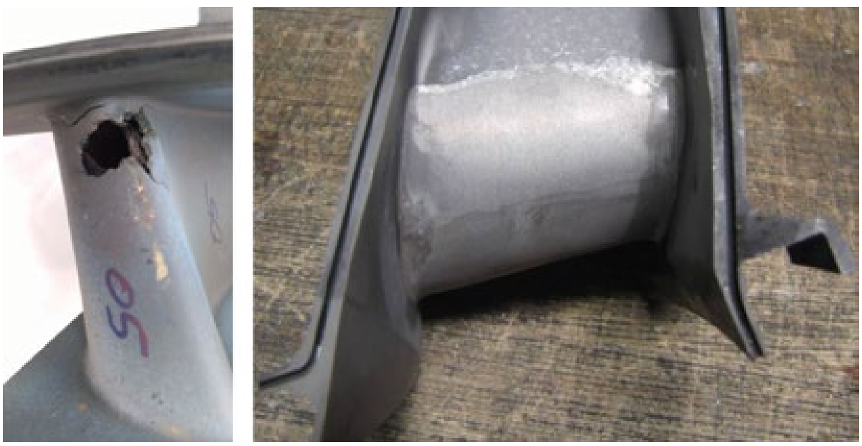
Nagy took attendees back to the company's founder, Joe Liburdi, at the sixth ASME Turbomachinery Symposium in 1977 and his paper on rejuvenation of used turbine blades by hot isostatic pressing. Liburdi was with Westinghouse Canada at the time.

Liburdi as a company is now talking about FSR® or Full Solution Rejuvenation (Fig 9), meaning:
- Full solution heat treatment (not partial).
- Proprietary vacuum heat treatments.
- Restoration of microstructure and

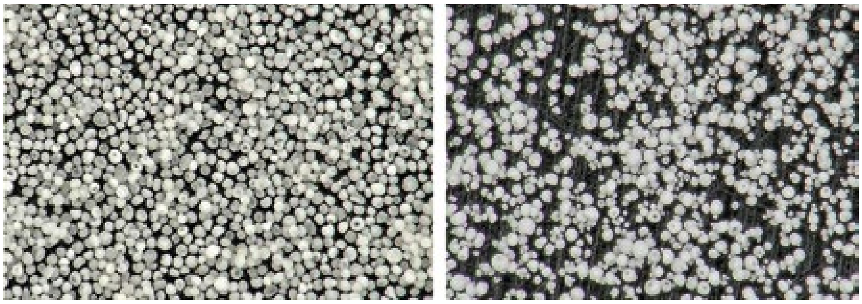
Questions followed about use of this technology for other parts. Nagy gave examples, and said capabilities can include the combustion section. LPM can be used for both rotating and stationary components, being mindful of pressure limits.

Allied Power Group

Richard Curtis focused on APG's ser-



10. **Impact damage to nozzle guide** vane is heavy on leading edge; some trailing-edge damage as well. Otherwise, however, part is in good shape with low hours (left). At right, repair success using Liburdi Powdered Metallurgy: Part was returned to service for a 24,000-hr interval. Post service inspection found no indications or material loss



11. Compare APG's high-density thermal barrier coating at left with one offered by the OEM (right)

12. GT11 airfoils, restored in APG's shop, are qualified for another service interval

vice and maintenance options for the GT11D5/N/N1 fleet— noting technical, shop, and field resources available for scheduled maintenance, component life extension, and durability improvements.

He first explained superalloy and thermal-barrier-coating capabilities, comparing APG's coating powder to that offered by OEM (Fig 11). The APG HD-TBC is applied generally with >95%-97% density, and up to 20 vertical cracks per linear inch depending on application, as applied to buckets/blades, nozzles, and shroud tiles.

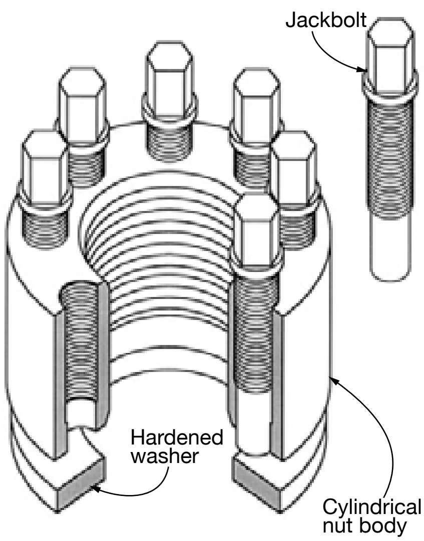
Curtis turned to APG parts, repairs, and field activities. Recent jobs specific to GT11 were varied, including rotor inspection and repair. Component-specific examples were the combustor—including upper inserts, tile carrier rings, tiles, lower inserts, U-duct inner liners, and hot-gas casing.

GT11 turbine airfoil repair (Fig 12) includes coating removal/stripping, weld/braze repair of defects, wall-thickness restoration, rejuvenation heat treatments, dimensional restoration, and advanced coatings.

Curtis also covered turbine vane carriers, new capital spares, and replacement parts.

He added field service for minor and major inspections. Examples included major reconditioning for a GT11 exhaust-gas housing. APG is also deeply involved in a G11D5 hydrogen-firing feasibility study.

When asked about burner/swirler components, Curtis noted that diffusion-burner testing is a current APG activity.



13. Superbolt™ tensioners, direct replacements for standard nuts and bolts, are comprised of the three components shown in the sketch

Nord-Lock Group

Juhani Karhatsu's presentation began with wedge-locking washer technology and moved on to Superbolt™, Boltight™, EzFit (fossil) and HyFit (nuclear). Superbolt is a replacement for standard nuts and bolts (Fig 13).

Boltight is a hydraulic tensioning system for the power industry and others. His example was turbine casings. EzFit and HyFit are expansion bolts designed to improve coupling maintenance efficiency, used largely in fossil and nuclear installations.

Advanced Valve

Advanced Valve addressed two major cooling systems, which are difficult to control properly:

- Steam attemperation.
- Turbine-blade cooling (OTC).

Jeroen Bakker walked through HRSG attemperation, highlighting the first steam-cooled units installed in 2012 at the UK's Marchwood Power Station. The design features a steam-cooled sleeve and these attemperators, designed to eliminate thermodynamic stresses, are still in operation after more than 2250 stop/start cycles.

He then turned to GT24/26 OTC valves, providing cooled compressor air to protect the gas turbine's first two stator rows and the combustion chamber. A major problem with OTC valves is cavitation.

Bakker offered the single-path, multi-stage solution working on the pressure-reduction principle (Fig 14).

Doosan Turbomachinery Services

The company's Houston (Tex) team presented a case study on GT11NM rotor lifetime evaluation (LTE) and repair. Doosan provides gas- and steam-turbine component and rotor repair, heavy mechanical work, new parts, and onsite services. Welded rotor capabilities (Fig 15) include reverse engineering (including metallurgical), lifetime analysis, and new rotor supply (including balance).

Dr Scott Keller, director of engineering, first focused on rotor inspections, stating that Doosan can offer an outline for rotor inspection and unit management (rotor-life process map).

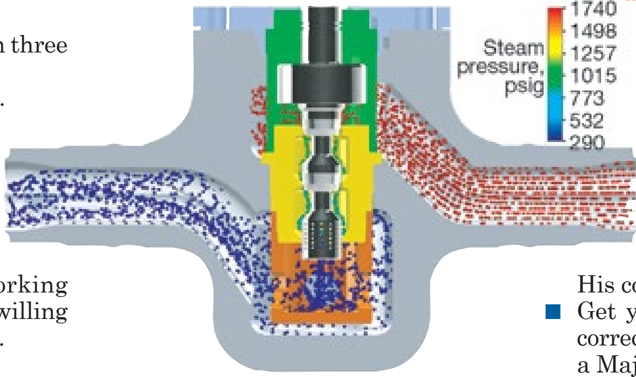
In-shop inspections shown in the case study included visual and diameter, cleaning, runout, incoming balance, and NDE and metallurgical evaluations. LTE findings included hardness, magnetic particle, ultrasonic, and eddy current.

He then turned to rotor repair based on customer targets of additional 115,000 hours and 800 starts.

Analytical evaluation focused on three main areas:

1. Creep damage/accumulation.
2. Radiant heat shield indication repair.
3. L-bore modification (details presented).

One attendee asked if Doosan got involved with the insurer. The answer was "yes," working with the customer. Doosan is willing to discuss its data and methods.



14. Pressure-reduction profile for OTC valves of the single-path, multi-stage design

15. Doosan Turbomachinery Services' reverse engineering involves internal and external characterization and metallurgical evaluation

Aim Power Consulting

Craig Nicholson offered a firing-temperature validation case study. Basically, he said that the inlet temperature of a gas turbine is an OEM-generated calculation that is put into the control system to optimize performance. However, this does not mean that the firing temperature is optimized.

That drove a detailed discussion of thermodynamics and conventional energy-balance calculations. Nicholson suggests an energy- and mass-balance approach as the most accurate.

With that, he presented a case study, an EPRI project, on a GT26 unit.

"Pain points" on the unit are shortened intervals, advanced hot-gas-path degradation, and premature replacement of parts.

Key performance indicators were determined for the high- and low-pressure expander sections, and for the compressor. Performance opportunities became the following:

- Under-firing LP turbine during dry operation.
- Under-firing HP turbine during wet operation (high fogging on).
- Adjustments to cooling-air flows to mitigate excess LP cooling air, bypassing the HP section as well as increasing cooling-air leakage at the platform of LP Row 1.

Detailed recommendations followed, with a summary that "Analysis provides the owner with a true engine baseline with tangible actions to optimize the unit and mitigate risk."

AGT Services

The editors saw this presentation (and one later by National Electric Coil) as a wake-up call. A key point: Generators are sometimes last in line for inspection and maintenance. Jamie Clark made this point clear with his title slide: "Are you abusing your generators?"

Generators suffer abuse, just like other parts of the plant, caused by actions and events such as the following:

- Start/stops.
- Shifts in outage planning or scope.
- Grid events and influences.

Clark offered some ideas on how to cope with limited inspection and maintenance budgets, including these:

- Replace field-out majors with field-in minors.
- Use robotics and borescopes.

Both the stator and field are impacted by mechanical and thermal forces, he continued, urging attendees to keep in mind that most problems with generators are mechanical in nature (Fig 16). The generator is put together primarily by hand and problems often are found in bolted and brazed areas.

Clark made a point that "Around 75% of combined cycle starts run less than 24 hours." Also, some generators are not well instrumented (monitored). He therefore suggested that plants have critical spares (field, stator bars, etc) available or know where to get them. Also have a plan for bushings, fuses, diodes, etc.

His conclusions:

- Get your unit's baseline condition correct now, even if it means taking a Major Inspection to do it.
- Going forward, consider robotic inspections in lieu of field removal.
- Significant changes (increases) in operating duty warrant shorter outage intervals.
- Compared to prior outages, recent findings confirm that the most involved repairs are caused by cycling.
- All OEM bulletins are significantly more important when cycling.
- Some units are suffering common problems. Talk to people in the know. Most likely you'll find them at meetings of the various industry users groups—like AOG, Generator Users Group, etc—where sharing experiences is part of the attendee culture.

KinetiClean (Groome)

Jorge Cadena discussed the KinetiClean HRSG tube cleaning technology by Groome Industrial Service Group. This technology came to Groome through its purchase of ExPro in 2021 and is an alternative technology to dry ice blasting, also used by Groome.

KinetiClean is a three-step process involving: (1) kinetic shockwaves from

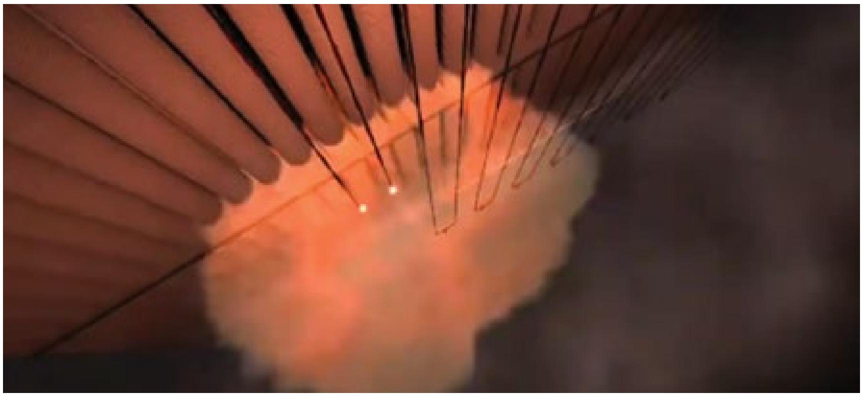
16. Stator and field are impacted by mechanical and thermal forces. Broken strands are one possible result a det-cord system (Fig 17), (2) an automated high-pressure, high-volume air distribution system to release debris trapped between adjacent fins (Fig 18), and (3) debris removal. Det-cord is a flexible linear explosive with a core of PETN encased in a textile jacket. Multiple tube faces are cleaned simultaneously. No scaffolding is required.

The case study presented was for a Vogt HRSG in the Northeast. Previous dry-ice blasting had reduced pressure drop by 2 in. H_2O. After using KinetiClean in the next cleaning cycle, pressure drop decreased by 3.6 in. Nearly 4 tons of dry debris was removed.

Groome has completed a detailed study with EPRI on the tube-cleaning effects, tube impact, and safety of KinetiClean. The study is available through the EPRI Boiler Reliability group.

Said Cadena, this process also increases the HRSG outlet temperature for the steam turbine.

He was questioned on explosive permits, and said that Groome is licensed in most states, parts of Mexico, and the Caribbean. Another question was blast noise level, which Cadena described as "underwhelming."



17, 18. Key steps in KinetiClean's HRSG tube-cleaning process include the hanging of det cord the full length of the heat-transfer surface (arranged similar to a festoon system typically used for electrical cables, as shown above) and using track-mounted compressed-air nozzles to traverse the tube bundles (below) and remove loosened debris

Emerson Automation

Emerson focused on control-system upgrades for Alstom GT series gas turbines: master controller, closed and open loop controller, protection, HMI layer and engineering station, and high-speed logging, all using the Advant system.

Advant component upgrades were shown for both plant and steam-turbine controls.

Emerson's overall system for combined-cycle applications is called the Ovation Distributed Control System.

Camfil

Tom Carter reviewed filters and their impact on plant efficiency.

Over time, he said, the dust holding (loading) of filters increases inlet pressure drop leading to more compressor work, less GT output, and higher GT heat rate. He offered selected site examples of power loss attributed to filter fouling, then listed various filter classes and efficiencies.

Carter also discussed inlet-system modifications to reduce pressure drop as well as Camfil's Life-Cycle-Cost (LCC) software.

National Electric Coil

Howard Moudy, director of operations at National Electric Coil, discussed "Lifecycle planning for aging generators." He explained that a typical generator lifespan for planning is 30 years, but there are other criteria: hours, cycles, bulletins, and model history.

19. Generator endwinding resonance and main lead failure are among the leading stator issues

Primary generator stator issues are:
- Endwinding resonance.
- Main lead failure.
- Endwinding support system looseness.
- Spark erosion.
- Partial discharge.

Primary rotor/field concerns are:
- Pole-to-pole crossover (TIL-2119).
- Collapse of top-turn hollow conductor and deformation.
- Slot liner cracking—top-cap interface (TIL-2256).
- Damper winding damage.
- Coil saddle connections/braze joints.

Moudy used Fig 19 to illustrate the consequences of endwinding resonance and main lead failure. This unit shown had run for 18 months and two weeks. The warranty period was 18 months.

He then reviewed bump-test methods, vibration, resonance, spark erosion (common on machines without side ripple filler), and partial discharge (common in most high-voltage air-cooled generators).

Pole-to-pole crossover failures, Moudy continued, usually are caused by one or a combination of design, material, or workmanship. The primary contributor is lack of flexibility, and this has a strong correlation to operating cycles.

He offered examples of collapsed top turns, slot-liner cracking (review MD&A comments above) and damper alignment finger liberation. He added a suggestion for new, upgraded zirconium-copper alloy damper segments with no braze joints.

Moudy then discussed the end-of-life period on the traditional lifecycle bathtub curve.

On the topic of new copper versus old, Moudy asked about two pennies, one new and one old: Which one has more value? It's not about appearance, he said, rather use and re-use can decrease reliability because of multiple heat/braze cycles, and there can be cycling fatigue depending on service.

Upgraded saddle braze joints can allow better column air flow, minimize air-inlet distortion, offer better control of process brazing, and help preserve the copper base in subsequent heat/braze cycles.

For stator rewinds, coil supply is critical, as is coil specification, he said. And as a general principle, basic materials and properties change every 10 years or so. Side note: National Electric Coil has its own roller mill and makes its own copper in Brownsville, Tex.

High-quality coil manufacturing requires a large investment. Robotic taping is a sign of quality, as are autoclaves (vacuum pressure impregnation systems). VPI improves heat transfer.

According to Moudy, some resin-rich processes, new to the market, look attractive with good quality characteristics. But below the surface, coils produced with these processes do not have the technical qualities that ensure good performance and long-term reliable operation.

When asked about cycling's impact, Moudy said that, in general, speed change has the greatest impact on the rotor. Load change has more impact on the stator (temperature changes, etc).

TRS Global

Matt Sokol and Charlie Wood presented on case-study repairs to GT11 and GT13 components—including hot-gas casings, vanes, and vane carriers. TRS works closely with Hughes Technical Services (HTS) to provide a comprehensive non-OEM Alstom repair and maintenance alternative.

The company has built its own furnace box capable of heat treating a 13DM hot-gas casing assembled to a heat-treat fixture and capable of withstanding temperatures of up to 2300F.

Sample jobs completed or in process were 11N2 hot-gas casing, 11NM components including vanes and blades, and 13DM vanes, blades, and casings.

Common issues seen and repaired for hot-gas casings are:

- Panel distortion.
- Wear on inlet and exit rings.
- Out-of-round inlet and exit rings.
- Joint gaps and erosion.

Common issues seen and repaired for Row 2 and 3 vanes are:

- Wear on honeycomb seals.
- Corrosion on gas-path surfaces.
- Inner-to-outer wall twists.

Common issues seen and repaired for turbine vane carriers are:

- Broken bolting.
- Out of roundness.
- Hook-fit wear.
- Cracking in cooling-air passages.

Selected before and after photos show the results.

Wrap-up

Reflecting on the content of presentations and discussions during the first three days of the conference, the editors believe the following topics as being top of mind among attendees:

- Lack of experts and bench strength in many user and supplier organizations.
- Finding and getting to the right people as companies change and people retire.

- Changing operating profiles.
- Getting top management to appreciate technical and operational issues (funding, time, etc).
- Supply chains and competition for base materials; parts orders versus inventory.
- Repair-technology options and capabilities/advice.
- Awareness of technology developments at the service providers.

There was an open group discussion before the EPRI tour. Selected comments/questions from that session, often rhetorical, are summarized below:

1. How do we get additional people, especially our own, more involved in what we are learning at AOG and discussing with each other? Can we increase the value of AOG at the plant level, perhaps with more online sessions? Can we make better use the Forum at AOGusers.com?
2. Users need to learn more about how GE handles purchase orders for parts, and the potential advantages of a long-term service agreement. One viewpoint: GE seems to have gotten out of the parts business to some extent.
3. How can we help third-party service providers keep up with technical developments being made by GE and others? It seems to be up to users to specify "the latest and greatest." We understand that we need to be our own advocates, and that is one benefit of AOG.
4. We just make sure that the Forum stays technical and does not become social, opinionated, or commercial. Some contractors already have access.
5. We also need to "listen to rumors" and get the word out. The example given was one participant overhearing someone say there was a spare rotor sitting in Switzerland. Turned out to be true. There is probably other "stranded stuff" out there. How do we do this?
6. We need to understand that not all divisions of GE communicate well with each other.
7. Should we have other OEMs here next year for controls?
8. Insurance companies seem to listen more to the OEMs. We as owners need to bring the insurers in with us for their buy-in and to share information. Insurability is very important. We should ask them, "What do you need from us?"
9. People: How should we address internal staffing for the future? A few companies described their summer intern programs as having some success in identifying promising candidates. Ideas included local community colleges and Associate Degree programs.
10. People: What about training materials for our employees? Can the Forum help share training? This seems to be a big common problem. And how can we better share and pass on knowledge even within our own plants?
11. People: How do we talk to our HR departments and tell them what they might not know (about our needs)? Perhaps we should take them through the plants.

EPRI tour, AOG training

AOG 2023 concluded with a tour of EPRI's many labs in Charlotte and summaries of some current projects of greatest interest to attendees. EPRI U, the onsite training and learning facility, was the final stop.

The following AOG training sessions then were conducted, concurrently, to complete the day:

- Gas Turbine Failure Analysis, Kevin Weins and Doug Nagy, Liburdi.
- Generational Diversity, Wade Younger, The Value Wave.
- P13 Blueline Training, Tom Douglas, Hughes Technical Services.
- Stator/Field Testing and Inspections, Jamie Clark, AGT Services. CCJ

Best Practices Awards

Owner/operators of 501F, G, and D5 engines share best practices

This compendium of award-winning best practices recognized by industry peers in 2023 focuses on the 501G, 501F, and 501D5 fleets. Six plants powered by these gas turbines received Best Practices Awards (photos). They are:

501G:

- Kings Mountain Energy Center (Storm shelter, "Magnetite catcher," Improve SCR maintenance to reduce emissions).
- Athens Generating Plant (Eliminate generator trips caused by fluctuations in seal-oil temperature).

501F:

- Kleen Energy Systems (Handling lube oil safely while avoiding its contamination, Safe handling of bottled gases).
- Rolling Hills Generating (3D-printed overload reset extension better than original).
- CPV Valley Energy Center (Overcoming challenges to optimize ACC performance, CCW system upgrade saves money, improves safety).

501D5:

- Milford Power (Automation logic for gas-turbine NO_x control).

Kings Mountain

CPV Valley

Milford Power

Ventanilla

Ventanilla Combined Cycle Power Plant

Owned and operated by ENEL Generacíon Perú

427 MW, 2 × 1 SGT6-4000F-powered dual-fuel powerplant, located in Callao, Perú

Plant manager: Dany Alcantara

Background. Endesa SA, Spain's largest electric utility, won a tender in December 1995 to take control of Empresa de Generación Termoeléctrica de Ventanilla (Etevensa), the genco operating the Ventanilla thermal plant in Perú's Callao Province, Lima Region. Etevensa had been spun off from Electroperu SA.

Endesa was the lead company in Consorcio Generalima, which also included two Peruvian companies. According to Christopher Bergesen, a Maryland-based consultant with deep knowledge of the global electric power business, the consortium bid $US120 million and agreed to modernize the plant.

The plant was upgraded in 1997 when the OEM of record supplied and installed a pair of 170-MW gas turbines, replacing the 110-MW 501D5 engines installed in 1993.

Endesa took full control of Etevensa in August 2003 and the following year converted Ventanilla to combined-cycle operation by adding a supplementary-fired HRSG downstream of each GT and a 184-MW steam turbine.

In September 2004, Ventanilla, now owned and operated by Endesa successor company Enel Generación Perú, began burning Peruvian gas and producing power for distribution via the national grid. In January 2021, Enel commissioned a 14.6-MW battery energy storage system—Perú's first—using lithium-ion technology.

1. A bushing failure several years ago forced Ventanilla out of service

Monitoring alerts to transformer issues, protecting against a forced outage

Challenge. Prevent the recurrence of a transformer forced outage suffered by Ventanilla a few years ago when an HV bushing failed (Fig 1).

Solution investigated was the installation of an online monitoring system capable of detecting changes in critical operating data that might suggest an impending failure. The daily cost of a transformer outage at Ventanilla is about $100,000.

Investigations by plant personnel pointed to Camlin Energy's Totus system, which is said to monitor all key components of the transformer, providing a picture of transformer health. It integrates dissolved gas analysis (DGA), partial discharge (PD), bushing monitoring (BM), through fault currents (a/k/a short-circuit currents), and transformer analytics into a single system.

The following instrumentation was installed on transformers serving the gas turbines: bushing sensor (Fig 2), load current monitor, communications mod bus TCP/IP, temperature monitor, oil leak detector, DGA, PD. Gases dissolved in the transformer oil, both analyzed and trended are hydrogen, ethylene, acetylene, CO_2, CO, ethane, methane, moisture, oxygen.

PD monitoring of transformer windings identifies amplitude, repetition rate, and PD persistence—the last to avoid a false alarm and provide reliable information. A PD-status level (scale of 1 to 10) is determined using amplitude and repetition rate.

Bushing health is tracked using tan delta and capacitance data. Leakage current from each bushing is monitored and variations in current amplitude and angle between adjacent phases calculated.

2. Online monitoring of critical transformer data helps identify issues before they cause an outage

Recall that tan delta test results help gauge the condition of transformer insulation and determine how close it may be to a fault condition. There are two ways to evaluate insulation health during a tan delta test, according to information provided by Altanova, a Doble company:

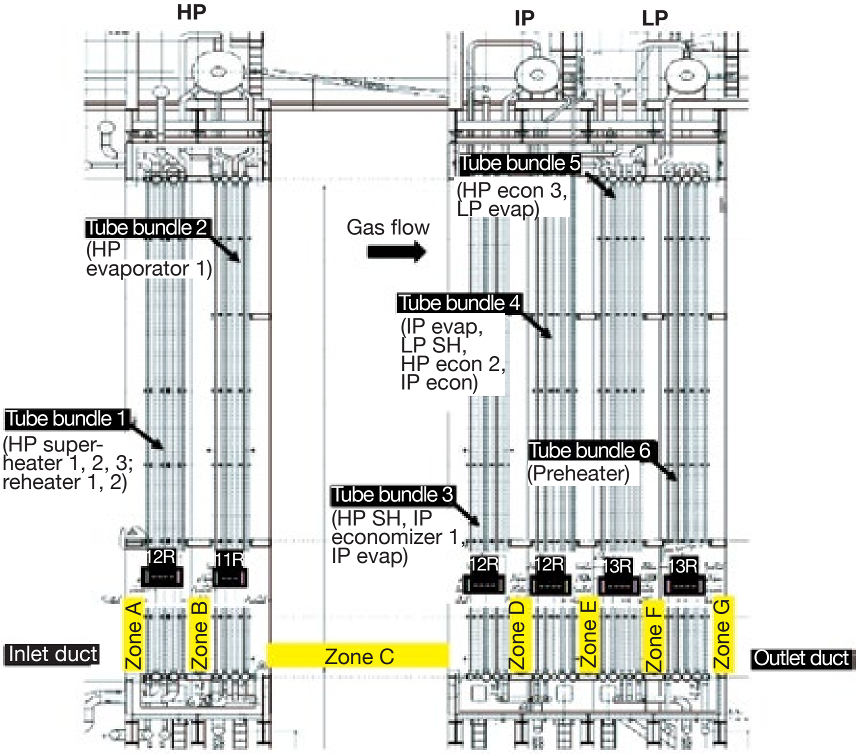
- The first is to compare current results to those from previous tests, thereby determining the impact of aging on deterioration.
- The second is to determine directly insulation condition using the tan delta value. If the insulation is perfect, the loss factor will be about the same for the range of test voltages. But if the insulation is less than perfect, the tan delta value will increase as the test voltage increases.

Results. Since Ventanilla's online monitoring program was implemented, there has not been a forced outage attributed to a transformer failure. Plus, plant personnel are more aware of the positive impact their vigilance can have on operating costs, as well as the safety benefits of avoiding a fire or explosion caused by a short circuit.

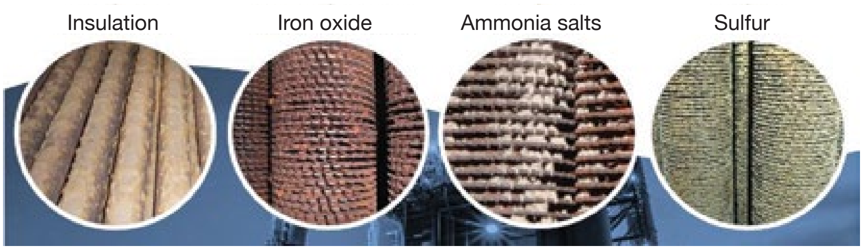
Enel project participants:
Gustavo Rodriguez, electrical specialist and project manager
Fernando Sarmiento, electrical supervisor
Eduardo Salinas, electrical supervisor

HRSG deep cleaning with dry ice pellets at high pressure meets plant's expectations

Challenge. Restore HRSG performance while assuring the highest level of boiler reliability and availability going forward. During HRSG operation, deposits build up on heat-transfer surfaces and impede heat transfer (Fig 3). The corrosion products, ammonia salts, sulfur, and foulants—such as particles of insulation—trapped between tube fins should be removed periodically (Fig 4).



3. Ventanilla's triple-pressure HRSGs were supplied by Vogt Power International



4. Types of fouling/deposits found on heat-transfer surfaces in Ventanilla's HRSGs (l to r): insulation, iron oxide (rust), ammonia salts, and sulfur

Solution. Plant personnel determined that a commercially available service for deep cleaning tube bundles using dry-ice pellets at high pressure (Fig 5) would remove about 95% of the performance-robbing deposits, thereby improving HRSG thermal efficiency, reducing gas-path backpressure, and increasing plant output. Cleaning also increases tube life and slows the corrosion processes conducive to tube failure.

Cleaning focused on the intermediate- and low-pressure circuits where the buildup of deposits was greatest. Scaffolding was erected in those sections in accordance with the following plan (refer back to Fig 3):

- Downstream face of tube bundle 6.
- Between tube bundles 5 and 6.
- Between tube bundles 4 and 5.
- Between tube bundles 3 and 4.
- Upstream face of bundle 3.

Cleaning then proceeded thusly:

- In the direction downstream of tube bundle 6 (so-called face 1 in the cleaning sequence).
- Direction upstream of tube bundle 6 (face 2).
- Downstream of tube bundle 5 (face 3).
- Upstream of tube bundle 5 (face 4).
- Downstream of tube bundle 4 (face 5).
- Upstream of tube bundle 4 (face 6).
- Downstream of tube bundle 3 (face 7).
- Upstream of tube bundle 3 (face 8).

5. Dry ice was injected at ultra-high pressure to remove the fouling/deposits found in HRSG tube bundles

Results for HRSG 1. The increase in power production for GT 1 was nearly 1 MW, for the steam turbine 0.5 MW. The annual economic benefit: $230,000 for increased production, plus $62,000 for increased capacity payments. Also:

- Backpressure reduction of 5%, which contributed to the economic benefit.
- Increased HRSG life attributed to the slowdown in corrosive processes that could cause tube failures.

Enel project participants:

Ivan Jimenez, project manager
Sandro Garcia, responsible person for operational optimization
Jose Soto, operational optimization specialist
Richard Mejia, safety supervisor
Marco Rivera, responsible person for plant maintenance

Cooling-tower upgrade increases electric generation

Challenge. Ventanilla's No. 2 cooling tower had deteriorated to the point that a total failure was a distinct possibility. Loss of a tower would force the plant into a 1 × 1 configuration with a loss in revenue of about $100,000 daily.

A thermal study conducted in 2018 revealed the following:

- An increase of 1.4 deg C in cold-water temperature compared to historical data. Causes included clogging of circulating-water circuits by sediment and leaks.
- A thorough inspection in 2019 identified severe structural wear and tear (Fig 6).
- A flow imbalance between the two towers which caused non-uniform heat transfer and operational inefficiency.

Solution. A complete overhaul of the tower (Fig 7) was necessary to increase cooling-air flow—including fill replacement—and to reduce the temperature of circulating water flowing to the condenser.

To increase air flow, it was necessary to stabilize the tower by reducing the vibrations attributed to worn/broken structural members.

But because the entire structure was in poor condition, plant management decided to replace it, changing the structural material from wood to glass-reinforced plastic (Fig 8, left and center).

The upgrade work was conducted in a manner to keep the plant operating. This was done by removing only two cells from service at a time, leaving four in operation.

6. Cooling tower 2 was in poor condition. Examples: Loose tie bolts (left) and deterioration of (center) and fractured (right) structural members

Also, to guarantee the circulating-water temperature at its design value of 2200 m³/h, the orifice plates for each cell in the six-cell tower were resized for a balanced supply condition and even distribution in all cells.

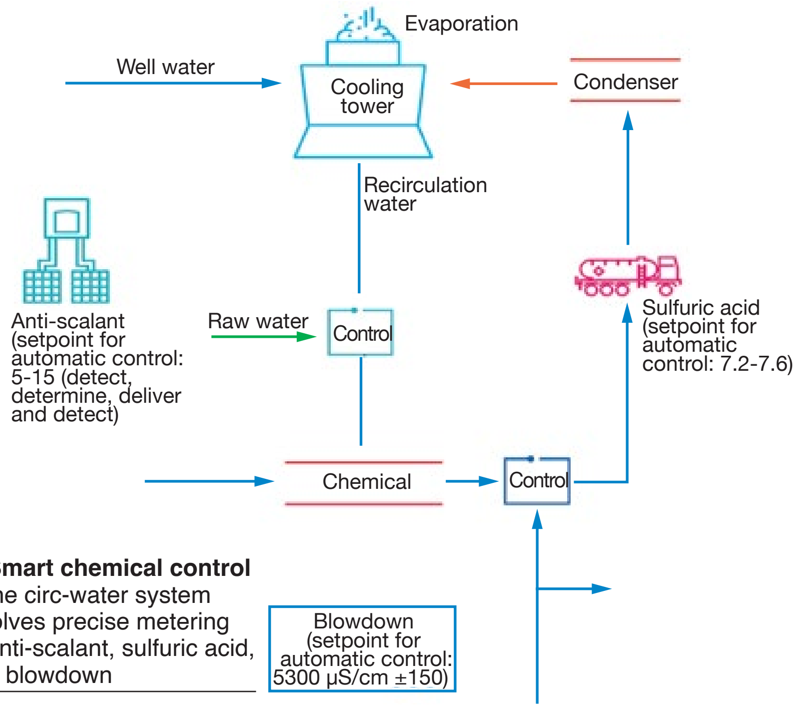
Result. Increasing cooling-air flow and changing fill improved tower performance to deliver 0.7 MW of increased generation. The financial impact was an additional $134,000 in energy production annually plus a $41,000 boost in capacity payments.

By removing two cells from service at a time, rather than all six, saved an

7. Ventanilla's wet cooling towers each have six fans. Four fans remained in service throughout the overhaul activity

8. Tower 2 was disassembled (left) and reassembled (center) using glass-fiber reinforced plastic in place of wood for structural members. Fans were upgraded to increase air flow (right) estimated $6 million.

Enel project participants:
Ivan Jimenez, mechanical specialist and project manager
Carloandhre Pareja, mechanical supervisor
Marco Rivera, responsible person for plant maintenance
Sandro Garcia, responsible person for operational optimization
Jose Soto, operational optimization specialist
Richard Mejia, safety supervisor



9. Smart chemical control in the circ-water system involves precise metering of anti-scalant, sulfuric acid, and blowdown

Tighter control of circ-water chemistry improves economics, safety

Challenge. The water source for Ventanilla's cooling towers is relatively poor-quality well water, requiring continuous blowdown and a high consumption of chemicals to maintain the recommended water chemistry. Cooling-water treatment in the plant's early years consisted of the following:

- 98% sulfuric-acid for control of scaling.
- 10% sodium hypochlorite for microbiological control.
- Internal water treatment for scaling control involved:
  - Automatic sulfuric acid dosing system.
  - Manual dosing system for anti-scalant with regulation based on residual grab analysis in the plant laboratory.
  - Manual water purge system with regulation based on periodic field measurement of specific conductivity in makeup and recirculation water.

The operator only measured online the pH to control sulfuric-acid dosage; the other systems were based on periodic measurements in the lab. They did not allow action to be taken in real time to optimize the chemical treatment without putting the condenser at risk of scaling problems.

Solution. The Smart Chemical Control system described in Fig 9 integrated and enhanced the internal chemical treatment in the cooling tower thusly:

- Dosage of sulfuric acid at 98%, with the pH setpoint determined by the new chemical treatment, which controls starting and stopping of the acid pumps.
- Automatic cooling-tower blowdown control, with a recirculating-water conductivity setpoint determined by the new chemical treatment, which controls the opening and closing of the blowdown valve.
- Automatic dosage of the Nalco anti-scalant relies on a tracer in the recirculating water to control operation of the dosing pumps. This new treatment integrates and enhances the original treatment.

The three blocks and their controls are independent, making it possible to eliminate a type of failure that affects more than one unit. Water samples are taken weekly and physiochemical analyses conducted of hardness, sulfates, chlorides, pH, and specific conductivity.

Result. In the 2021-2022 period, Ventanilla saved $650,000 with its Smart Chemical Control program. The details: Reductions of 12% in makeup consumption, 7% in sulfuric acid, and 70% in anti-scaling chemicals, and a 25% saving in chemical handling time.

Enel project participants:
Jorge Tuya Rodriguez, chemical specialist and project manager
Juan Arteaga, chemical supervisor
Jose Gomez, I&C maintenance supervisor

Kings Mountain

Storm shelter protects staff during weather events

Challenge. A mid 2020 tornado that touched down within a mile of Kings Mountain (KMEC), plus several storms that spawned high winds, encouraged a reassessment of the plant's capabilities for personnel protection. There was an emergency protection plan, of course, but staff believed it could do better.

The best place to shelter in the existing building was a small room with no windows on an exterior wall. However, it was difficult to accommodate the entire staff safely in that space.

Solution was to implement a Management of Change action to build a tornado shelter. Plant personnel worked with an engineering group to create a blueprint for an independent structure adjacent to the plant (Fig 1) and sent it out for bids. The contractor selected built the specified shelter in its shop and poured the concrete pad.

Once the concrete slab had cured, KMEC O&M staff engaged a crane to install the prebuilt shelter on the pad. Plant electricians installed the lighting in the shelter. Finally, the site's emergency action plan was updated and a tornado drill was conducted.

Result. KMEC now has a designated shelter to protect personnel during possible future weather events.

Project participants: The plant's entire O&M team

1. Storm shelter was constructed in the contractor's shop and trucked to the plant, where it was lifted by crane, placed on the concrete pad, and secured

Kings Mountain Energy Center

Owned by Carolina Power Partners LLC

Managed by CAMS

Operated by NAES Corp

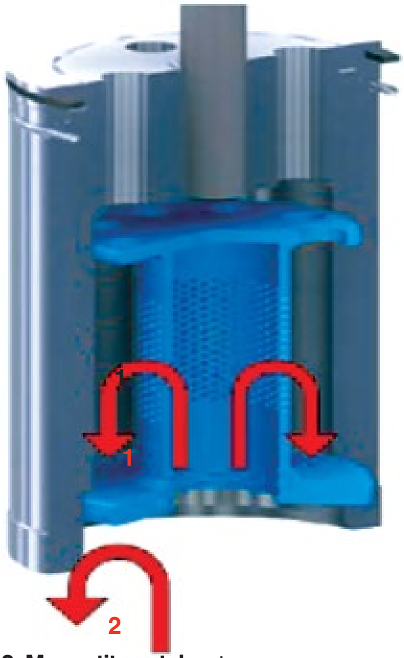
475 MW, gas-fired 1 × 1 M501GAC-powered combined cycle, located in Kings Mountain, NC

Plant manager: Sean Spain

'Magnetite catcher' helps prevent sticking issues with steam-turbine valves

Challenge. KMEC uses its steam-turbine bypass system for steam-system control during starts, shutdowns, upsets, and other situations when the turbine is not available. Bypass valves are of the Fisher ™ TBX pressure control type with a "flow under the seat" design. Two of the plant's three bypass valves have experienced sticking during a vast majority of the starts—both hot and cold—since commissioning in 2018, causing upsets and inconveniences.

Fisher was contacted to troubleshoot



2. Magnetite catcher turns away magnetite that impacts the bottom of the lower plate and redirects it to pass through cage holes (flow arrow 1 in the diagram). It also creates a flow "dead zone" that allows any particulates passing through the strainer to fall out of the stream and settle inside the plug (flow arrow 2)

the problem and run diagnostics on the valves and their actuators. Interestingly, the valves functioned satisfactorily during outage diagnostic testing.

Additional investigation revealed a possible issue with magnetite from the steam system causing operability issues with this valve design. Plant staff contacted other facilities with valves of the same type and learned the sticking issue could be resolved by using "magnetite catchers" (Fig 2) on hot-reheat (HRH) and main-steam (HP) bypass valves.

Solution. When first removed from the valve body, the plug, stem, and cage assembly couldn't be separated because of the magnetite (Fig 3). But after heating the cage and using hydraulic jacks (Fig 4), the parts were separated.

A valve services company was engaged to retrofit spare sets of HP and HRH bypass valve trim. This was done in four days during a routine outage.

Results. Subsequent to the install of magnetite catchers, several plant cycles have been performed with no sticking issues on the upgraded valves. Current plans are to open and inspect the valves after three years of service to determine overall condition and the amount of magnetite captured.

Project participants:
The plant's entire O&M team

Improve SCR maintenance to reduce emissions, cost

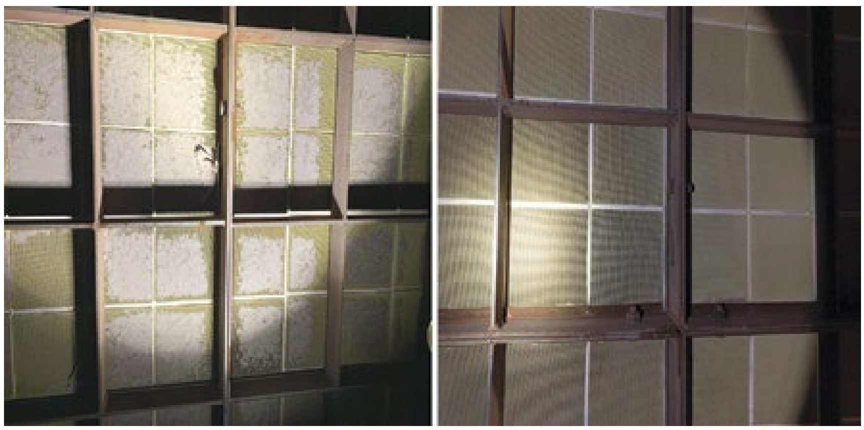
Challenge. Since commissioning, KMEC has had various challenges in maintaining NO_x and CO emissions. Staff quickly worked through short-term fixes to achieve better results, but some long-term recurring challenges are associated with increasing pressure drop across the catalysts caused by airborne particles of insulation from the duct-burner area impeding gas flow (Fig 5).

Another problem: An increase in SCR injection-blower discharge pressure attributed to ammonia deposits and the build-up of insulation in the injection nozzles. A tuning grid was installed to help adjust ammonia injection in sections of catalyst so affected (Fig 6).

Solution. During planned outages, CO and SCR catalysts are cleaned to reduce performance-robbing pressure drop. Also, a flange was installed

3. Plug and cage are stuck in position

4. Separator rig relies on heat and jacks to separate the parts



5. Periodic cleaning of catalyst (dirty at left, clean at right) is required to reduce performance-robbing pressure drop

6. AIG tuning sample grid helps insure proper distribution of reagent across the catalyst

7. SCR piping is modified to allow connection of a vacuum truck for cleaning ammonia injection nozzles

in the SCR injection-blower discharge piping to allow a vacuum truck to connect to the injection piping and remove deposits in the injection nozzles (Fig 7).

To better gauge SCR catalyst performance, a sampling grid was installed on the downstream side of the SCR catalyst modules. It provides an array of 18 sampling locations—three wide in each of the six AIG (ammonia injection grid) zones.

Results. KMEC's ability to reduce emissions and adhere to permit limits has been improved. Plus staff can perform SCR maintenance better and faster during planned outages, thereby helping to prevent unplanned outages. Another benefit is reduced ammonia consumption and associated cost.

Project participants:
The plant's entire O&M team

Athens Generating Plant

Owned by Kelson Energy
Operated by NAES Corp
1080 MW, gas-fired facility equipped with three 501G-powered 1 × 1 combined cycles, located in Athens, NY
Plant manager: Steve Cole

Eliminate generator trips caused by fluctuations in seal-oil temperature

Challenge. Athens Generating Plant has been plagued with seal-oil issues since first fire more than 20 years ago. Throughout the years, the seal-oil systems have received small tweaks and alterations with the goal of improving temperature regulation of the air-side seal oil at the gas turbine (TE) and collector ends (CE) of the hydrogen-cooled generator. Goals: Maintain the 120F ±5 deg F setpoint, and maintain the delta between the air-side and hydrogen-side seals at 3 deg F.

Most recently, Unit 3 tripped offline in early April 2022 because of generator vibrations. After the trip, the OEM's diagnostic center was contacted to look into what could have caused the excessive vibrations. Its analysis concluded that there may have been a foreign object that passed through the rings, some sort of internal rub, or the fluctuation of seal-oil temperature and pressure, which they had noted in their report as having occurred just before the trip.

The recommendation was that a restart could be attempted while paying close attention to the vibration levels and seal-oil parameters. Athens restarted the unit and observed the vibrations and seal-oil parameters both locally and remotely. Personnel noticed that the upstream local thermometer (Fig 1)—located immediately after the pipe tee where the air-side seal-oil cooler outlet and cooler bypass come together—displayed a different temperature than the gauge installed roughly 14 ft downstream. The difference was about 10 deg F.

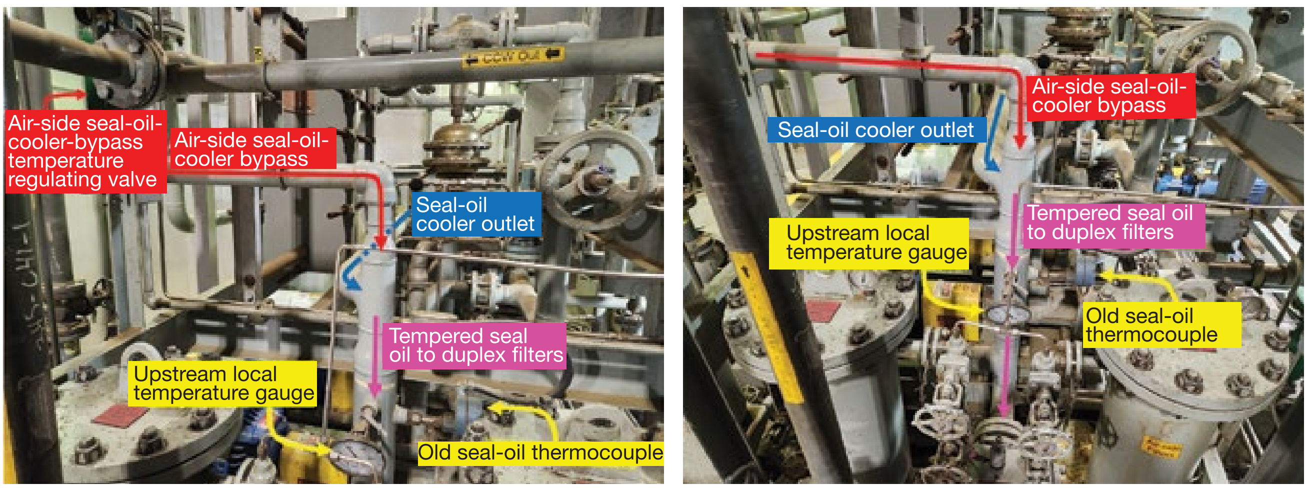
The local air-side seal-oil temperature gauge located furthest downstream on the skid (Fig 2) was most closely representative of the temperature read by the DCS at the turbine and collector ends of the generator.

Investigation of historical data on the seal-oil temperatures revealed that the air-side seal oil at the turbine and collector ends of the generator would fluctuate anywhere from 20 deg F cooler to over 10 deg F warmer than the seal-oil temperature setpoint. The regulating valve was maintaining the 122F setpoint, which receives feedback from that thermocouple, with very little error, while the temperatures at the generator TE and CE would fluctuate from as low as 102F to 132F.

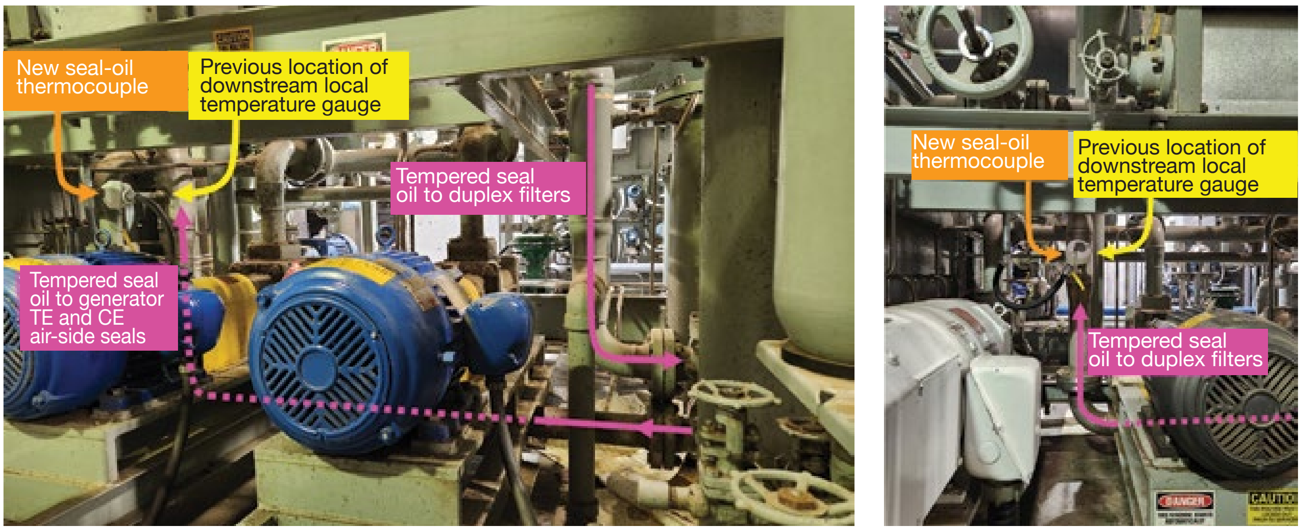
Solution. The Athens team presented to the OEM's engineering team its idea to install a thermocouple in the downstream drywell, where the local gauge is, and change the logic controlling the air-side seal-oil temperature regulating valve to use the value from the new thermocouple. The OEM approved the idea, and a management of change was created.

Athens I&C technicians installed a new thermocouple in place of the local indicator, wired the thermocouple to available terminals in the nearest I/O cabinet, and reworked the logic so the air-side seal-oil temperature was regulated using the values from the new thermocouple.

In addition, a single point of failure was mitigated by adding logic to revert to the old thermocouple, with a limited regulation rate, in the event of the new thermocouple provided inaccurate information. The intent is to keep the unit online while personnel troubleshoot and correct the bad-quality signal.



1. Athens personnel traced generator vibrations to poor control of air-side seal-oil temperature at the collector and turbine ends of the hydrogen-cooled machine. They noticed that the upstream local thermometer—located immediately after the pipe tee where the air-side seal-oil cooler outlet and cooler bypass come together—displayed a different temperature than the gauge installed roughly 14 ft downstream



2. The local air-side seal-oil temperature gauge located farthest downstream on the skid was most closely representative of the temperature read by the DCS at the turbine and collector ends of the generator

Results. After the new thermocouple was installed and logic confirmed, Athens put the thermocouple in service as main feedback to control the air-side seal-oil temperature regulating valve. It has had more than 3000 hours of service since the change was implemented and the results have been excellent.

The air-side seal-oil temperatures at the turbine and collector ends of the generator have been maintained within a 3-deg-F error since the new thermocouple was installed. That is much better than the periodic 20-deg-F error Athens was seeing prior to the change.

Since the change, there have been no vibrations or trips associated with the fluctuations in seal-oil temperatures. All three units at Athens have been changed, or are in the process of being changed, to the new seal-oil temperature regulating setup.

Project participants:
Chris Mitchell
Kyle Kubler
Todd Wolford
Eric VanZant
Kevin MacNeill
Jesse Ferenczy

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7HA & 9HA USERS GROUP

Dates: Summer 2024
Location: TBD

Legacy Turbine Users Annual Conferences

FRAME 5 Users Group · Frame 6B Users Group · 7EA Users Group

July 15-18, 2024
The Woodlands Waterway Marriott Hotel
The Woodlands, Texas

Power Users Annual Combined Conferences

CCUG Combined Cycle Users Group · GUG Generator Users Group · Low Carbon · Power Plant Controls Users Group · STUG Steam Turbine Users Group

August 26-29, 2024
Arizona Grand Resort, Phoenix, AZ

WUG — Wärtsilä Users Group

Dates: Fall 2024
Location: TBD

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Kleen Energy Systems LLC

Owned by Elf Kleen LLC

Operated by NAES Corp/Kleen Energy Systems LLC

620 MW, 2 × 1 501FD3-powered combined cycle, located in Middletown, Conn

Plant manager: John O'Rourke

Handling lube oil safely while avoiding its contamination

Challenge. Powerplants have many rotating machines with an ongoing need for oil replenishment and/or oil changes. Thus, there exists a chance for cross contamination of oils given the multiple grades used for the various types of equipment.

Safety is another concern. For example, to service cooling-tower fan gearboxes, a technician would have to carry 5-gal pails of oil up and down from the top of the tower—a labor-intensive and time-consuming task. In the same vein, moving drums or totes around the site can be cumbersome and difficult. Plus, this activity presents a potential for an environmental incident should a container tip and spill.

Solution. Kleen's maintenance technicians designed and fabricated three totes for managing oil in the field. Each is dedicated to specific tasks, and/or type of oil, and equipped with hose reels, pumps, and spill equipment storage.

- Two identical totes are used for transferring DTE™ (Fig 1 left) and SHC™ (Fig 1 right) oils. Each is dedicated to the individual oil thereby eliminating the possibility of cross contamination. Reels provided on the totes make it easy to neatly and safely store the hose. The skids also are equipped with pneumatic oil pumps which are powered by compressed air, available throughout most of the plant.
- The third tote is dedicated to cooling-tower gearbox oil maintenance. Its design is such that the tote remains at ground level with a reel of hose that can reach the top deck of the tower. This is used to evacuate the oil from the gearbox down to the tote at ground level. There is a second compartment with new oil and a second reel for replenishing the gearbox oil level. This tote has an electric pump because there is no plant air in the cooling-tower area.

Results. The two identical totes have eliminated the potential for cross contamination of non-compatible oils. It also mitigates the potential for any safety and/or environmental exposure associated with transporting individual drums along with pumps and associated equipment.

The cooling-tower tote has eliminated the need to carry 5-gal pails of oil—new and used—multiple times to/from the tower's top deck. With a gearbox reservoir of 28 gal and 10 fans, this has saved many hours when making oil changes. Also, it has prevented any potential injuries that could have resulted from the fatigue of carrying the nominal 40-lb pails up and down a 50-ft tower's stairs.

Project participants:

Gary Thibodeau, maintenance technician

Doug Rusczyk, maintenance technician

Jeff Erksa, maintenance supervisor

1. Identical totes are used for handling DTE (left) and SHC (right) oils separately

2. Cooling-tower tote, at ground level, eliminates the need to carry 40-lb pails of oil up and down the tower's stairs

Safe handling of welding and other bottled compressed gases

Challenge. Kleen Energy's maintenance team performs a fair amount of component fabrication and repair work using the plant's MIG and TIG welding machines. Both require inert gas, which is delivered bottles as needed. The bottles present a potential safety hazard to personnel responsible for handling them given their weight (nearly 200 lb when full) and gaseous cargo under high pressure (2640 psig when full).

Solution. The bottles normally are stored on the exterior of the shop's south wall. By running 0.5-in.-diam tubing from the storage area through the wall to a manifold inside the building (Fig 3 left), the bottles do not have to be moved when gas is needed. They remain outside the shop in a caged storage area. When empty, a technician simply exchanges the bottle in the cage and connects it to the appropriate manifold port.

This eliminates both (1) the need to roll bottles any distance, thus mitigating a previous safety concern, and (2) the risk of bottles tipping and necks breaking off as they remain in the cage.

Results. The ease of bottle changes is a great improvement. The fixed manifold promotes safety while having a continuous supply of inert gas inside the shop to meet fabrication needs.

Project participants:
Gary Thibodeau, maintenance technician
Jeff Erksa, maintenance supervisor

3. Bottles of inert gas are secured outside the shop (left); tubing brings the gas inside to the fixed manifold serving the welding machines (right)

Rolling Hills

Rolling Hills Generating

Owned by LS Power

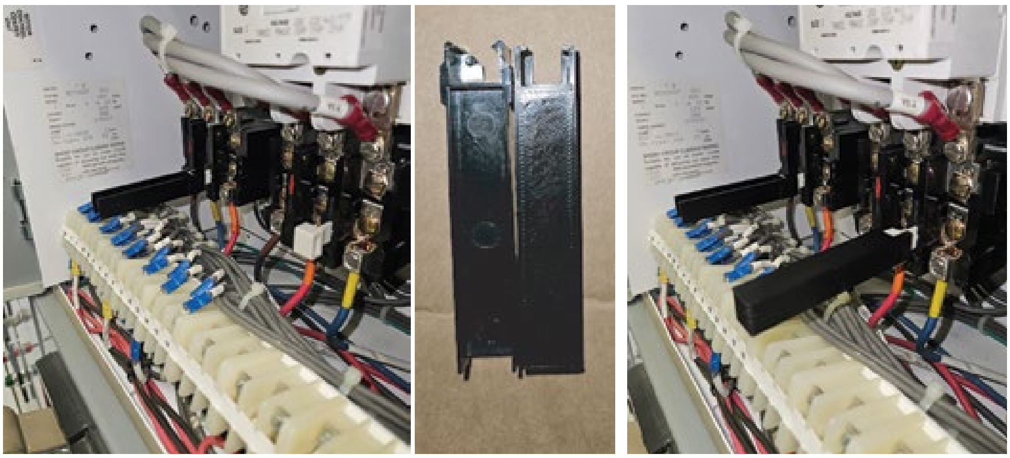
Operated by PIC Group Inc

850 MW, gas-fired simple-cycle generating facility powered by five 501F engines, located in Wilkesville, Ohio

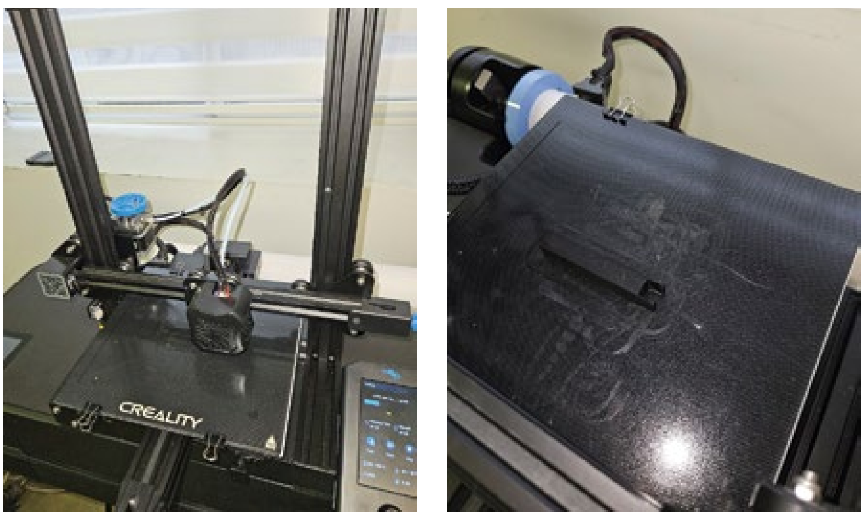
Plant manager: Corey Lyons

3D-printed overload reset extension better than the original

1. Pushbutton located outside motor starter, at left, is for resetting of the thermal overload; back side of the panel is at right



2. Single reset extension is at left, 3D-printer extensions in the center, and a two-extension arrangement at right



3. 3D printer is at left, finished product at right

Challenge. Rolling Hills Generating has several pieces of equipment that rely on a motor starter to operate. Each motor starter has a resettable group of thermal overloads. The reset buttons for the overloads are installed inside the power-supply buckets. The only way to operate the reset is via an external pushbutton located on the outside of the cabinet (Fig 1)—this to avoid crossing the electrical boundary of the equipment.

Operating the reset button on an overload, in the event of coming across a broken extension, requires either a LOTO or the wearing of arc-flash PPE. This adds significantly to downtime. Between the overload reset and the external push button is a removable reset extension (Fig 2). This is installed to span the gap between the outside reset button and the internally mounted thermal overload.

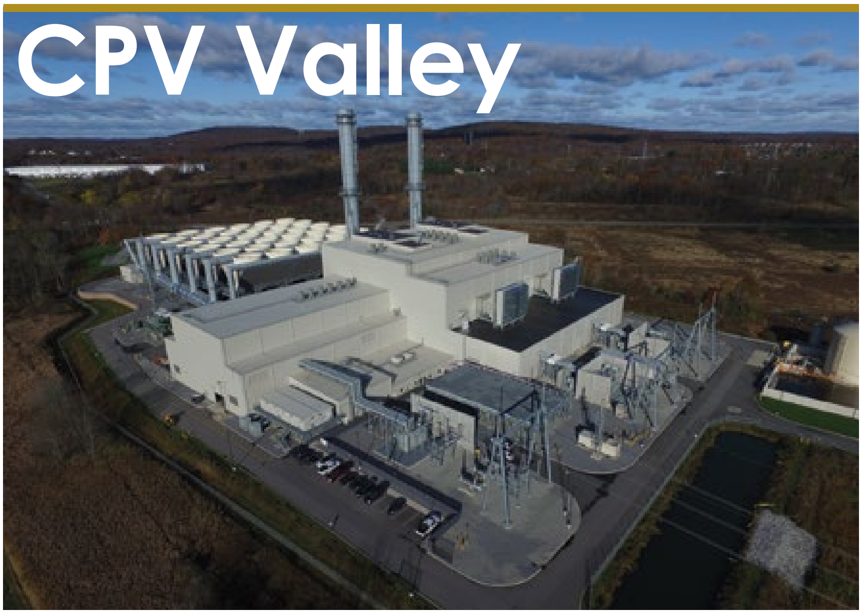
Over time, extensions begin to flex and eventually break. While working with local vendors it became apparent that supplying these pieces was a cumbersome task that typically required purchasing the entire assembly, as spare parts were not available.

Solution was to use modern accessible technology to design and develop a reset arrangement using CAD and printing it on a desktop 3D printer (Fig 3). The design was made onsite using the OEM extension that was measured and modified to add extra strength to make a unit that will not flex or break easily like the original piece. The design was then uploaded to the 3D printer and 20 minutes later, a new reset extension was born.

The results have met expectations. The extensions go onto the housings with a snug fit that gives confidence that they will stay in place with integrity for many years. The site has printed several extensions to create inventory in the event other OEM extensions break.

Project participant:
Tyler Legg

CPV Valley



CPV Valley Energy Center

Owned by CPV/Diamond Generating Corp

Managed by Competitive Power Ventures

Operated by DGC Operations LLC

680 MW, gas-fired 2 × 1 SGT6-5000-powered combined cycle, located in Middletown, NY

Plant manager: Michael Baier

Overcoming unique challenges to optimize ACC performance

Challenge. At first glance, the air-cooled condenser (ACC) at Valley Energy Center (VEC) appeared to operate efficiently, as designers intended. However, proactive staff analysis revealed performance-robbing subcooling, despite use of a second vacuum pump to compensate for air ingress.

Solution. VEC worked with SPG Dry Cooling to survey the ACC, identify leaks, and perform corrective measures; however, the subcooling remained. Further investigation revealed that increased air flow across the heat-exchanger bundles, paired with slight air ingress, was driving the subcooling anomaly. Although the system's design backpressure, temperature, and steam load were in sync, more fans than required were operating. Further investigative work, found that the DCS logic prevented the fans from turning off to counteract the subcooling.

DCS logic. The ACC was operating at 2.0 in. Hg Abs, but the deadband within the logic required the pressure to reach 1.91 in. for 10 minutes to allow the control logic to adjust fan steps and reduce air flow. Several things were found that did not permit the ACC to drop to the required pressure for the prescribed duration, including the following:

- The vacuum system was designed according to specifications developed by the Heat Exchange Institute for ACCs, with a minimum design suction pressure of 1.0 in. Hg Abs. The steam path through an ACC is several hundred feet long, and the associated pressure drop can range from 0.5 to 1.0 in., putting the capacity of the vacuum system near the 2.0 in. setpoint (as measured at the ST exhaust).
- The air ingress persisted, spreading throughout the ACC, and limiting its cooling capacity. Conceptually, 1 ft^3 of atmospheric air expands to 15 ft^3 under vacuum, occupying volume intended for steam condensing.

The limitation of the vacuum system and persistent air ingress prevented the ACC from overcoming the deadband. It eliminated the control logic's ability to adjust and optimize parasitic power alongside the backpressure. With the assistance of SPG, VEC made minor adjustments to the deadband and setpoint and reduced parasitic power by nearly 3 MW while maintaining the required backpressure. The improvement was achieved by turning multiple fans from full speed to half speed (reducing the required power per fan by seven-eighths) and eliminating the need to run a second vacuum pump. Additionally, VEC improved its overall heat rate by reducing subcooling and parasitic power consumption.

Note that the subcooling issue was unique to the time of year when ambient temperatures were between 35F and 75F. VEC operates approximately 5000 hours within this temperature range, resulting in a loss of approximately 15,000 MWh/yr prior to the new ACC logic implementation.

Results. VEC's experience highlights the importance of investigating all aspects of ACC performance to optimize efficiency. As a result of this improvement, VEC will implement SPG's remote performance monitoring system (ACC360) to maintain the realized results and continually improve the ACC system.

Project participants:
McKenzie Slauenwhite, plant engineer
Thomas Viertel, maintenance manager
Dave Engelman, operations manager
Efrain Morales, lead shift operator
Ernest Hill, lead shift operator
Bob Arraiz, lead IC&E technician
Daniel DeVito, IC&E technician

Closed-cooling-water-system upgrade saves money, improves safety

Challenge. If VEC lost station power, both pumps serving the closed cooling water (CCW) system would lose their power supply. Note that the power draw is too great to supply the pumps from the essential-services bus.

Were station power lost with the pumps in service, the flow of water to the steam-turbine lube-oil cooler (LOC) would stop. To mitigate this risk, a diaphragm pump was installed to maintain the required lube-oil temperature for turning-gear operation.

However, a challenge associated with the diaphragm pump is the amount of plant air required for its operation. Plus, the plant air compressors also are not on the essential services bus, which meant VEC would have to rent a diesel-powered air compressor during loss-of-power events.

Plus, plus, acquiring a diesel-powered compressor in timely fashion during an unexpected loss of station power is less than ideal for a rapid and guaranteed response. Finally, the diaphragm pump's discharge flow is

less than that required by the LOC to meet all possible needs.

Solution. Staff specified a centrifugal pump that maximizes CCW flow through the LOC to assure oil temperature can be maintained as necessary. A spare breaker on the essential-services bus met the power requirement of the centrifugal pump's motor. Plant verified operation of the new pump during commissioning by using power supplied by the site's emergency diesel/generator.

Additionally, the CCW discharge lines from the steam turbine's LOC were tapped and valves were installed in the pump's discharge and suction connections. Limit switches were added to the valves and brought into the DCS. The plant generated logic that allows the pump to be started from the DCS with the limit switches being a start permissive. Lastly, an HOA (hands off auto) switch was added to the pump's motor breaker to allow manual operation.

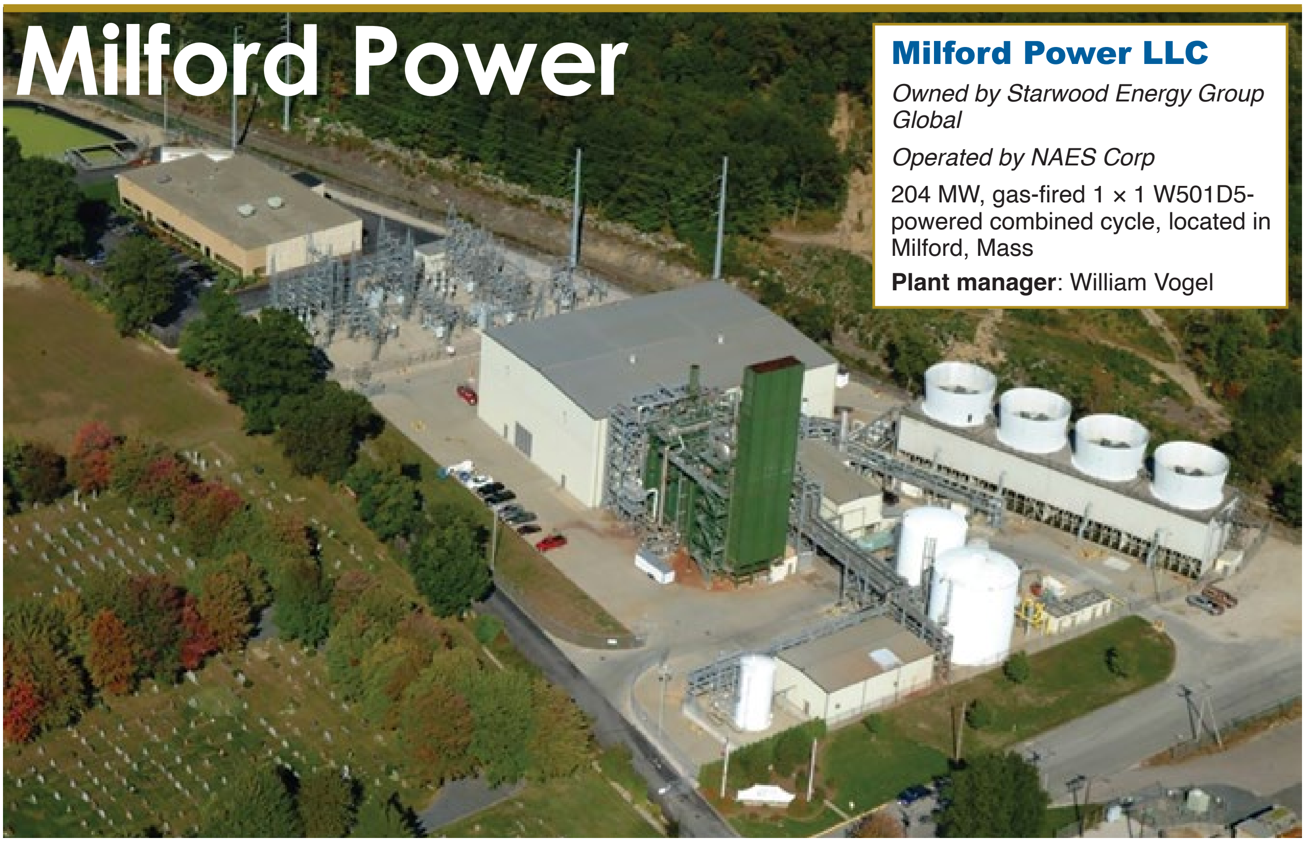
Results:

- Increased safety: For example, less chance of steam-turbine damage caused by high lube-oil temperature.
- Eliminates the need to rent a diesel-driven air compressor on loss of electrical power.
- Fewer steps to put a pump in service during an emergency.

Project participants:

Thomas Viertel, maintenance manager
Bob Arraiz, lead IC&E technician
McKenzie Slauenwhite, plant engineer
Daniel DeVito, IC&E technician
Liam Collins, maintenance mechanic

Milford Power



Milford Power LLC

Owned by Starwood Energy Group Global

Operated by NAES Corp

204 MW, gas-fired 1 × 1 W501D5-powered combined cycle, located in Milford, Mass

Plant manager: William Vogel

Automation logic for gas-turbine NO_x control

Background. Milford Power began operating in 1993 as a nominal 150-MW (90F day)/171-MW (winter day) facility. At the time, the gas turbine exhausted into an unfired, SCR-equipped HRSG with air-emissions permit limits of 9 ppm NO_x, 50 ppm CO, and 10 ppm ammonia slip. The steam generated drives an SST-700HP/LP VAX ST6 turbine.

In 2016 the plant control system was upgraded from WDPF to Ovation and included an integrated steam-turbine controller and AVR.

Challenge. An uprate project in 2019—including addition of HRSG duct firing, an upgrade of the steam turbine's rotating elements, and gas-turbine wet compression—dictated a new air permit for the plant. It limited emissions of NO_x, CO, and ammonia slip to 2 ppm each, effective May 6, 2020.

Solution. Tighter control of steam injection for gas-turbine NO_x reduction was needed to meet the new emissions limits. Steam injected into the GT comes from three sources in the combined-cycle process and they required tight regulation to get the optimal emissions profile. In addition, the GT steam injection ratio (steam to fuel) had to be increased at baseload from 1.4 to 1.75.

Automating control of the steam-to-fuel ratio. Originally, the operator manually increased the steam-injection ratio as load increased, but this was not an ideal control strategy. Plant management implemented logic,with assistance from the OEM, to modulate the steam ratio in FX control from 1.4 to 1.75. This was accomplished by strategically mapping turbine operation from minimum load to baseload. An algorithm curve was created with the information captured.

Automating control of HP-to-IP logic. This controller logic was designed by implementing gain, reset, and slew setpoints. Minimum pressure for the controller is 235 psig. If GT NO_x increases to 29 ppm or higher and/or stack NO_x is 2 ppm or higher, the controller increases the setpoint by 5 psi above the extraction-process pressure. The setpoint is increased automatically by 4 psig every 15 seconds.

This means it will take about 3 minutes to achieve a setpoint of about 275 psig to assist in the steam requirements of steam-to-fuel ratio. The control valve will move fast enough to achieve this within about 5 minutes.

When assistance of the HP-to-IP steam system is no longer required, the setpoint will move back to 235 psig when GT NO_x is equal to or less than 27 ppm and stack NO_x equal to or less than 1.8 ppm. The controller setpoint will decrease by 2 psi every 30 seconds. Thus, it will take approximately 11 minutes to achieve 235 psig.

Results:
- More accurate control of the steam-to-fuel ratio
- Increased efficiency of the steam-to-fuel-ratio operation.
- Less chance of over- or under-shooting the desired steam pressure for steam/fuel-ratio control.
- Reduced chance of permit violations.
- More efficient control of the ammonia injection system.
- Operators have more time to focus on other plant duties.
- Faster handling of system upsets.
- Relatively inexpensive to implement logic.
- No added equipment needed.
- Immediate cost savings.

Dig deeper on this topic by reviewing Milford Power's previous three Best Practices articles:
- *Uprate project boosts plant output by one-third,* CCJ No. 64 (2020), p 42.
- *Upgrading emissions controls to meet today's more stringent requirements,* CCJ No. 69 (2022), p 76.
- *Repurposing old parts, materials,* CCJ No. 73 (2023), p 98.

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2023 EPRI Technology Transfer Workshop

Steven C Stultz, Consulting Editor

Editor's note: To access the comprehensive slide deck developed by EPRI for its HRSG Technology Transfer Workshop, go to www.powerusers.org, click the HRSG Forum logo and then the "Conference Archives" button at the top of the screen.

As a final day attached to the HRSG Forum's 2023 Conference and Vendor Fair, June 12 – 15, at the Renaissance Atlanta Waverly, the Electric Power Research Institute presented *EPRI heat-recovery steam generator technology transfer day*, open to all Forum attendees.

Principal organizers were these EPRI program leaders:

- Bill Carson, HRSG.
- Tom Sambor, Power Plant Piping.
- John Siefert, Materials.

Primary agenda topics included the following:

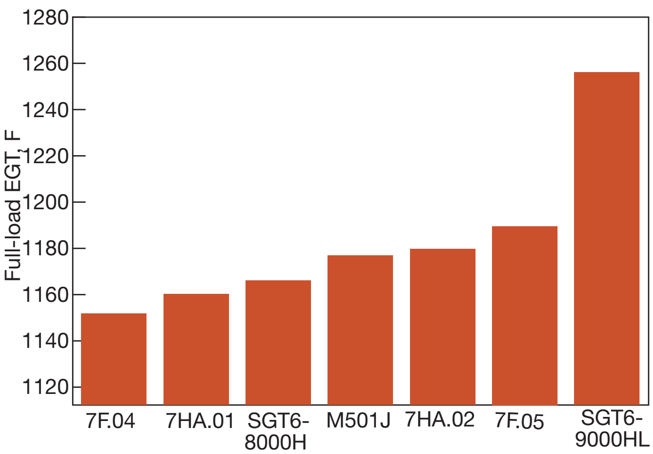
- Current industry challenges.
- Safety issues with header end caps.
- Activities with high-temperature components.
- Steam leaks in high-temperature intersections (tees).
- Damage related to attemperators/desuperheaters.
- Activities with low-temperature components.

Bill Carson opened the program with a safety session on personal protective equipment, followed by an overview of information available through the EPRI website. Those interested should visit https://enroll.epri.com (scan EPRI QR1 for a quick connection).

Eugene Eagle, Duke Energy, the utility chair of the HRSG program, then presented an overview of EPRI Program 218, *Heat-recovery steam generators,* and research areas that include damage mitigation, improved performance, life management, flexible operation, and HRSG innovations. He included specific values gained from EPRI Program technology research activities. Scan EPRI QR2 for details on Program 218.

Today's challenges

Tom Sambor offered an interesting assessment of the state-of-the-industry, and summarized HRSG infrastructure challenges (table), stating "Uncertainty is increasing; resources are decreasing."



1. Gas-turbine exit-gas temperatures, and HRSG steam temperatures, are exceeding practical limits for Grade 91 steel

Sambor focused on the increasing need for an "integrated life-management" strategy, which EPRI has organized into seven parts. An integrated-life management approach for a component relies on, at a minimum, an equivalent consideration of mechanics (structural analysis, thermal hydraulics, etc), metallurgy, and nondestructive evaluation.

HRSG infrastructure challenges

Increasing	Decreasing (resources)
Flexible operation	O&M budgets
Material complexity	Codes/standards awareness
Supply-chain challenges	Power-generation service provider expertise
Alternative repair solutions	Engineering and support staff (owner/operators)
Fitness-for-service needs	—

EPRI has numerous examples where each of these elements, he stated, are performed "poorly" by power generation service providers as they frequently lack a "rigorous approach." See "Integrated Life Management of Grade 91 Steel Components: A Summary of Research Supporting the Electric Power Research Institute's Well-Engineered Approach" (EPRI QR3).

Sambor then reviewed how EPRI has a suite of information available for HRSGs that fits within each part of an integrated life-management strategy in detail.

Fundamentals. The "industry is reliant on NDE as the only tool in the toolbox," despite industry codes and standards emphasizing the impor-

EPRI QR1 EPRI QR2 EPRI QR3 EPRI QR4 EPRI QR5 EPRI QR6 EPRI QR7 tance of materials testing and engineering evaluation, Sambor stated. He referenced a series of documents that the HRSG program at EPRI has on fundamentals, increasingly important because of the loss of both service-provider expertise and engineering and support staff within utilities.

Service experience. Sambor explained how the examination of unexpected, premature, or early-in-life industry failures has led EPRI to identify some components or systems as systemic "industry issues."

Specifically, attemperators/desuperheaters, flat end closures, seamless and welded intersections, stainless-steel flowmeters, seam welded fittings/piping, small-bore DMWs, and, more generally, CSEF steels were all identified as industry issues relevant to HRSGs.

He identified that flat end closures, intersections, and attemperators/desuperheaters would be discussed as part of the day-long technology-transfer meeting because there have been recent and historical examples for each identified issue. See "Life Assessment Primer for Heat Recovery Steam Generator Internal and External Piping" (EPRI QR4).

Specifications. Sambor next noted the increasing need for specifications that go above and beyond the minimum requirements in relevant HRSG codes and standards. Emphasizing this need is the fact that the previously discussed industry issues are typically associated with components that comply with the ASME Code.

To that end, EPRI has developed a range of guidance initiatives that includes product forms, processes, components, and plants. Sambor further explained that "EPRI is uniquely positioned to provide comprehensive technical assistance for material/component replacement or new construction," including specification guidance.

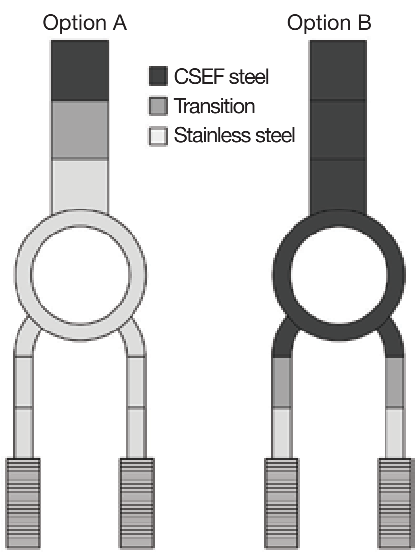
Guidelines. Sambor then reviewed numerous guidelines focusing on strategies to avoid pressure-part failures—including those during startup and shutdown, HRSG materials selection, and operating HRSG drains, etc. He highlighted the need for reducing uncertainty, and pointed to additional information available for that purpose.

NDE and FFS. Interesting discussions followed on nondestructive evaluation and analysis. Showing large-feature cross-welds in Grade 91 material, Sambor stated that there is "limited detectability of creep damage in modern alloys via NDE."

He also stated that "NDE alone

EPRI QR8

EPRI QR9



2. Think through transitions from stainless to creep-strength-enhanced steels. Should your transitions be made in the link piping (Option A) or in the tubing (Option B)?

is not an adequate life-management strategy. Mechanics and metallurgy (at a minimum) must be considered, and the uncertainty in these areas needs to be reduced as much as practical."

Further support for this statement: "A significant portion of the costs to perform NDE is for no-value-added activities such as scaffolding, insulation removal, surface preparation, and project management," he explained.

He also addressed fitness-for-service (FFS), noting that EPRI has a large ongoing effort in this area. FFS methods developed as part of this work are being used for tees and other geometries. EPRI also has the capability, in its lab or otherwise, to subject components removed from service to post-mortem evaluation and analysis. See "An Informed Perspective on the Adoption of Comprehensive Fitness-for-Service in an Integrated Life Management Strategy" (EPRI QR5).

Repair or replace. Decisions can be difficult, and repairs are "typically not one-size-fits-all." Each needs to be engineered, but more critical is the determination of root causes. "Root causes must be identified and mitigated," he said.

Sambor offered an extensive list of information that is available to assist in repair/replace decisions. Subjects include weld overlay, tube and tube-to-header repairs, steam turbines, fans, and deaerators. Another long list focuses on CSEF steel alternative weld repair and includes effects of filler metal or process, weld geometry, and other component specifics such as girth and dissimilar metal welds.

3. Failure in stainless-to-CSEF steel transition. EPRI is aware of steam leaks or failures in both link piping and tubing

After outlining a multitude of research programs and results, Sambor stated that "research is not complete. EPRI continues to assess repairs on materials removed from service," and encourages owners/operators to donate samples.

Technology transfer. Sambor concluded this section of the program stating that EPRI technology transfer includes numerous activities that are publicly available, such as:

- EPRI presentations at industry workshops.
- Participation in codes and standards.
- Published papers and articles to raise awareness.
- Industry alerts. See example by scanning EPRI QR6.

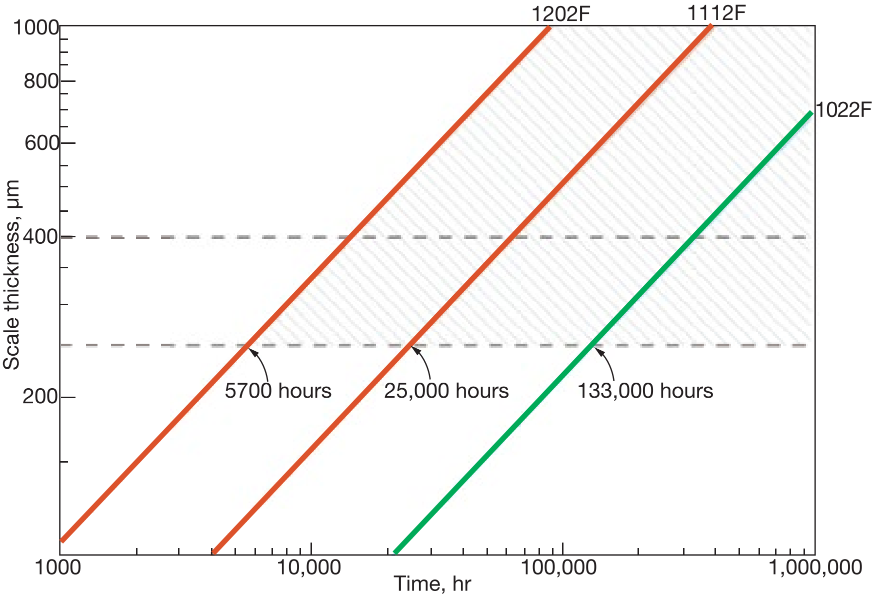
He then said that "Technology transfer is not a one-way street. Reach out to EPRI if you have experienced and/or identified a unique failure or have a question" (email ppa@epri.com).

New construction challenges

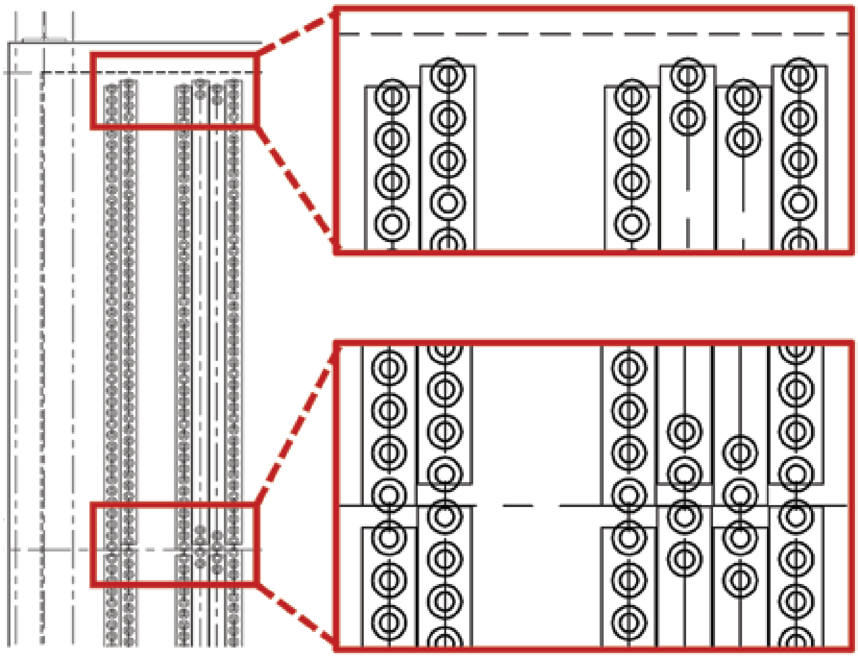
With modern gas turbines, exit gas temperatures of 1150F and steam temperatures of 1050F are exceeding the practical limits for Grade 91 steel (Fig 1).

So, the question becomes: "Do you (the owner/operator) opt for advanced stainless/higher chrome CSEF steels, or push the 9Cr performance envelope?"

Advanced alloys offer options, but also some learning curves. For example, there could be options when transitioning from stainless steel to CSEF steel within the HRSG (Fig 2). The transition shown could be in



4. Tube oxidation/exfoliation is impacted by time and temperature



5. Flat header end closures generally are preferred over torispherical caps in HRSGs to save space. However, some flat-cap designs are failure-prone and should be supported by a life-management plan. See EPRI report 3002011049 for details

the piping (Option A) or in the tubing (Option B).

Said Sambor, "EPRI is aware of steam leaks or failures in each case" (Fig 3).

There are similar issues with tube oxidation/exfoliation (Fig 4).

Basically, care must be taken because modern gas turbines could be "abusing the HRSGs," cautioned Sambor.

Header end caps

John Siefert next took the stage to discuss the state of knowledge and screening methodologies for header end caps, a growing industry safety concern. Flat-end closures are used in many HRSG headers primarily for their space-saving design (Fig 5). See "Life Management of 9%Cr Steels—Assessment of Header End Cap Geometries" (EPRI QR7).

While surface stresses can be high during startup and shutdown, which may lead to fatigue damage, the state of stress in the weld during normal operation also makes end caps susceptible to creep damage. EPRI is aware of failures attributed to both damage mechanisms. It is impossible to know if a failure is caused by fatigue or creep without a rigorous and integrated analysis of the root causes.

Case studies show that failure incidents are not new, and a few "catastrophic failures" were reviewed where the end cap was ejected without warning.

Siefert discussed the various end-cap designs and design rules, typical creep redistribution stresses, and cyclic operation thermal stresses, material chemical analyses, and typical inspection techniques.

EPRI's recommendation is to implement an integrated life-management plan that considers the following:

- Geometric configuration (including fabrication quality).
- Design margins (excess thickness, for example).
- Operating conditions (temperature imbalances and transients).
- Metallurgy and risk (deformation and damage susceptibility).
- Access for inspection, including where resulting damage is likely to occur.
- Lifetime predictions.
- Consequences of failure including plant operations and personnel.

Recent activities

Sambor returned to the podium to review the global installation totals for 9Cr steels, both Grade 91 and Grade 92. The totals include more than 1000 supercritical and ultra-supercritical steam systems and more than 2600 combined cycles installed globally in the past 25 years.

Several factors, including material ductility, can compound and increase the risk to rupture for these materials (Fig 6).

Two interesting points:

- For most of the *ASME Boiler nd Pressure Vessel Code's* existence, the use of ductile materials has largely protected the industry from widespread creep concerns in the high-temperature regime.
- If materials are to be classified by Section II as possessing low creep ductility, then an optimized set of design rules should be invoked by Section I to responsibly design safe structures, as there is no explicit design life.

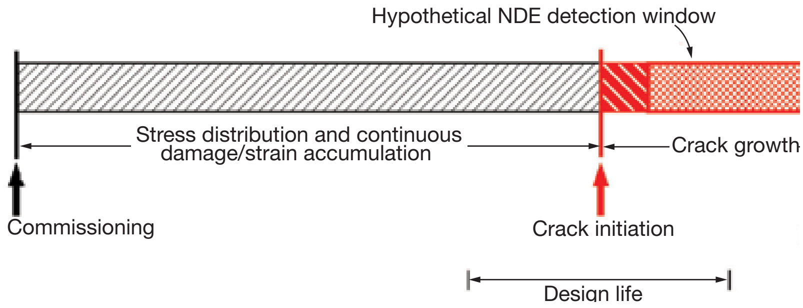
Noted Sambor, "The thrust behind Grade-91 Type-2 composition was to reduce the future population of low-ductility heats."

After reviewing Code Case 3048, *Design rules for CSEF steels which are creep intolerant for construction (May 4, 2022)*, he summarized: "Extensive challenges remain to improve design rules for complex materials, structures, and operating modes."

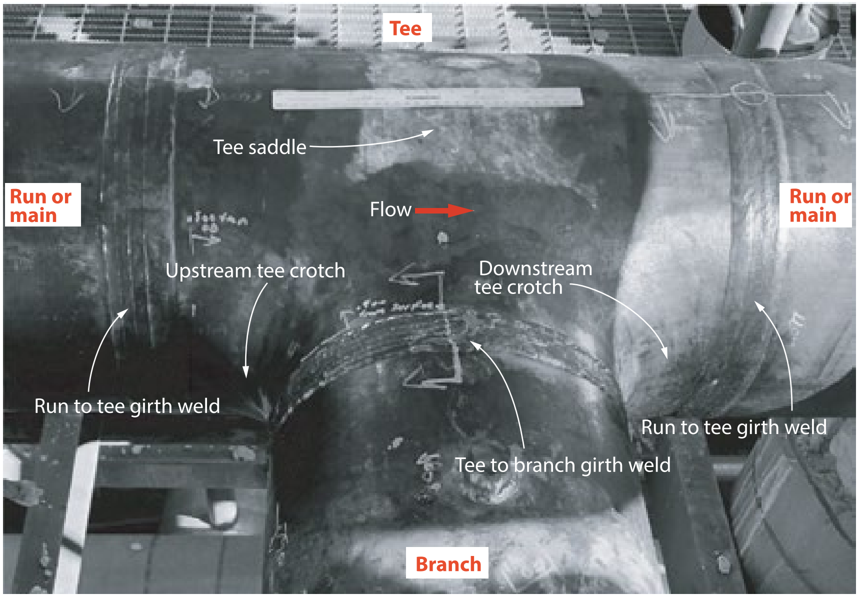
He then presented a recent case study of a reheater tube-to-header failure to emphasize the importance of rigorous analysis. Sambor recalled that he once shared photos of the failure with several individuals and asked their opinion on what caused the failure; all were quick to attribute the failure to fatigue. He then showed various metallographic sections of the failure, all of which illustrated that the failure region was "loaded" with creep damage, indicating the failure was due to creep rather than fatigue.

The importance of this determination, Sambor emphasized, is that the utility/plant now is aware of a systemic problem (attributed to component configuration and operating conditions) rather than a one-off failure.

He finished off the discussion on high-temperature components with a presentation on new efforts towards online creep and fatigue damage trending of HRSG components and the development of various web-based calculators available through EPRI. See EPRI QR8.



6. Crack-growth phase may be unacceptably short for materials with low creep ductility, which will be sensitive to the development of damage at stress concentrations (local geometries or welds)



7. Terminology for a tee intersection in a high-temperature, high-energy piping system

Tee intersections

Siefert returned to discuss another Safety Alert for steam leaks in high-temperature intersections, specific to tees.

An EPRI Industry Alert, *Seamless tee intersections,* was issued February 2023, suggesting that a single unit generally may have four to eight at-risk tees (EPRI QR9). See Fig 7 for terminology. Discussions covered damage mechanisms, design, fabrication, operation, and metallurgy.

The damage mechanism discussion concluded that all the tee steam leaks to date could be attributed to the creep mechanism. Siefert emphasized that external metallurgical laboratory evaluation has also reached that same conclusion.

One reason for creep-related failures associated with these tees is inadequate design requirements, which may result in a lack of reinforcement and/or significant variability between supposedly identical tees.

In terms of fabrication, Siefert highlighted that the steam leaks "do not suggest gross issues linked to shop or field post-weld heat treatment," which is a common concern with CSEF steel material. He instead identified a case where a tee crotch weld repair was performed and another case where a vee shape was roughly machined into the ID surface of the tee crotch, both fabrication issues that have affected the lives of tees.

Operation discussions summarized that units with tee steam leaks have all been operating within their design envelope (that is, operating below their design temperature/pressure), and summarized analyses that EPRI has performed to determine if cyclic operation (fatigue) is a concern.

For one case study analyzed, there is no evidence that the inelastic strain range calculated during cyclic operation would result in fatigue cracking within the number of cycles the tee has experienced, and there was no evidence to support ID-initiation for any of the observed damage.

Siefert finished the tee discussion on the topic of metallurgy, where he detailed a recent failure that is the first reported tee steam leak in a Grade 22 system, which means that this industry issue is not isolated to only CSEF steels. He also highlighted a case study where a tee was found to be the incorrect alloy, X20 rather than Grade 91, and emphasized the importance of positive material identification (PMI) on tees in the field for this reason.

Finally, Siefert emphasized the importance of metallurgical risk on CSEF steel tees by illustrating how the time-to-creep crack initiation could decrease by a factor of 10 because of increased metallurgical risk.

Attemperators/desuperheaters

Sambor covered common approaches for diagnosis and mitigation of

attemperator damage issues using historian data, instrumentation, metallurgical analysis, and operating data.

In his first example, he illustrated how a review of historian data revealed "several easy to identify, detrimental phenomena occurring." Further, he explained how historian data can be used to perform an energy balance around the attemperator to determine if a detrimental condition exists, and mentioned that EPRI has a tool available for doing so.

In a second example, Sambor emphasized the importance of adding surface-mounted thermocouples at select locations upstream and downstream of attemperator piping for improved attemperator diagnostics. He showed how, in one case study, the historian data did not indicate an issue with the attemperator, but thermocouple data on the downstream elbow did reveal that relatively cool spray water was impinging on the relatively hot piping, which is a thermal fatigue concern that has resulted in steam leaks.

Since a concern with adding more thermocouples often is how to collect the data, Sambor mentioned that EPRI has developed a low-cost data logger for doing so. Finally, he emphasized that some issues with attemperators could be associated with less-than-ideal operational strategies, such as trying to roll the steam turbine with a too-high gas-turbine exhaust gas temperature.

Sambor finished the topic with a recent bypass desuperheater case study that involved laboratory evaluation and an analysis of plant operating data.

He highlighted how easy it has become to analyze what he labels "big-data" from the plant (data evaluated was for dozens of tags at one-minute intervals for a calendar year) and the importance of doing so; the operating data he illustrated revealed the same detrimental patterns occurring for most startups and shutdowns, rather than just the occasional occurrence.

Low-temperature components

Sambor finished the day by leading a discussion on HP drums. Based on the comments made by attendees, it was clear that additional technology transfer around integrated life-management strategies for drums was necessary. This will be included in a future HRSG Forum event. CCJ

International Association for the Properties of Water and Steam

IAWPS is a global non-profit association involving 25 countries in all aspects of the formulations of water and steam and seawater, as well as in power-plant cycle chemistry. It provides internationally accepted cycle-chemistry guidance for power generation facilities in Technical Guidance Documents freely downloadable from the organization's website at www.IAPWS.org. Specific TGDs for combined-cycle/HRSG plants include the following:

- Procedures for the measurement of carryover of boiler water into steam.
- Instrumentation for monitoring and control of cycle chemistry.
- Volatile treatments for the steam-water circuits of power plants.
- Phosphate and NaOH treatments for the steam-water circuits of drum boilers.
- Steam purity for turbine operation.
- Corrosion-product sampling and analysis.
- HRSG high-pressure evaporator sampling for internal deposit identification and determining the need to chemical clean.
- Application of film-forming amines in power plants.

Air-Cooled Condenser Users Group

The 13th annual meeting of the Air-Cooled Condenser Users Group (ACCUG) was held June 20 - 22 (2023) at Dominion Energy's offices in Glen Allen (Richmond), Va. Strong international participation, interaction, and discussion enhanced the benefit of this event to all ACC owner/operators, service providers, and technical consultants worldwide.

The presentations discussed below, which focus on chemistry and corrosion, design and performance, and operation and maintenance, are available at https://acc-usersgroup.org.

Chemistry and corrosion

Barry Dooley, Structural Integrity (UK) and conference co-chair, opened the conference with a backgrounder on *ACC corrosion and cycle chemistry*, stating that flow-accelerated corrosion (FAC) damage to ACCs is the same worldwide with all chemistries and plant types. This led to a discussion of global ACC inspections and common indicators of both single- and two-phase FAC, and a review of the phase transition zone in the LP steam turbine.

Dooley included details on corrosion damage and analysis, and a reference to document ACC.01, *Guideline for internal inspection of air-cooled condensers*, available at no cost on the user group's website.

He concluded with an update on film-forming substances, and various technical guidance documents for plants with ACCs, available at www.iapws.org, and also free of charge.

Andy Howell, EPRI and conference co-chair, then examined *ACC steam-side finned-tube corrosion downstream of tube entries.* He focused on "new information, and a new investigation."

Howell began with erosion and corrosion of carbon steel in the LP turbine exhaust contributing iron oxide to the condensate, which would impact the surface of the ACC heat exchanger tubing (Fig 1).

More evidence of metal loss typically is found in the ACC steam distribution upper duct and at the tube entries (Fig 2). Metal-loss drivers are velocity and corrosion. At the tube entries, turbulence (velocity) is the highest, and the initial steam condensate is the most corrosive (lower pH).

Observations in 2022 identified metal loss downstream of the tube entry (Fig 3). This is the new information and investigation. Previously, industry focus was on the tube-entry area, and downstream corrosion had not been widely investigated or reported.

So, what are the implications of this down-tube corrosion? According to Howell, investigations are important because:

1. This may be a major source of iron transport to the steam cycle.
2. There is potential for tube leaks (air in-leakage).
3. Investigations will help clarify whether all ACCs are susceptible and may provide more opportunities to reduce metals transport throughout the steam cycle.

Dooley then returned with a detailed look at film-forming substances, focusing on the latest international activities. For more on this topic, see *FFS: Sixth International Conference,* CCJ No. 75, p 75.

Sam Dunning, Virginia City Hybrid Energy Center, next offered a plant experience report on air in-leakage. Dominion Virginia Power's VCHEC features two circulating fluidized-bed boilers and one 610-MW turbine/generator, commissioned in 2012. Fuels are waste coal and biomass.

The air-cooled condenser, by SPG Dry Cooling (formerly SPX), contains 10 streets of six bays each, with 36-ft-diam fans. Steam jet air ejectors remove non-condensable gasses from the ACC. Hogging ejectors are used to evacuate the ACC and dual-stage holding ejectors are used for normal operations.

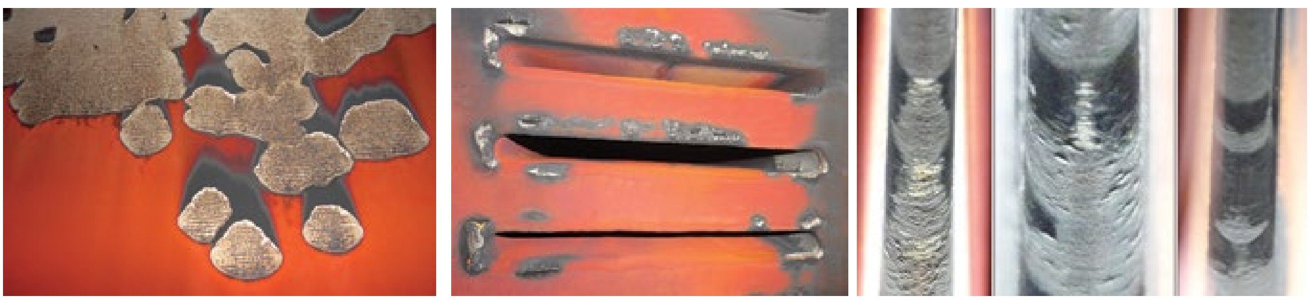
Following a 2021 outage, VCHEC was dispatched to full load. Operators noticed that when switching from hoggers to holding ejectors, backpressure was not maintained. Hoggers were returned to service.

Typical air in-leakage indicators suggested a major leak in the ACC. The energy center was derated by 200 MW for two days and by 100 MW for five days. Troubleshooting, including use of all typical methods of leak detection, met with no success.

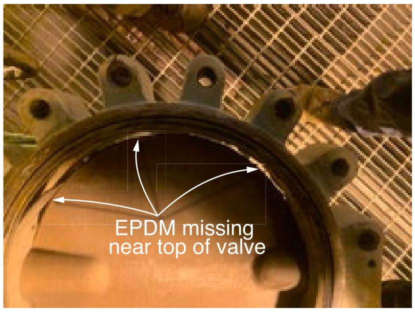
Then, a large leak was found in the hogging-ejector isolation valves. It allowed air to be pulled back into the discharge side of the out-of-service hoggers. Said Dunning, "inspection of the valve internals showed the rubber (EPDM) seated valves had lost more than half of their seals" (Fig 4). The rubber had become brittle and the adhesive used to hold the seal in place had deteriorated. Other valves were checked and all were experiencing the same failures.

Valves were replaced in-kind for operations, and later replaced with metal-seated ones.

Dunning's observation and recommendation: The seat design of the rubber-lined seal limits the rating level



1-3. Metal loss from ACC duct walls attributed to LP-turbine steam exhaust (left); erosion/corrosion at ACC tube inlets (center) and 3 to 6 ft downstream of the tube inlets (right)



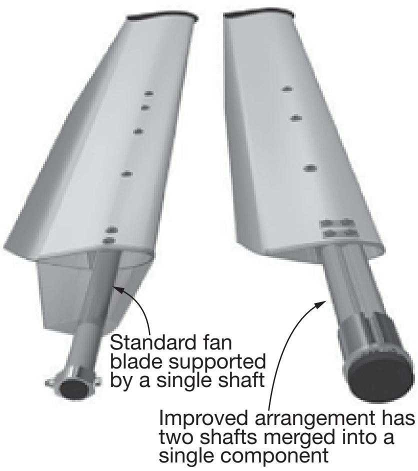
4. Damage to and loss of EPDM (ethylene propylene diene monomer) valve seating material provided a pathway for air in-leakage

of vacuum valves. High-performance butterfly, including triple offset styles, should be considered. He added that "if rubber-seated valves are currently in vacuum service, periodic inspections should be conducted more frequently as the valves age."

Design and performance

Carlo Gallina, Cofimco (Italy), presented *FRP-carbon twin shaft for axial fan blades*. Said Gallina, "research and experience showed the need for an improved shaft to connect the blade airfoils to the hub. This led to the pultruded FRP-carbon twin shaft to improve the blade load capacity of large fans in both ACCs and cooling towers."

He reviewed the basics. Lift must be generated for each blade, but varies because of aerodynamic disturbances—including mechanical obstacles (walkways, etc), wind gusts, and fan location within the ACC. Bending moment and lift are transferred to the hub, drive system, and structure, all influenced by the varying loads.



5. In the binocular shape (right) two shafts are merged in a single component without increasing airfoil size

"Therefore," he explained, "the blade connection to the hub must be strong enough to withstand high loads generated at the shaft."

Rigid solutions transmit loads to the structure and can cause vibrations. "Using pultruded FRP-carbon shafts gives the blades suitable flexibility, and reduces vibration. Plus, the high strength of carbon limits blade deflection." Plus, plus, the natural frequency of these blades is far from typical fan forcing frequencies.

Next, Gallina introduced the Cofimco twin shaft for axial fan blades featuring a "binocular shape" (Fig 5, right). He then reviewed full details of work at Cofimco's test rig complex in Italy. Conclusions:

- The twin-shaft blades can withstand severe duty points and manage high, abrupt loads.
- Blades generally can be operated from zero to 100% speed when driven by a VFD.
- Vibrations and loads introduced to the structure are greatly reduced.

Huub Hubregtse, ACC Team (The Netherlands), discussed Common performance problems for ACCs . "In general," he began, "there is a lack of technical knowledge by operators, and many ACCs have performance problems, especially in summer. Not all operators have enough knowledge of the processes to analyze the system."

He outlined and discussed the primary impacts on performance:

- Fans in respect to air flow and static pressure.
- Recirculation of hot air.
- Fouling.
- Steam distribution in heat exchangers.
- Leaks.
- Noise (indirectly).

Static pressure reduces air flow and increases motor power requirements. He discussed fan measurement criteria for air flow, static pressure, and absorbed power.

"Recirculation means hot air from the top is sucked down to the fan inlet, resulting in warmer air for cooling," he explained. The main cause is the difference in suction pressure at the fan inlet and the pressure at the outlet of the ACC. This can be caused by a nearby building, wind, or other factors. To check this, he suggests measuring air temperature in the plenum and air temperature at a distance.

"Fouling from dust, seeds, and insects can obstruct the space between the tube fins, resulting in higher static pressure and less air flow," he continued. Most fouling can be removed with high-pressure washing (1300 to 1600 psig). Other fouling can be difficult and require blasting with sodium bicarbonate or similar method. "The performance impact of cleaning can be enormous," he offered.

Hubregtse continued: Steam flow through the ACC heat exchangers is controlled by the small (15 mbar) pressure difference between inlet and outlet. Flow reduction causes can be fouling, vacuum pumps, or layout of the suction piping. Testing with thermal imaging should reveal the problems.

Imaging can show low pressure differentials in the middle of the tubes, for example. The suction processes will take vapor/steam before they take air. If there is a leak, air can penetrate the system, blanketing the inside of the finned tubes. A simple vacuum drop test can indicate leak rate.

But finding the leak can be difficult. "The most common and reliable way to find leaks is to spray helium gas near a suspect location and test the ACC for helium in real time. Helium testing can be expensive (and time-consuming), but is reliable," he explained.

Although noise is not directly related to performance, "some operators reduce the speed of the fan when noise is a concern," he noted. If this occurs, "the blade angle has to be increased to compensate for the loss of air flow." One danger is that the fan can go into stall, reducing the air flow.

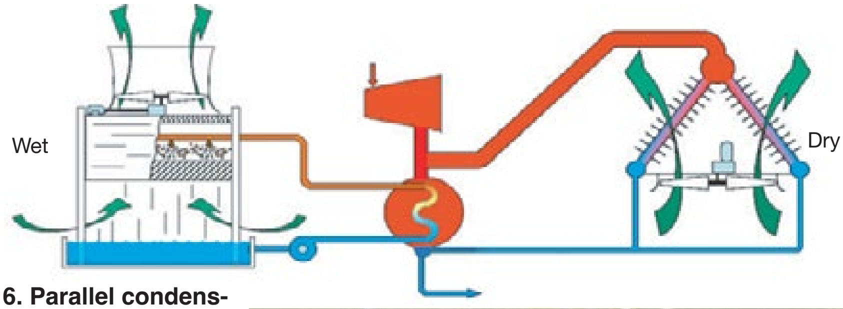
Keith Paul, EPRI, followed with *Infrared drone inspection of an air-cooled condenser* to analyze heat distribution. The subject site was New York Power Authority's Zeltmann Power Project, a 576-MW, 2 × 1 7F-powered combined cycle in Astoria, NY, commissioned in 2005.

Before the site visit, drone calibration runs were conducted at Evapco Test Labs in Maryland. "We ran the same drone, tested camera resolution and distances, and tested air in-leakage detection with intentional in-leakage."

His conclusion: "Based on our experience at Zeltmann, and at Evapco's test lab, we cannot say that drone infrared inspections provide definitive leak-detection services. This is still a work in progress." The site switched to still cameras.

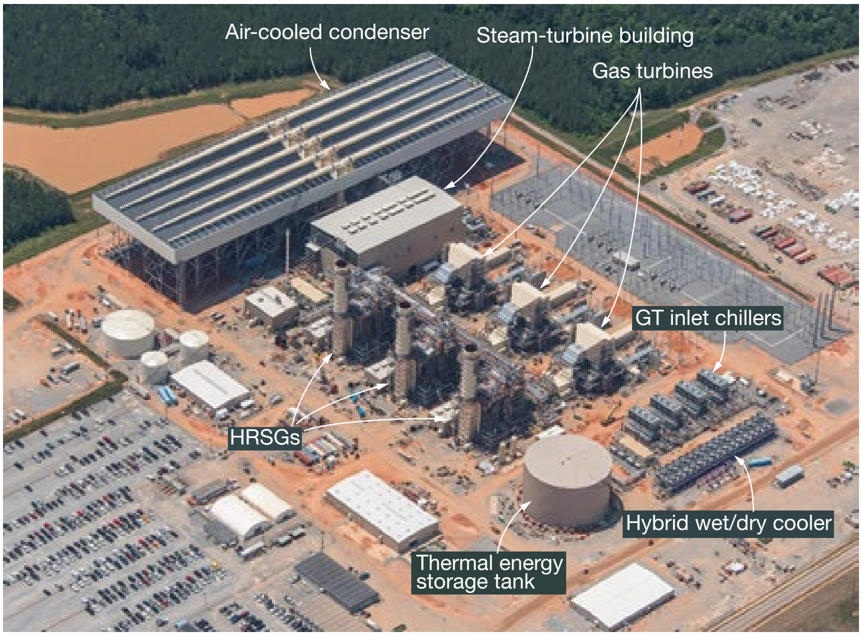
On the positive side, initial results at Zeltmann allowed the plant to focus on specific sections for possible repairs in an upcoming outage.

"EPRI is now developing a test methodology to use acoustic cameras mounted on a drone to inspect air-cooled condensers," Paul explained. This is based on success with hand-held acoustic cameras. This ongoing drone work is a potentially strong time-saving technique.



6. Parallel condensing: Steam is condensed in both dry and wet cooling systems simultaneously

7. The two-cell wet cooling module retrofitted at Rio Bravo IV contributed a 20-MW increase in plant output



8. Dominion's Greensville is a 1680-MW 3 × 1 combined cycle which began commercial operation in December 2018. It has three Mitsubishi 501J gas turbines with steam-cooled combustors, a four-flow steamer of Alstom design, an 80-cell ACC, GT inlet chillers capable of boosting the plant's output by up to 150 MW, and six levels of duct burners capable of adding 200 MW

Hector Moctezuma, Valia Energía (Mexico), offered an *Update on a hybrid cooling retrofit installation*, first presented to ACCUG in 2014. He spoke first about the plants in his country.

"Plants are often not able to reach maximum output during summer due to high steam-turbine backpressure from the main condenser, which limits use of duct burners and sometimes means reducing CT output to avoid a steam-turbine trip," he said.

More specifically, "This significant power output reduction is due to ACC under performance in summer and with windy conditions." ACCs have also experienced physical degradation through the years, mainly severe fouling and tube damage.

"With the help of SPIG USA, a parallel condensing system (PCS) was chosen in which exhaust steam is simultaneously condensed in both a wet evaporative and the existing dry cooling system" (Fig 6).

"The goal is to remove the steam-turbine backpressure limitation during all periods with ambient temperature higher than 86F (1000 hours per year) by adding enough wet cooling capacity to the existing 32-cell ACC." The design considers local water limitations.

The speaker reviewed results for the nominal 500-MW Unit IV at Rio Bravo Energy Park after addition of the wet cooling module in Fig 7. The highlights:

- Elimination of the backpressure limitation, with a significant sustained improvement of up to 80 mBar (2.36 in. Hg).
- Power output increase of 20 MW attributed to the condenser pressure reduction and ability to increase condenser load.
- Heat-rate improvement due to lower condenser pressure (lower backpressure on steam turbine).
- Power-consumption increase by auxiliaries of about 500 kW for the cooling-water pumps, blowdown and makeup pumps, and cooling-tower fans.

This gives "consistent and repeatable operational reliability under adverse summer conditions after nine years of operation," he stated.

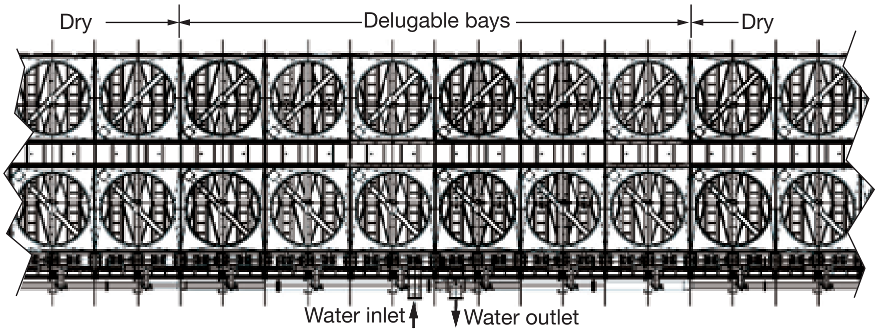
György Budik, MVM EGI (Hungary), presented on the *Hybrid delugable cooler in Dominion's Greensville CCPP* which satisfies the facility's auxiliary cooling needs using a 50/50 mixture of glycol and demin water. The cooler is located at the opposite end of the plant from the 80-cell ACC (Fig 8).

Hybrid wet/dry coolers like Greensville's (Fig 9), Budik explained, "offer a dramatic reduction in cooler size relative to all-dry coolers, and, therefore, a significant reduction in civil and maintenance work." The speaker reviewed some delugable systems installed by his company, including the first such units, which were installed in Iran.

The auxiliary cooler consists of 16 modules arranged side by side, the first five (left side) and the last five (right side) are dry, the remaining six (bays 6 – 11) are capable of deluge service.

Bays have two cooling modules, each with two 12-m-long aluminum cooling elements, best illustrated in the Fig 10 photo. The cooling modules serving all bays are connected in parallel to a common inlet and outlet manifold.

In the deluging bays, sprinkler pipes are installed at the top of the cooling elements, providing a continuous downward flow of water on the external surfaces of the heat exchangers. The Fig 10 illustration explains this.



9. Greensville's 276 × 46 × 32-ft-tall hybrid cooler is designed to handle 18,300 gpm. It has 16 bays with two fans each (10 dry, six delugable). Fans rotate at 232 rpm in dry operation, 155 rpm in deluge service. The six deluge pumps (one per bay) are each rated 7.5 hp. Deluge water consumption by design is 250 gpm on a 107F (dry bulb) day

The operating principle of the deluge system is that partial evaporation of the deluge water keeps relatively cold the rest of the water on the heat-transfer surface, thereby providing additional cooling.

Deluge water is supplied to the heat exchangers from the tank shown in the figure. Water not evaporated is collected in a trough at the bottom of the module. The trough drains to the deluge water tank. A makeup line keeps the amount of water in the system constant. Note that water of good quality is required for makeup, with first-pass RO product acceptable.

Motors driving the deluge pumps are equipped with variable-frequency drives. Operation of the deluge system is not recommended at ambient temperatures lower than 98F, all-dry operation providing sufficient cooling. Use of the deluge system would result in unnecessary water loss from drift, evaporation, and blowdown.

At temperatures above 98F, the number of fans operating in deluge modules are governed according to the following control steps:

- Step 0: standby, steady state.
- 1: 12 VFD-controlled fans in bays 6-11 start simultaneously.
- 2: Front-side fans in bays 1-5 and 12-16 start.
- 3: Dummy step.
- 4: Remaining fans in bays 1-5 and 12-16 start.
- 5: Deluging starts in two bays.
- 6: Deluging expanded to four bays.
- 7: Deluging expanded to all six bays (Nos. 6-11).

Note that with Step 7 actuated, design performance conditions are achieved with one fan out of operation.

Next objective for the new hybrid cooling technology demonstrated at Greensville likely is its use in conjunction with dry cooling systems for combined-cycle plants (sidebar). The deluge ACC is touted by its EU sponsors as being the most efficient dry-cooling solution for high peak ambient temperatures. Plus, it is said to resist adverse ambient conditions such as high-speed winds and hot air recirculation.

Other benefits include less auxiliary power consumption, smaller footprint, and lower construction costs compared to dry-only systems. And less water consumption compared to all-wet systems.

Galebreaker Industrial's Gary Mirsky presented *CFD study of airflow and performance improvement potential*. His example was a 2 × 1 plant rated at 578 MW (steam turbine output, 295 MW) commissioned in 2008.

The goal was to increase backpressure trip limits as part of a larger upgrade to increase both gas-turbine output and ACC heat rejection. Another objective: Mitigate wind effects on ACC performance.

The ACC is two units, each with three streets and five cells per street. There are buildings in the immediate area. The best performance solution was a combination of options with both perimeter and cruciform screens.

Operations and maintenance

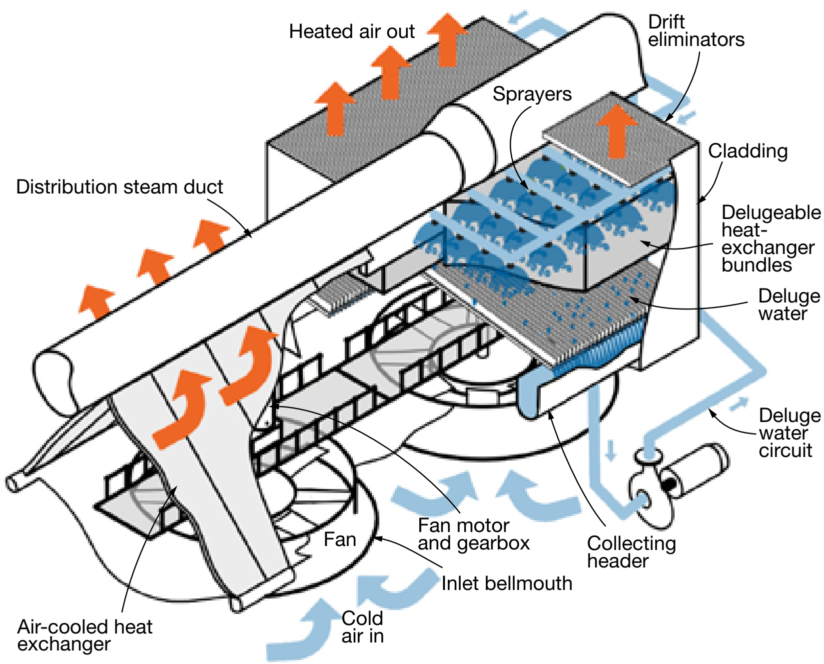
Mike Owen then presented the latest ACC-related research activities at Stellenbosch University in South Africa. It is home to an active research group specializing in ACC and dry-cooling

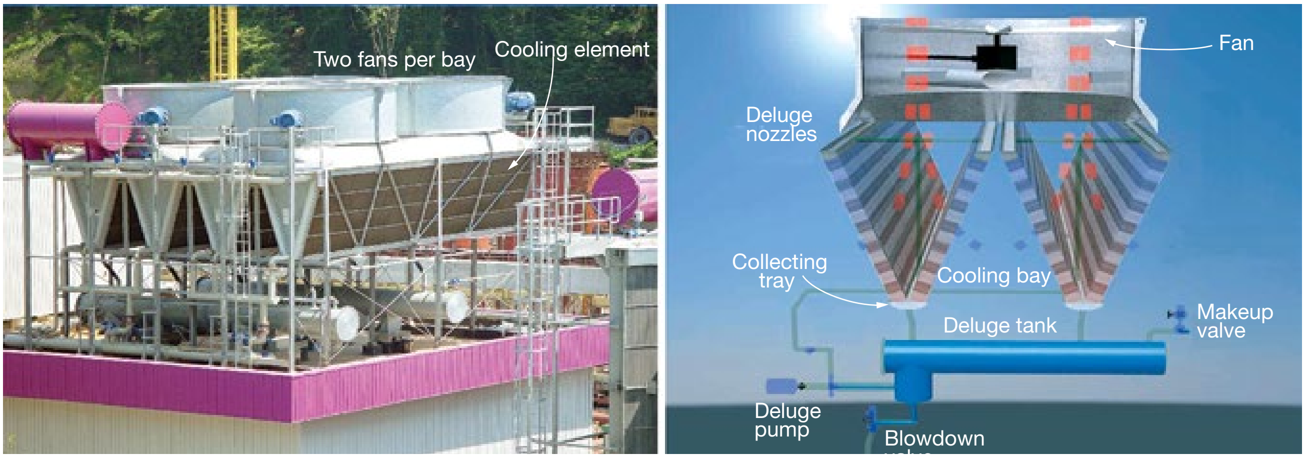
ACC with deluge cooling: Not yet, but likely soon

Literature from Enexio Water Technologies GmbH touts Deluge ACC, described in the diagram, as the latest technological achievement in hybrid cooling, where the primary interest is in dry cooling, but where limited water resources are available for use during certain times of the year.

Recall that while dry cooling methods offer an order-of-magnitude reduction in cooling-water consumption compared to wet cooling, overall power-cycle efficiency generally is higher when wet cooling can be part of the solution.

Enexio is one of the consortium partners of the EU-funded Horizon 2020 research and innovation program called MinWaterCSP. Its goal is the development of cooling technologies and water management plans to reduce cooling-system water consumption by up to 95% relative to wet-only cooling systems.



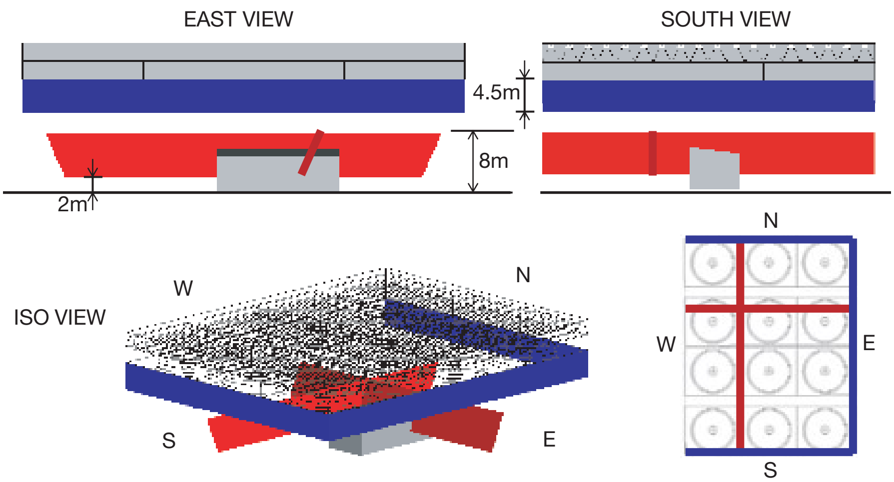


10. Two-bay hybrid cooler (left) facilitates understanding the heat exchanger's design; drawing at right shows how deluge water cools

activities, and is a frequent participant at ACCUG events.

Topics this year included prediction of large-diameter axial-flow fan noise and performance, dynamic blade loading, modeling improvements, machine learning for performance monitoring, and fan drive-train dynamics.

Owen also covered specifics of operation and controls—including air-extraction valves, fan speed range and fan hardware, fan gearbox/motor/VFDs, two-stage air ejectors, drain pot, and pumps. Most of these items would be mentioned during the site tour of Greensville on the last day of the conference.



11. Windscreen configuration to mitigate the effects of high winds had a cruciform height of 8 m/solidity of 75%; perimeter height of 4.5 m/solidity of 60%

Jeff Petrillo, Dominion, introduced the group to the Greensville County Power Station with *ACC lessons learned*. He presented a site overview to familiarize those joining the tour with the facility's layout and principal equipment. The latter included the following:

- 80-fan (VFD) ACC with 10 streets (five east, five west).
- One condensate receiver tank with two deaerators.
- Four liquid-ring vacuum pumps.
- Two two-stage steam-jet air ejectors.
- One drain pot with two pumps.

Jacques Muiyser, Howden Netherlands, presented *ACC fan dynamics: Potential problems and solutions.* The basis of this discussion: ACC fan blades and/or connection bolts can fail because of high dynamic loads. Muiyser discussed sources and consequences of dynamic/cyclical blade loads, and development work to confirm that a stronger hub design with a more rigid bolt-to-bolt connection can help avoid bolt failure from fatigue.

He began with a refresher course on blade dynamics and mechanical properties, also covering flow distortions attributed to obstructions and crosswinds before moving on to case studies.

In the first case study, owner/operators noticed isolated U-bolt failures at a site. Strain-gauge measurements revealed resonance at high fan speed. Performance measurements then showed the blade angle could be increased while reducing fan speed to avoid the failures while maintaining performance.

In the second case, recurring issues were blade separation at the leading edge, and blade clamping-bolt failures (straight bolts). For the blades, strength was corrected with additional laminate on the leading edge. The clamping bolt issues were corrected by adding a secondary hub ring, connecting all of the clamping pieces.

In Case Three, straight-bolt failures shortly after installation showed signs of failure, primarily at edge cell fans. Root cause was high dynamic loads attributed to winds and high-speed resonance. A modified hub ring was installed to reduce equivalent dynamic loads.

"The hub ring assembly has proven to be an excellent retrofit solution for sites with high dynamic loads. This solution has been tested on site and the design has been refined through testing in the laboratory and numerical simulations," said Muiyser.

Edwin Houberg, Sumitomo Drive Technologies/Hansen Industrial Transmissions, introduced the Hansen M4ACC gearbox for forced-draft and the Hansen M5CT for induced-draft applications.

The first features mono-block housing, no external piping, and an integrated drywell to reduce leakage risk. One option is a patented mobile brake system to slow down and stop the gear unit during maintenance activities.

The M5CT is a "new right-angle industrial gearbox series dedicated to induced-draft cooling technology," he explained. This features an extended bearing span with heavy-duty roller bearings for strong shaft support. Numerous instruments and accessories are available.

Jeff Ebert, Galebreaker, then discussed *Mitigation of extreme high*

seasonal winds. His example was a 353-MW gas-fired powerplant in Saskatchewan, Canada, commissioned at the end of 2019. Seasonal winds there can blow at 19 m/s, reducing plant performance.

Galebreaker was asked to determine the best windscreen configuration, height, and solidity to resolve the performance issues.

Ebert described the evaluations and installation that was completed in April 2023.

Various options were considered and material was delivered in October 2022. This was Galebreaker's first sloped-structure ACC project (Fig 11).

Various tubular products were added for structural support.

Hubregtse returned to discuss gearboxes for ACCs, listing these critical items to include in specifications:

- Fan shaft power.
- Power absorbed during worst conditions (during a storm, for example).
- Inverter installed, variable or direct.
- Service factor.
- Lubrication.
- Vibrations.
- Temperature range.

A standard service factor, usually between two and three, allows for vibrations, extreme conditions, startup power, and wear. This is also valid for gears, bearings, shafts, and housing.

He also covered thermal power (heat generated inside the gearbox), forces in gearbox, gearbox selection, lubrication, humidity in oil, vibrations, and deformations. CCJ

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Attending in-person meetings not possible? Go webinar!

If there was a positive outcome of the pandemic for power O&M professionals it might be the emergence of the webinar as an indispensable training tool. Power Users relied on the virtual medium to conduct the annual meetings of its various user groups for a year or two until Covid subsided. Its HRSG Forum (https://hrsgforum.com/) continues to present technical webinars periodically to keep its vibrant global membership informed.

Vendors also are increasing their use of webinars to help customers grow in their jobs and make better decisions. GE Vernova has done good job in this regard, the editors believe, with its Gas Power Resources library (access by scanning the GE QR1 code with your smartphone or tablet). It allows you to search by type of resource (articles, white papers, webinars, etc—each served by a single-click button on the site's home page), product of interest (gas turbine, steam turbine, generator, etc), topic (asset management, cybersecurity, outage planning, etc), and via a keyword search.

What follows are thumbnails of webinars presented by GE Gas Power engineers during October that may be of interest to CCJ readers. The editors listened to them online and then, to confirm facts, went to the website and found the recorded webinars quickly by clicking on "webinars" and "gas turbines" (or "steam turbines"). Couldn't be easier to get useful information. Take a test drive.

Managing your F-class rotor: Mitigating risk and enhancing value with Penny Leahy, F-rotor product line leader; Srinivas Ravi, principal rotor engineer; and Frederic Sbaffo, senior engineer—fleet management.

Learn about proper planning throughout your rotor's lifetime and what you can do to run your equipment to its highest potential. Plus, explore the benefits of preventive maintenance to avoid serious issues—such as corrosion.

Preparing for the unexpected: Outage planning for steam turbines with Matt Foreman, ST platform leader; and Mark Kowalczyk, global repairs leader.

Focuses on how GE Verona can help you plan and prepare for any scenario that might be encountered in the next three to five years. Learn what goes into putting together a solid plan for a successful outage, and why getting started sooner is always better than later.

Generator exchange-rotor program is designed to help users ensure routine maintenance doesn't extend outages beyond their planned durations. Chad Snyder, global segment leader for upgrades of generators, steam turbines, and HRSGs is the session leader.

He leads a discussion on how a generator rotor exchange could help you reduce risk and valuable time during both planned and forced outages. Also, how exchange rotors can be enhanced to accommodate your particular cyclic-duty plant operations to ensure capacity, availability, and reliability.

Outages: Lessons learned and continuous improvement reviews the unprecedented challenges experienced by GE Vernova and its customers during the pandemic and how the OEM and users collaborated for success.

Amir Hafzalla, president of FieldCore; Eric Gray, president of GE Gas Power Americas; and Mark Albenze, president of GE Gas Power Services, explain how remote technologies and innovative changes are supporting the OEM in its efforts to successfully deal with today's challenges. The executives then review the processes developed in partnership with users to enhance the outage experience. Finally, they present real-world examples of lean practices being implemented company-wide and the impact they have had on outage results.

The editors rated as most valuable to owner/operators GE Vernova's mid-October webinar, *Freeze protection considerations for gas turbine power plants* (GE QR2) operating in regions subjected to ambient temperatures as low as minus 50F. You might know a thing or two about freeze protection, but is that enough to keep your plant out of harm's way?

A panel of three consulting engineers from the company's product services group—Alston Scipio, PE, Will McEntaggart, and Ronald Wifling—review solutions you may have forgotten or never were aware of in the first place. The presentations/discussions were chaired by Tom Freeman, chief customer consultant, well known to owner/operators of GE frame engines.

Gas turbines and combined-cycle plants were the focal point of the 90-min webinar. Systems and equipment outside the plant fence/boundary were not part of the discussion. The session began with safety moment to get attendees thinking about such things as possible impacts of off-normal weather conditions, the importance of proper PPE, potential dangers of slippery ladders and steps, being aware of the consequences of icing conditions—such as stranded workers, falling ice, etc.

Stressors also were injected into the discussion—including how to deal with intermittent cold weather, ice rain/sleet, freezing fog, less than resilient grid connections, supply limitations for fuel and other fluids, long durations between cold snaps such that you drop your guard regarding freeze effects, etc.

Plant configuration (indoor/outdoor) and site location are important considerations for the analytical effort required. They influence ambient max/min temperatures, potential wind/snow/ice impacts of elevation, water availability, emissions limits, plant emergency plans, etc.

GE QR1

GE QR2

A significant portion of the webinar is dedicated to mechanical systems and their vulnerabilities. Discussion here covers air inlet systems, cooling-water considerations, power augmentation systems and their layup, hydraulic oil systems for steam and gas turbines, gas fuel system and pressure, and liquid fuel system—among others.

Next comes instrumentation considerations, both for exhaust systems and instrument air. Discussion continues with air-operated valves, then operability, with protection of the air-inlet system against icing called out along with assuring proper combustion.

A valuable adjunct to the discussion is the list of applicable O&M manuals (GEKs) and technical information letters (TILs) provided. Read them to advance in your job. Plus, there's a comprehensive winterization checklist to refer to so you don't forget anything. CCJ

Turn down to mitigate the effects of increased cycling

EthosEnergy Group presented two complementary webinars in early fall: "Turndown or shutdown?" (scan Ethos turndown QR) and "How to keep your aging GE gas turbine running longer" (see p 4 or scan Ethos rotor QR). Presenter and moderator for the first was Jeff Schleis, chief engineer, products and application. He was supported by Principal Engineer Chris Chandler, an expert in turbine optimization and engineered solutions for gas turbines.

Schleis noted at the outset that for a significant number of gas-turbine owners and operators today, "the unspoken question is 'turndown or shutdown'?" Greater investment in, and prioritization of, renewables generation is reducing the capacity factors of gas-fired assets because of increased cycling operation. Result is many plants are examining the benefits of extended turndown and wondering if it can improve the bottom line.

Most likely, it was said, a bottom-line improvement will be experienced where the share of renewables in electric production exceeds 40%. According to data from S&P Global Market Intelligence, 13 states are poised to exceed the 40% threshold in 2023.

Schleis cautioned that knowing the financial impact of cycling versus the net loss to generate at off-peak times is not easy to evaluate accurately. Fewer starts, lower fuel costs, and ultimately extending the time between outages all factor into the return on investment. Enabling turndown beyond the unit's current capability can tip the economic scales and reduce the negative impact of cycling.

The moderator identified the following steps on the path to extended-turndown profit: 1, understand turndown limits; 2, conduct testing; 3, consider modifications; 4, validate financial analysis; 5, install an integrated solution. If the stars align, you will improve the bottom line.

To get a better feel for what attendees were experiencing, Schleis asked a couple of questions:

First concerned current operations. The takeaways included:

- Cycling more, 72%.
- Cycling less, 4%.
- Operating at different times of the day, 31%.
- Running less, 18%.

Answers to the second question revealed where attendees were on the path to extended turndown:

- Actively operating in an extended-turndown mode, 17%.
- Creating a formal business case, 9%.
- Testing turndown limits, 15%.
- Researching solutions, 31%.
- Operating profile does not benefit from extended turndown at this time, 25%.

Ethos turndown

Ethos rotor

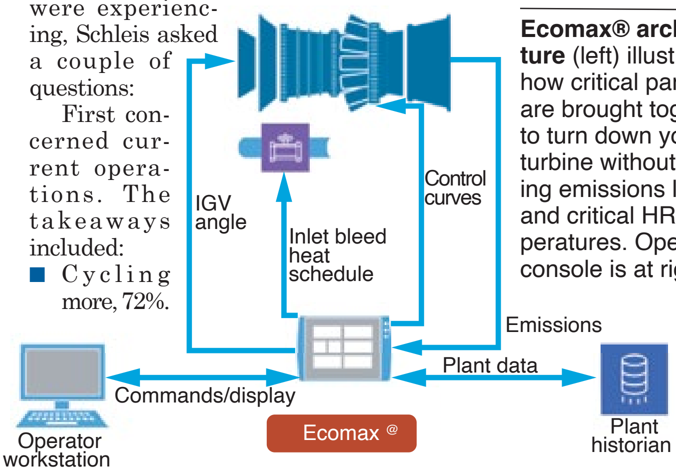
Benefits of turndown discussed included the following:

1. The switch from starts-based to hours-based maintenance provides a greater opportunity for parts (and rotor) life extensions. Plus, it decreases the severity of parts repairs.
2. Decrease in midday losses attributed to renewables generation because you continue to run when large amounts of solar/wind kilowatt-hours drive down prices.
3. Cogeneration plants may satisfy their contractual requirements at reduced load. When steam production is more profitable than power, turn down the unit to maximize thermal energy with minimum power generation. Another strategy: Run redundant units for reliable steam production at minimum power generation.

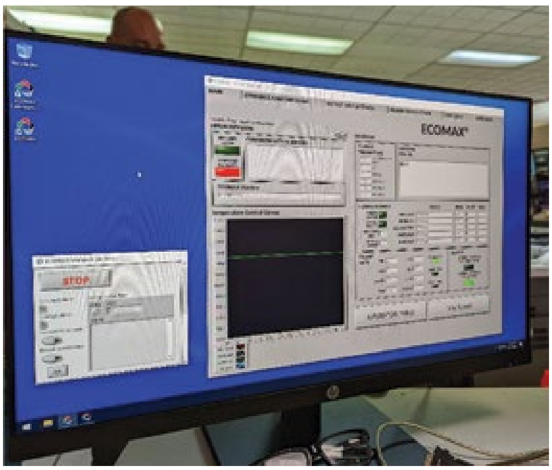
Ecomax®, an EthosEnergy solution, is discussed as a critical tool for maximizing turndown. As the diagram shows, its automatic tuning feature manipulates control curves and IGVs to keep your GT within emissions limits. Plus, automatic tuning of GT control curves reduces the isotherm. Getting down to 50% of the baseload rating, or lower, might also mean reducing air flow through the machine. Addition of inlet bleed heat and automatic adjustment of the IGV angle can contribute here.

One of the case studies presented illustrates how EthosEnergy achieves its operational goals. A cogeneration plant with three GE Frame 6B engines served as the example. Key points:

- Premix minimum load decreased from 70% to 50%.
- Testing proved turndown to 30% possible before CO limits are exceeded.
- NO_x emissions are maintained below 25 ppm.
- Exhaust gas temperature is limited to 1022F (max isotherm of 1085F) to maintain 950F in HRSG piping, by design.
- Process steam production was maximized with minimum generation and no duct firing. CCJ



Ecomax® architecture (left) illustrates how critical parameters are brought together to turn down your gas turbine without exceeding emissions limits and critical HRSG temperatures. Operator console is at right



CUTSFORTH

Fall 2023 webinars

■ Real-world case studies
■ Wireless monitoring solutions

Cutsforth Inc's first webinar in fall 2023 focused on electromagnetic interference monitoring (EMI), a valuable diagnostic tool for detecting impending problems with generators, motors, isophase bus, bearings, and other plant equipment. Primary presenter and discussion leader was Kent Smith, well respected in the electric power industry for his deep knowledge of EMI, honed by years of service as the lead generator expert for one of the world's largest utilities and as the chairman of the Generator Users Group, one of the planets in the Power Users universe (p 29).

Plant personnel not able to participate in the webinar when it aired can access a recording by scanning the QR code with their smartphone or tablet. The editors believe you will benefit professionally from Smith's case studies which illustrate findings by way of data scans. Smith, who was supported by Cutsforth's Steve Tanner, VP business development, shared several case histories, including these:

Generator monitoring with EMI. Water was affecting the calibration of hydrogen analyzers. A cooler leak was found and the unit repaired. Generator reached end of life without a winding replacement.

Motor monitoring with EMI. Plant's six pump motors had started multiple times without cooldown between starts; the possibility of damage to the induction-motor rotor bars was a concern. EMI and motor-current signature analyses were performed. One motor registered higher EMI values than the others. It was found to have a salt-encrusted winding and some cooling passages plugged with salt. Cleaning was the fix.

Excitation power rectifier. Data revealed significant arcing and discharge in the lower frequency band and suggested a loose connection in the excitation system. Connections checked when the unit was in a "not-in-demand" (NID) state were found loose and tightened. EMI data returned to normal after exiting the NID state.

Wet stator bars and loose wedges. Generator was going into a rotor-out outage. Retaining-ring and stator-wedge replacements were scheduled, plus a hydraulic integrity test (HIT). Replacements were made with no issues.

However, when performing the HIT skid test, plant personnel couldn't pull the required vacuum on the unit. Capacitance mapping and helium leak testing was performed. The findings: four significant clip leaks, minor plumbing leaks, wet bar found on the "B" phase. Corrective action: Leaks were repaired, bar dried out, and the unit HiPot-tested to an operational level. The generator was returned to service with a rewind planned for the following year.

Bearing electrolysis. EMI trending located a loose ground lead.

Isophase-bus flex link. One unit had been monitored for years because of its high EMI readings. The brushing box was suspected because of the frequency content, time-domain waveform, and sniffer readings. Overheated flex links and moisture intrusion found by transformers was repaired, but improved EMI improved only slightly. During the next outage, flex links under the generator were removed and inspected. The results of that investigation were not available at the time of the webinar.

Water pumping stations. Electromagnetic signature data were collected and analyzed for two pumping stations, each having nine synchronous-motor-driven pumps. The motors were equipped with rotating pilot exciters and rotating main-exciter-to-feed-motor main fields.

The worst-case motor at one pumping station was found with pilot-exciter brush rigging and commutator arcing. It was experiencing alignment/rotor wobble and had loose connections at the bus connector and/or insulator.

The worst-case motor at the second pumping state had similar issue characteristics, plus loose windings in the slot causing slot discharge.

Bearing electrolysis. A generator was removed from service with high vibration on the No. 1 turbine bearing attributed to electrolysis, which caused pitting and melting of the babbitt material. An enhanced shaft grounding system, with a sensing point for voltage, was installed. Plus, a ground current monitor was installed for the turbine. Instrumentation was connected to the main server to access the EMSA data.

Engineers believed there were the following three possible sources of the high voltage:

- Static voltage build-up because of a brush rider in the turbine blading.
- A magnetic driving force from turbine-shaft magnetism.
- Static exciter thyristor firing voltage transition.

Turbine bearing data are presented both graphically and in tabular form.

The unit was removed from service several times because of high vibration, with bearing electrolysis believed to be the cause. The bearing was replaced and clearances validated. Vibration analysis suggested electrolysis was still occurring. The fix was installation of a high-frequency blocking filter on the exciter field circuit. That eliminated the high vibrations and electrolysis.

Wireless monitoring solutions

Chuck Requet, principal applications engineer, and Steve McAlonan, director of business development, began their presentation by explaining the value proposition of the company's InsightCM™ architecture, which can accommodate multiple measurement technologies in a single platform.

Vibration monitoring was a focal point of the presentation. InsightCM was said to support industry-standard viewers for vibration—including trend, waveform, spectrum, waterfall, orbit, polar, bode, shaft centerline, full spectrum, envelope (amplitude demodulation), order (even angle), time synchronous average, and autocorrection.

Wireless is particularly advantageous for monitoring the many common assets—such as pumps, fans, compressors, etc—that would benefit from more attention. Also, when assets are not deemed critical enough to warrant 24/7 screening, or may be located in remote, difficult, or hazardous locations. InsightCM supports two wireless families, NI and Erbessd, which, in turn, support Bluetooth 5.

An example illustrating the value of wireless was for a large user with 35,000 sensors. This project was said to have three-year breakeven cost for hardwired vibration of $80-million. Wireless reduced the install cost by 70% and the planned major design effort was shifted to "minor modification." The breakeven went from three years to 18 months. CCJ

Clean boiler tubes save fuel, improve plant's bottom line

The headline should not surprise any reader of the COMBINED CYCLE Journal. It's a "given." The challenge is how to maximize the saving at the least cost.

Until relatively recently, the widely preferred method for cleaning tubes in heat-recovery steam generators serving cogeneration and combined-cycle plants was dry-ice blasting. It effectively dislodges iron oxides, ammonia salts, and other foulants which drop to the floor and are shoveled into barrels for removal offsite. However, dry ice only reaches what it can "see." Plus, the longer it sits at the plant awaiting use, the less effective it is.

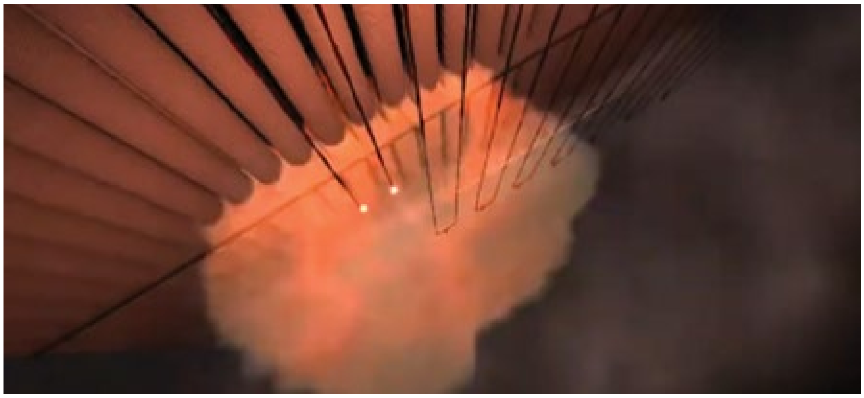
Today, there's a promising new option to consider—KinetiClean™. It's getting positive reviews from owner/operators and industry experts, such as EPRI (results are available through the research organization's HRSG program for members). The name derives from a patented shock-wave technique now owned by Groome Industrial Service Group, one of the pioneers in dry-ice blasting.

KinetiClean is a three-step process. First, shock waves created by a det-cord curtain (Fig 1) dislodges deposits from the HRSG's tubes, then compressed air removes any loosened deposits that remain (Fig 2), and the floor is vacuumed clean.

Of importance is that detonation (a/k/a det) cord is a flexible linear explosive having a core of PETN (chemical name: pentaerythritol tetranitrate) encased in a textile outer jacket—it is *not* dynamite. Also, that the explosive does not come in direct contact with any plant equipment.

Regarding the safety aspects of PETN, keep in mind that it is installed and detonated by a team of well-trained licensed professionals. That it is "safe," consider that KinetiClean has maintained an enviable EMR rating of 0.81 for the last couple of years. The Experience Modification Rating is a calculation used by insurance firms to determine workers' compensation premiums. A rating less than 1.0 generally is considered good, or relatively safe.

QR1



1. A continuous length of detonating cord is hung among tube bundles from the top of the HRSG via sky-climber ports

2. High-pressure air is delivered to track-mounted nozzles via the automated distribution system which traverses the tube bundles side to side and top to bottom. Loose debris falls to the floor and is vacuumed up

Access a short video explaining the KinetiClean process by scanning QR1 with your smartphone or tablet. More detail—including actual footage of tube cleaning—is presented in the recorded webinar, "HRSG tube cleaning technology." Scan QR2.

QR2

The major advantage KinetiClean has over dry ice, based on Groome's research and experience, is that it recovers about 75% of the backpressure lost to the deposits; dry ice typically recovers 30% to 50%.

Two case histories summarized in the webinar offer some insight to the results possible by implementing KinetiClean. The first concerned a 7EA-powered cogen unit that had not been cleaned in its 20-plus years of service. It had been derated to operate at 75% of its baseload rating and was in jeopardy of not meeting its contractual requirements.

The facility was able to return to baseload operation following eight 12-hr shifts of cleaning activity. Other results: 6 MW was recovered, stack temperature reduced by 12 deg F.

Case-history 2 compared the results of cleaning with dry ice and KinetiClean. Experience with dry-ice blasting of the HRSG behind an SGT6-5000F gas turbine indicated a pressure drop of 2-in. H_2O was to be expected. Six 12-hr shifts with KinetiClean reduced backpressure by 3.6 in.

The Groome team said a pressure drop of 3 in. offers an extremely good ROI. In this case the estimated annual fuel saving was $315,000, the estimated annual energy saving was $185,000.

To determine how much you might save by using KinetiClean, a calculator is incorporated into the YouTube video (QR2).

EMISSIONS CONTROL

The importance of perforated-plate design in simple-cycle SCR systems

By Vaughn Watson, Vector Systems Inc

The performance of an SCR system depends on the robustness and efficiency of the sum of its parts. The flow-distribution devices placed into the exhaust stream are no exception. Each of the critical parts of the system must be designed and built to effectively provide the proper distribution and mixing for the catalyst to perform the required reaction with minimal bypass and carryover.

The catalyst tends to get all the credit for singlehandedly achieving emissions goals, and *all* the blame when there are performance issues. But the SCR is a system that has several key components.

Every manufacturer sizes the required volume of catalyst to achieve the performance based on parameters such as exhaust flow and emissions-reduction efficiency. To achieve this, the catalyst needs a required set of parameters—typically velocity profile (nominally ±15%), temperature profile (nominally ±25 deg F), and NH_3:NO_x maldistribution (<10% RMS).

In a simple-cycle gas-turbine application, the exhaust flow to the SCR system poses a particular set of design considerations for the unit to operate effectively. Consider that designers are dealing with a turbulent high-temperature exhaust stream—one resembling a tornado—that must be cooled to the proper temperature, distributed uniformly across the cross-sectional area of the catalyst bed, and mixed effectively with ammonia for the catalyst bed to achieve the required NO_x reduction efficiently.

Most simple-cycle applications involve the introduction of a significant amount of ambient air to cool the turbine exhaust gas down to a temperature that the catalyst can safely handle based on its formulation.

The cooling air must be mixed with the turbulent exhaust gas to achieve the desired temperature. The cooled exhaust stream then must be straightened and spread out so the velocity and temperature requirements of the SCR catalyst are met across the catalyst bed. Depending on exhaust-duct cross-section, this can create a geometrical challenge for gas flow traveling to the catalyst.

The common practice is to use a perforated plate as a flow-straightening device. Perf-plate design is essential to proper exhaust-gas distribution. The perf plate has a pattern of holes across the exhaust cross section to force the gas to flow through an open-area pattern, also known as hole porosity. This creates about 1 in. H_2O backpressure to mix the flows from the gas turbine and the cooling-air system, and to straighten the combined flow through the hole pattern of the perforated plate.

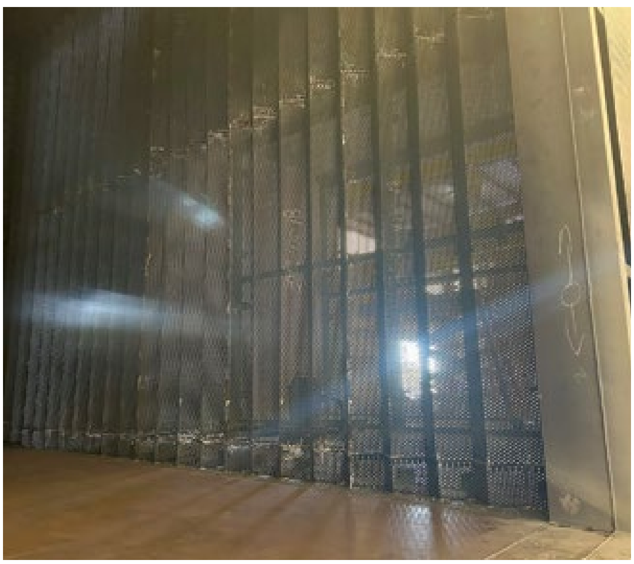
Simple-cycle exhaust ducts that have steep approach angles to the catalyst bed often require a more sophisticated perforated plate design—one that features variable open-area sections to push turbulent exhaust flow upwards toward the ceiling and corners of the exhaust duct.

The perforated plate lives in a very torturous environment because of the high velocities, high temperature gradients, and backpressure putting mechanical and thermal stresses on the flow-straightening device and its frame. Thus, careful design, robust framework, and heavy-gauge plate are required (Fig 1). Care must be taken to manage thermal growth without binding.

Strength is important. This is why corrugated bent perf panels often are used to add rigidity to the perf-plate sheets—to stiffen them (Fig 2). Light-gauge plates and floating angle supports are not up to the task of restraining anywhere from 1 million to 5 million lb/hr of exhaust flow.

If your SCR system is not meeting expectations, consider engaging a consultant with years of relevant design and problem-solving experience to review your situation and develop a plan to improve its performance. CCJ

1. Careful design, robust framework, and heavy-gauge plate are required to prevent mechanical damage caused by the demanding environment downstream of the gas turbine



2. Corrugated bent perf panels add the rigidity necessary for the flow-distribution device to do its job