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Number 68 2021

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COMBINED CYCLE Journal

User Group Conference Schedule, First Quarter 2022

Virtual Conference and Powerplant Training
February 7 – 11 and 14 – 18
Contact: ashley@aogusers.com

Annual Meeting and Vendor Fair
February 20 – 24, New Orleans, La
Contact: tammy@somp.co

Annual Meeting and Vendor Fair
February 21 – 25, New Orleans, La
Contact: tammy@somp.co

2022 Virtual Conference
Follow www.wtui.com for schedule
Contact: wkawamoto@wtui.com

User Group Reports

Combined Cycle Users Group.....6

- Presentations/discussions address safety regarding chemical handling, lighting, plant access, fall risks (p 6); cooling-water algae control using ultrasonic energy, radio-frequency waves, sun shades (p 8); fluid-handling issues involving pumps, valves, piping, ductwork, filters (p 12); performance improvements possible from generator fast purge, reducing condenser losses, operating along a variable load path, faster starts (p 14).
- Siemens Day highlights (p 18).
- GE Day highlights (p 22).

Alstom Owners Users Group 39

- End-user session provides details on GT11N inspection and maintenance (p 40).
- OEM session focuses on generator maintenance and recommendations, including Technical Information Letters of importance (p 41).
- Vendor presentations: AGT Services Inc, Arnold Group, Camfil, Doosan Turbomachinery Services, Emerson, EPRI, Global Consulting & Mechanical Services, Hughes Technical Services, Liburdi Turbine Services, Major Tool & Machine, MD&A, National Electric Coil, Noxco, Pioneer Motor Bearing, PSM, Power Services Group, Rochem, TRS Services (p 42).
- Training workshops (p 53).

Middle East/North Africa Users 70

- HRSG mods, performance enhancements, steam-turbine warming, GT repairs, air filters are among the presentation/discussion topics covered during the virtual meeting.
- Getting more performance from your old machine (p 72).
- GE Day highlights (p 74).

Best Practices Awards

Eight plants earn Best of the Best honors in CCJ's 2021 program ...84

- Effingham County Power (p 86) shares experiences with/solutions for flashover events caused by HV insulator failures, transition to metal-seated ball valves for HRSG drain service.
- Green Country Energy (p 90) improves both the process and safety of HRSG pressure-wave cleaning, eliminates compressor fouling caused by inlet-filter seal bypass, offers suggestions on managing outages during a pandemic.
- CPV Towantic Energy Center (p 94) offers technology-driven safety solutions to reduce emergency response times, suggests DCS improvements to strengthen alerting and analytical capabilities based on its experience.

Miscellany

Clyde Maughan and the Generator Community..... 3

Performance is key on the path to net-zero. 32

Professional services..... 97

Features

Challenges to SCR performance and NO_x compliance just keep growing 28

Repairs to gas baffles between tube panels restore SCR performance 34

Boost performance with an upgraded insulation system 36

NEW! Ask the Chairman 55
What is an acceptable amount of sagging/deflection for superheater tubes?

KneticClean presents new option for HRSG tube cleaning 56

HRSG Forum.....59
Water chemistry, acoustic monitoring, level gages, attemperators, and more.

Webinar roundup, 3Q/2021..... 64
Upgrades to support aging turbine fleets, ACC cleaning and leak detection, extended turndown, simplifying turbine outages, EMSA helps make better maintenance decisions.

'Interesting' breaker events dictate stronger maintenance practices..... 76

Proper HRSG inspection guards against a forced outage..... 78

Turbine tip 15: Secondary ignition in gas-turbine exhaust..... 80

Learn from one utility's arc-flash safety program..... 83

Get more from renewables with seasonal, central H_2 assets..... 98

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The Generator Community

Editor's note: Clyde Maughan has shared unselfishly his extensive technical knowledge and respect for generators with the global electric power industry for more than seven decades—roughly half that time as a GE engineer, half in private practice. So, it came as no surprise that the 95-year-old recent retiree would call and ask the editors to remind generator engineers of the many resources available to them today for learning and problem-solving—tools that weren't even contemplated when he entered the workforce in 1950.

Not leaving anything to chance, he jotted down a few thoughts which are captured in the passage below. Jane Hutt, the muscle behind the respected online forum, International Generator Technical Community, for which The Clyde serves as a discussion leader, contributed to the dialog.

In the last dozen years, several important tools have been made available to assist engineers and technicians on generators. At the top of the list is the International Generator Technical Community (IGTC, www.GeneratorTechnicalForum.org), an online forum, brought into existence by National Electric Coil under the guidance of Jane Hutt, which draws on extensive technical input from the industry's renowned generator experts.

Goal of the project was to form a vibrant Internet-based community that would provide a convenient way to tap into the pool of generator experts for assistance with problems being experienced, no matter where in the world the plant was located. The IGTC has more than 5000 members in over a hundred countries today. There is no membership fee.

Having followed the group's online discussions closely over the years, Maughan noted that he had never seen a response that he felt was "wrong," nor rarely one that seemed argumentative.

Given its rapid acceptance, the IGTC soon went beyond its powerful discussion benefit to add the Resource Center, a vast library with hundreds of technical papers, an e-book on generator maintenance, and other helpful information—all downloadable at no cost.

The IGTC again innovated by adding a Round Table Discussion. Here's how it works: A premise is stated (a topic of particular interest to generator users) and comments are provided by members with experience relating to that premise.

With the IGTC bringing together an identifiable, online community of generator engineers and specialists, other needs were identified. Once coalesced as a technical community, many members expressed interest in coming together for face-to-face exchanges of generator information and ideas.

That motivated Maughan to lobby for the formation of a Generator Users Group—like those in existence to serve gas and steam turbine owner/operators. The GUG was launched in 2015, with help from CCJ and NV Energy, to share experiences, best practices, and lessons learned on generator design, installation, operation, maintenance, and overhaul. Conferences have been held annually since. Today the group operates under the Power Users umbrella (www.powerusers.org; see pages 25 and 87); Hutt is a member of the steering committee.

Maughan has not stopped working/thinking/doing for others in his entire life, having learned as an Idaho farm boy that taking a break generally is not good use of one's time. A case in point is the 10-hr online training program, "Generator Monitoring, Inspection, and Maintenance," that he compiled from notes taken over the decades. It is available on-demand and at no cost at www.ccj-online.com/onscreen.

Two years ago, he developed the Generator Expert Skill Register to help powerplant owner/operators find experts with the particular skill sets required for a given assignment. Aware that the pool of generator experts was becoming increasingly shallow, Maughan believed the online register, hosted by CCJ, would benefit the industry. This service is vintage Maughan: No cost. A generator expert can join the register at https://www.ccj-online.com/generator-expert-skill-register; users can search for expert help at https://www.ccj-online.com/generator-experts.

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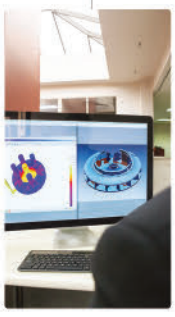

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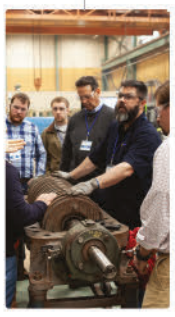

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COMBINED CYCLE USERS GROUP

The 10th annual conference of the Combined Cycle Users Group was conducted online over a four-week period in July and August of 2021. This was the group's second consecutive virtual meeting after eight years of in-person events. It was highly successful with more than 400 participants. The 2022 Conference is scheduled for August 29 through September 1 at the San Antonio Marriott Rivercenter in Texas.

Plan is to co-locate the CCUG meeting with the Steam Turbine, Generator, and Power Plant Controls Users Groups annual conferences as was done before the pandemic. All of these organizations operate under the Power Users umbrella, enabling some joint functions, including meals and vendor fair. Follow www.powerusers.org for details and registration.

CCJ's coverage of CCUG 2021, one of the electric-power industry's most important meetings, includes this report with its summaries of both GE Day (July 20) and Siemens Day (July 28), notes on cooling-water algae control, plant experiences discussed at the safety session, plus summaries of presentations by both users and equipment/services providers focused on performance-improvement and fluid-handling challenges.

In addition, there are individual articles, developed from presentations and discussions of importance, throughout the issue. The CCUG logo identifies them at a glance. The topics: A new option for HRSG tube cleaning from KineticClean—a Groome company; circuit-breaker maintenance; confined-space best practices; the $400 relay that failed, initiating a catastrophic steam-turbine event; arc-flash safety; cold-weather preparations; and the importance of keeping a close eye on welding contractors.

Vendors participating in the meeting with special technical presentations, in addition to OEMs GE and Siemens, included Lectrodryer, Suez, EthosEnergy Group, Hydro, MD&A, Groome Industrial Service Group, HRST, Intek, Industrial Air Flow Dynamics. EPRI also was on the program.

Important to owner/operators who want to go beyond the coverage in this issue is that non-OEM presentations and discussions are only a couple of clicks away on the Power Users website (www.powerusers.org). However, you must be registered to gain access; registration is a simple, complimentary process. The GE presentations are available to customers on its MyDashboard website at https://mydashboard.gepower.com. Siemens Energy presentations can be accessed by approved users via the company's Customer Extranet Portal at https://siemens.force.com/cep.

Safety

Safety is a perennial favorite topic at Combined Cycle Users Group annual meetings for obvious reasons and at least one non-obvious one: With declining staff at sites, each person is responsible for more, and more-varied, tasks. Chances for human error grow. While the safety issues addressed here are very site-specific, the take-away should more be a gentle reminder about anything similar at your plant.

Chemical handling. Marih Salvat, operations manager, Tenaska Virginia Generating Station (and member of the CCUG Steering Committee), said they "overhauled chemical handling and safety" to avoid wearing full PPE (personnel protection equipment) when not necessary. Because low- and high-risk chemicals often were handled near each other, policy was to default to the most restrictive PPE for containment areas. Now, the plant separates high-risk areas from nearby low-risk areas using plexiglass curtains and safety shields (Fig 1).

1. Amine skid is separated from phosphates handling area so PPE appropriate to each area can be used (left); safety curtains are installed around acid, caustic, and bleach handling to protect work conducted adjacent to this area (right)

2. Railing near access ladder to HRSG south LP drum, LP economizer vent isolations, stack-balloon door, and other critical equipment was upgraded

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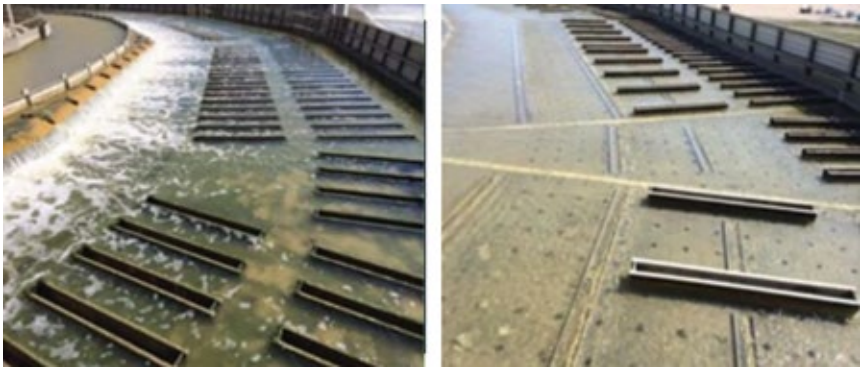
3. "Non-cash-crop" harvest, 4000 lb and costing $3500 every two to three days for crane removal, was mostly eliminated from River Road's cooling water system with a combination of ultrasonic energy, radio frequency waves, and sun shades



4. Engineered carboxylate oxide filming treatment can substantially mitigate algae growth, as shown in this comparison of a clarifier under phosphate treatment (left) and under E.C.O. treatment (right)—a so-called non-P program

Access, lighting, fall risks. Robert Mash, plant manager, River Road Generating Plant, (also a steering committee member), opened with a tale of an intruder (non-malicious, apparently) who breached the perimeter fence and entered the unsecured transformer yard fencing, which prompted several upgrades for access and control—including electronic card-reader access (tied into the existing access control system), and installation of tamper-resistant emergency-exit crash bars to manway gate doors on the east and west side of the yard.

Previously, the transformer yard, location of the generator breaker and step-up transformers, generator excitation and LCI systems, and other critical plant equipment, was thought secure because it was inside the perimeter fence. The yard is accessed at least four times a day for routine equipment checks.

In response to an audience question, Mash said there was nothing wrong with the fencing, but they did add security cameras as well.

Then Mash identified with photos several potential fall hazards and remedies around the HRSG, including insufficient handrail/guardrails in areas where critical work is performed. This was followed by a review of lighting-system additions in areas like the gas yard, behind the cooling tower, and turbine transition to the HRSG. All existing lights were replaced with LEDs in 2017; the assessment of additional lighting needs followed.

Readers are urged to review the presentation at www.powerusers.org for before-and-after lighting and railing photos, only one of which is shown here (Fig 2).

During the Q&A period, attendees and presenters discussed upgrading intercom systems. One plant rep said they were currently reviewing the existing system. Another mentioned that some folks have a hard time hearing the lightning alerts. A third reported that all people on their site were required to have radios, with "extenders" installed to cover the entire plant. At the "all-hands" monthly meetings, personnel are re-familiarized with the sounds and what they signify.

Finally, a user mentioned the value of a "lone worker" or "man down" device for sites with minimal staffing. Testing at his plant proved it "works well." A best practice from Orlando Cogen offers another positive assessment (CCJ No. 55, 2017, p 22).

Cooling-water algae control

A combination of ultrasonic energy, AM radio-frequency waves, and sun shades managed to tame severe algae growth in the cooling tower at River Road Generating Station, according to Operations Manager Justin Hartsoch, GE Gas Power O&M. He told CCUG participants that algae blooms became a problem after the plant was compelled to shift from chloride to a bromine-based treatment to meet EPA NPDES regulations.

In a moment of levity, Hartsoch called the collected algae a "non-cash crop" (Fig 3), but also noted that the plant's "unique algae bloom is seasonal." Well water is the source for the plant.

The biocide formula that was being used also fed on silica, creating resistant algae which would coat the forebay trash screens, and require cleaning every two to three days. So, the plant undertook a campaign to identify a non-chemical approach to algae control. The solution to date ("the story is not over," Hartsoch said) has proved to be the following:

- Adding floating-head ultrasonic transducers at key locations throughout the cooling-tower basin.
- Installing nursery sun shades on three faces of the tower to deprive algae of the sunlight necessary for growth.
- Installing radio-frequency devices on each of the circulating- and service-water lines.

Details of this unique cooling water treatment approach, the theory of design, the circumstances which led to it, and the subsequent results and benefits were reported last year in CCJ No. 64, p 53. In the CCUG presentation, Hartsoch did note that the payback was a year and a half.

E.C.O. filming technology. Another "cash crop" tale emerged a few presentations later. Greg Boileau, Suez SA, described a new proprietary, non-phosphate, circulating-water treatment based on E.C.O., an "engineered carboxylate oxide" filming technology (Fig 4). Phosphates are being phased out because of deposition challenges and formation of algae in receiving waters. Boileau said that one pound of phosphate can lead to 500 lb (wet) of algae.

Boileau reviewed the key drivers for reducing phosphates, sources of phosphates in the plant water balance, and several case studies. Much of the return on investment comes from avoiding the capital cost of a phosphorus removal system.

Other Suez information online suggests the proprietary technology reduced phosphates by up to 80% in the pilot study at a large gas-fired plant while maintaining acceptable mild-steel corrosion rates.

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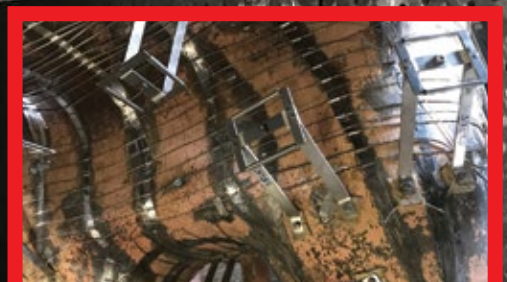

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Fluid handling

The gas turbine/generator, steam turbine/generator, and HRSG get the lion's share of attention at most user-group meetings, but one hallmark of the Combined Cycle Users Group is a focus on the connecting fluid handling equipment—pumps, valves, piping, ducting, and filters—covered in the presentations summarized below.

New challenges for filters. Headlines on the weather of course impact plant operations. Smoke and ash are plaguing facilities in the Northwest, severe weather challenges combined-cycle plants everywhere. A highly experienced plant manager, and member of the CCUG's steering committee, led a roundtable discussion on how all this impacts filters.

Wildfire smoke particles are "really, really small" (comparable to bacterium and coronavirus particles and two orders of magnitude smaller than a grain of salt) and can pass through pre-filters and "quickly overwhelm" the filter media protecting the gas turbine. Plus, peaking units with tempering air run the risk of putting smoke particles directly into the SCR and fouling catalyst.

Planned maintenance for air inlet filters is a no-brainer, but there are materials shortages and delivery issues these days. The speaker reminded the audience that filters must be stored properly, with attention to maximum temperature for seals; auxiliary equipment like puffers should be included in PM programs.

Consider as well upgrading your pre-filters to a Minimum Efficiency Reporting Value (MERV) of 11 - 12 to trap some smoke particles and protect the final filter. One attendee recommended adding a transmitter to the DCS to monitor filter performance.

In severe cold, driving snow impacts filters, and causes ice buildup and freezing, regardless of protective hood size and configuration. Freezing of fog particles or cooling-water drift can impair filter performance in short order. It's important to think through blockage scenarios before they occur and plan for heating panels or changes to the dispatch plan and reduced-load operation.

Boiler-feed-pump reliability. Segmental ring designs are lower first cost than barrel pumps but are less robust, said Robby Byron, Hydro Inc. They exhibit significantly less mass and therefore lower stiffness and damping, and are more susceptible to external factors (pipe strain, soft foot, tie rod's torque value, and sequence) and hydraulic instability when operating off the best-efficiency point.

5. Individual TrimKit suitcases, supplied by Millennium Power Services, contain all the parts necessary for the repair of specific valves (left); multiple kits arrive onsite by pallet for outage work (right)

Byron then detailed a case study of how a segmental ring pump exhibiting repeated catastrophic failures (that is, shaft breakage) was analyzed for root causes, then modified with engineered solutions.

One impressive result, among others: Reducing the last-stage casing gap from 0.007 to 0.008 in. to 0.001 to 0.002 in. improved pressure-carrying capacity from 2500 to 4000 psig.

Pump testing as PM tactic. A second presentation by Hydro Inc, this delivered by Ares Panagoulias, argued for certified performance testing and vibration/condition monitoring for pumps as part of a preventive-maintenance (PM) strategy, especially for plants at which "original design may not be how the plant operates today." Difference in performance at low flow or maximum flow conditions are considerable, he said, plus impellers may have been modified, or other factors are likely affecting performance and reliability.

Hydro Inc tests the full train, motor and pump, while simulating real-world conditions. In fact, Panagoulias stated that his company was the first to be certified by the Hydraulic Institute for a full range of pump designs, and helped create the audit and inspection standards.

Panagoulias showed several slides on how pump testing relates to reliability and performance and can help assess impact of process demands on pump condition. He offered a case study of a "between bearings" pump suffering repeated failures. The proposed engineering solution was verified through performance and vibration testing, which also was used to set a baseline in a controlled environment for trending and subsequently understanding system influences.

Steam isolation valves. If you've ever said, or heard someone say, "flapper-type valves do not have to 'blue' 100%," Jason Wheeler and Dean Casey, Mechanical Dynamics & Analysis (MD&A), beg to differ. More likely, the valves just haven't ever been *properly* repaired so users accept a new normal.

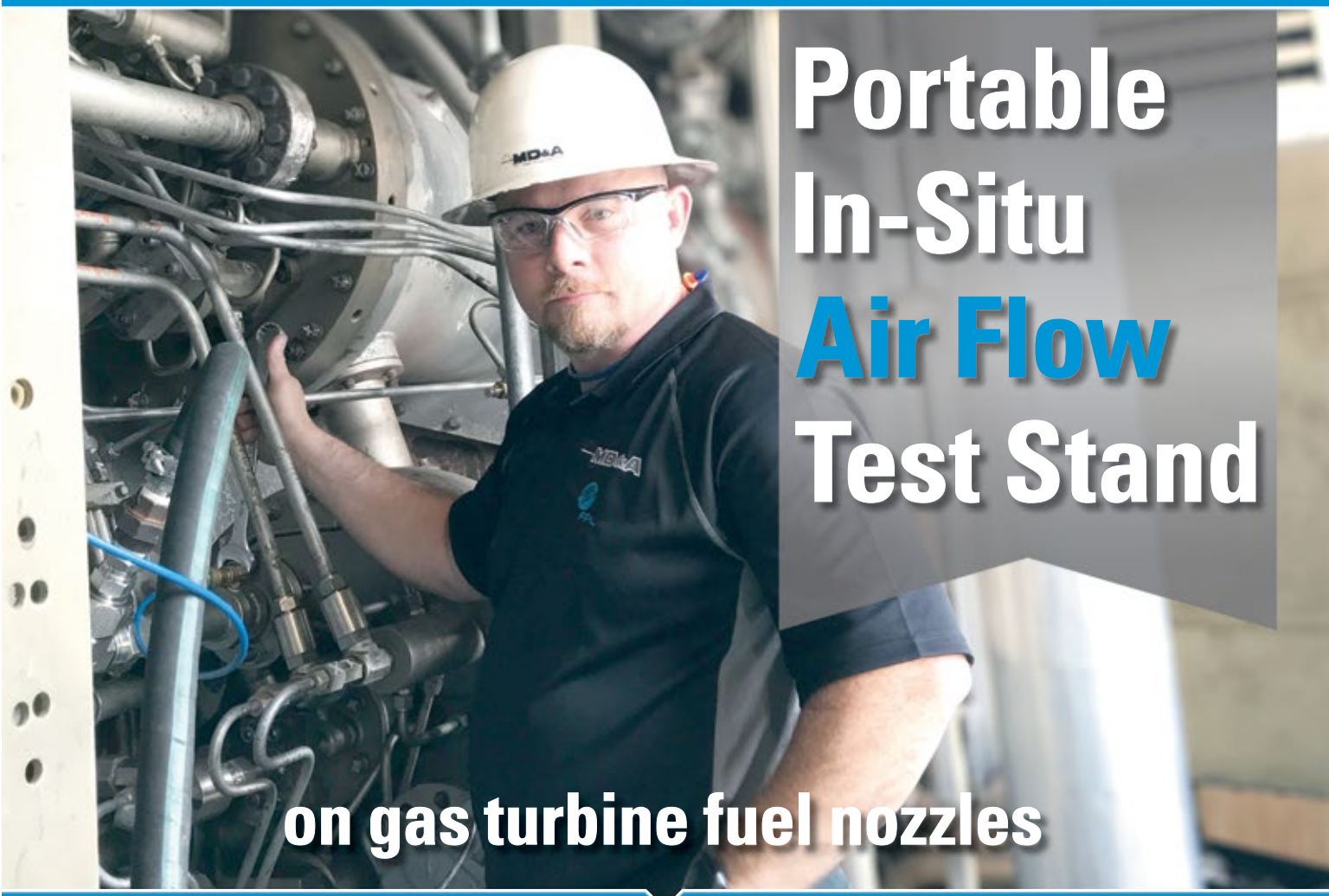
6. Liner plates may need to be improved/upgraded by increasing the quantity of retention studs, compartmentalizing insulation on round ductwork, ensuring uniformity for even distribution of heat, and over-insulating cavity spaces

Generally, check/non-return/flapper-type valves, or valves which allow flow in only one direction, are difficult to service because they operate with two centerlines which must be maintained during servicing and require special tooling that many repair shops do not keep on-hand. In addition, these valves show lots of indications from cycling service.

MD&A's experience with these valves is additionally captured in these bullet points:

- Because these valves are difficult to overhaul, normally just the disc and flapper-arm assemblies are removed and sent to the shop for inspection.
- Some valve shafts are prone to bending.
- The integral valve seats can distort through years of cycling.
- Most companies are "thrilled" to get 80% blue contact at the seat during reassembly.

Wheeler and Casey then proceeded through an inspection and repair case study for a Westinghouse reheat flapper type valve, which can be of an articulated or rigid disc design, with



Read this case study at www.MDAturbines.com/Flow

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photos illustrating each step in the process onsite and in the shop.

Valve maintenance program. To eliminate a costly reactive maintenance posture, a 3 × 1 501G-powered combined cycle partnered with Millennium Power Services, to track valve performance and health and prioritize maintenance. The service provider follows all industry valve repair standards, keeps the plant informed at all times, transmits photos of damage, and issues reports within 30 days of an outage.

Among the program features discussed by the plant's O&M manager is Millennium's TrimKit program (Fig 5), which reduces costs and labor by having all new parts for specific valves arrive in one "suitcase." This allows all parties to keep better control over inventory.

In response to an audience question, the speaker said the scope includes all severe-service valves, "really everything repaired during each outage," except for the steam turbine valves, which are serviced by the turbine OEM. However, TrimKits are not necessarily available for every valve, he added.

Covered steam piping. Madeleine Fink, HRST Inc, reviewed ASME standard B31.1, "Covered Piping Systems," which includes specific creep-regime requirements. She focused much of her talk on scope of the standard, "overlooked Code requirements," common problem areas, and case studies.

Frequently overlooked requirements include written O&M procedures covering topics mandated by the Code, review of dynamic events since the last condition assessment, and record-keeping—including procedures, drawings, findings, material history, failure analysis, etc. Support documentation and maintenance are not limited to spring supports, Fink cautions, but include *all* supports.

The listed common problem areas for combined cycles are:

- Areas undergoing thermal stresses, especially during transient operations—such as bypass valves and attemperator piping.
- Areas of highest stress and temperature at risk of creep damage—including under-supported areas, over-constrained areas, piping susceptible to thermal cycles, and thermal stresses at dissimilar-metal welds or piping-thickness changes.
- Attemperator spools, large valve bodies (stop valves, for example), branch welds, undrainable low points, and transition from HRSG OEM scope to piping scope

You'll want to review Fink's four richly detailed case studies, covering an HRSG interstage attemperator serving a G-class, 2001-vintage gas turbine; a spray-water line to a bypass valve for an HRSG at a 2010-vintage LM6000-powered cycling plant; HP interstage piping at a 2004-vintage G-class unit exhibiting vibration issues; and creep damage at a P91-P22 dissimilar metal weld on a HRSG.

Underground pipe inspection. "After eight years with no visual inspection," said the plant engineer for a combined-cycle plant, "we found oscillating vibration on one of our cooling-water (CW) pumps and decided to pull it for inspection." It turned out that the cast-iron impeller had severe erosion, the root cause being the wrong material being selected in the first place. It was replaced with a stainless-steel impeller, and rebalanced with stiffeners added to the upright pump support. No visible damage has been exhibited after five years of service.

The plant took the opportunity to conduct an inspection of the CW piping. The slides included in the presentation are a veritable tutorial with critical bulleted checklists on these topics:

- Planning for safety and timing (including restricting exhaust-emitting equipment from accessing the area).
- Tools and aids (don't forget your rock, or geologist's hammer and an extra radio).
- What to look for during the inspection (including valve internals).
- Notes of caution, such as not allowing heavy loads to cross where the piping is buried.

Duct liner plates. As Ryan Sachetti, CEO of Industrial Air Flow Dynamics Inc, reminded the audience, a liner plate is any internal duct/piping steel that "touches" the gas path directly, usually the insulation and protection systems. Hot spots identified from external thermography are "the first-line indication of heat getting in behind the liner system."

Inside when offline and cool, look for broken hardware, fallen washers, spongy or soft sections when you push against the material, large gaps between plates, and exposed insulation. Analyze for root cause before you select a repair or upgrade option, the latter necessary if gas-turbine performance has been enhanced.

As if the photos of failures and subsequent repaired and upgraded areas weren't enough, the presentation also includes a not-to-be missed video of a "complete liner failure." The repair/upgrade photos tell the story of liners ready for years of future service, at least one (Fig 6) in which you can visualize astronauts comfortably floating inside a la "2001: A Space Odyssey."

Performance improvement

You could forgive CCUG attendees if their eyes glazed over looking at slides on how to modify equipment and/or operating sequences to meet changing performance objectives. Several of the presentations could have been half- to full-day seminars by themselves. At the same time, it shows the quality and depth of the content the conference displays year over year.

Collectively, as suggested by the summaries below, they attest to how combined-cycle facilities are having to adapt to meet today's reality and how much more adapting will be required in the future, if present trends hold. Let's begin with the more straightforward ideas and work our way up the food chain of complexity.

Generator fast purge. There's a premium on minutes or hours that can be knocked off of a start or shutdown sequence, especially at plants experiencing more downtime between runs. One 4 × 2 facility, commissioned in 2002 with Siemens Energy 501FD2s, Nooter/Eriksen HRSGs, and Siemens KN steam turbine/generators, grabbed a few of those precious hours by installing a new automated fast-purge system for its hydrogen-cooled generators. Report was presented by Rob Kallgren, Lectrodryer, and the plant's engineer.

Bottom line is that the plant cut generator purge time from 12 to four hours, and added the ability to "emergency purge," something the presenters said most combined-cycle plants do not have. Also, the automated system can purge during a storm, thereby assuring staff can remain inside when there's lightning in the vicinity.

The Lectrodryer package includes a generator fast-degas system and a generator gas monitoring and control piping skid. During a spring outage earlier this year, the plant installed the system (Fig 7) in three weeks. Although the plant has not yet done this, the system can be equipped so purging is done entirely from the control room.

Condenser losses. Performance engineers have been chasing thermal losses in condensers for decades. Collin Eckel, Intek inc, discussed how four categories of new instrumentation can make it easier to both monitor condenser performance and identify the root causes of degradation.

Standard instrumentation for cooling-water inlet and outlet temperatures, steam pressure and temperature, and condensate temperature allows you to calculate condenser performance based on the cleanliness factor but

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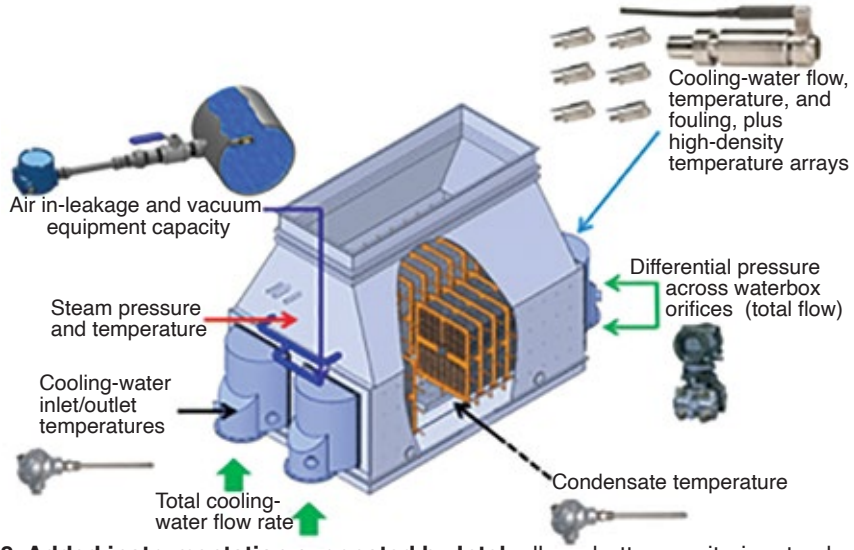
7. Automated fast-purge equipment from Lectrodryer shaved eight hours off the generator hydrogen-purge cycle at Acadia Power Station



8. Added instrumentation suggested by Intek allows better monitoring, tracking, and identification of condenser performance losses

that's about it, and that can be misleading, Eckel stressed.

Adding instrumentation for air in-leakage; cooling-water flow, temperature and fouling, and high-density temperature arrays; and differential-pressure meters (Fig 8), allows a far richer and deeper analysis for troubleshooting losses and what to do about them. Good computational flow dynamics (CFD) modeling is necessary to determine the best locations for these instruments.

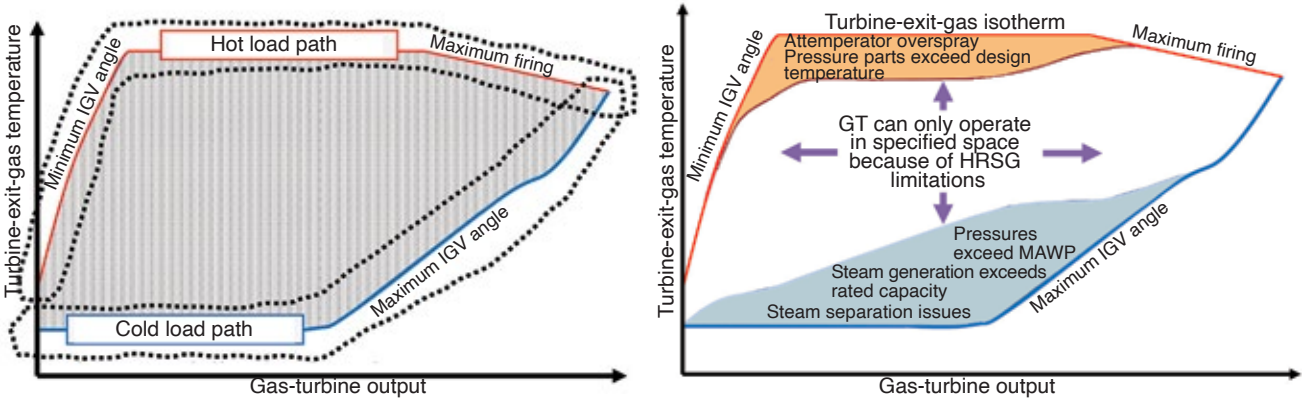
As examples, the RheoVac air in-leakage monitors give an absolute measure of all non-condensable gases, a mass ratio (measure of vacuum quality), flow in acfm at the common header before the vacuum pump, and mass flow ahead of the steam-jet ejector. The high-density temperature array—in one case 192 individual measurements—provides data on air binding and micro-fouling.

The slides include graphs and graphics showing how the data are converted into performance insights, supported by several case studies.

Variable load paths. Evan Almberg, HRST Inc, opened his slides with what could be called "the writing on the wall." According to the Energy Information Administration (EIA), 70% of all 2021 planned new capacity additions in the US are solar and wind. Thus, gas turbines and combined cycles will find even more ways to be flexible into the future.

Variable load path (VLP) operation is one such way. The typical GT operating curve is linear, Almberg said, fixing the turbine exhaust gas (TEG) flow rate and temperature based on cold, average, or hot ambient temperature. Essence of VLP is to modify the system to operate within an "envelope" in which GT load and TEG are controlled independently by modulating the IGVs to achieve the desired TEG mass flow (Fig 9).

The balance of Almberg's slides



9, 10. Modifying the gas turbine to operate along a variable load path *envelope,* rather than *linear* path, can add needed flexibility to the combined-cycle unit, but HRSG impacts must be analyzed in detail and addressed; some operating points simply may not pencil-out financially with the cost of the necessary equipment modifications. Note: Diagrams are not to scale and do not indicate actual operating conditions

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explains five categories of impacts on the HRSG of operating within this envelope: tube metal temperatures and overheat, attemperator overspray and valve capacities, rated steaming capacity and maximum allowable working pressure, economizer downflow and instability, and steam separation and carryover.

All of these can be addressed with equipment modifications or changes to lifecycle expectations, but the important point is to intimately understand the impacts using detailed thermal analysis, and then optimize the upgrade options with a practical operating envelope (Fig 10).

Simple-cycle startup speed in a combined cycle. HRST's Brandon Hall and Anand Gupta, along with Joseph Miller, The Energy Corp, delivered a treatise on whether and how a plant can adapt to meet the 30-min non-spinning reserve (NSR) markets (the 10-min market is the domain of aero machines, they said). Five combined cycle fast-start considerations addressed were drum ramp rates, purge-time calculation/credit, startup procedure checks, venting capacity, and demineralized-water capacity. The slides dive deep into the analysis for each category.

The bottom line is that many older combined cycles can adapt to participate in the NSR30 markets (Table 1) but there are, of course, risks and rewards (Table 2). Some of the risks are not insignificant when modifying a unit for faster starts—such as premature-ignition and water-induction events—but still could be offset by the financial rewards.

Performance gains for high-capacity-factor plants. Sam Korellis, EPRI, began with some statistics on the Top 20 combined-cycle plants to engage the audience in a review of techniques to improve heat rate and boost output:

- The Top-20 plants have an average 88% capacity factor, while the rest of the fleet hovers at around 60%.
- Heat rate for the Top 20 averages 6860 Btu/kWh, the best combined-cycle heat rate is 6649 Btu/kWh, and the remainder of the fleet averages 7400.
- A 1% improvement in heat rate can save a 1000-MW facility $1.3-million in fuel costs annually.

Korellis' slides amount to a summary of EPRI products, including report #3002005048 which identifies and analyzes 50 modifications and actions to improve combined-cycle heat rate, 32 capital projects, and 18 maintenance actions; "first of a kind" guidelines for combined-cycle performance monitoring and recovery; and a gas-turbine performance analyzer.

A few salient points:

- Through EPRI onsite projects, one plant found six steam/water leaks which accounted for a 0.8% heat-rate impact, one leak alone amounting to 0.6%; another plant discovered nine leaks for a total penalty of 0.6%.
- Installing and using a performance monitoring system is a high-cost, high-return capital project.
- Installing HEPA filters ahead of the gas turbine is a medium-cost, high-return mod.
- Reducing condenser air in-leakage and repairing valves in high-energy piping systems are low-cost, high-return maintenance actions
- Monitoring control loops (several companies supply this software) via data from the plant historian is a low-cost means of identifying easily correctable tuning problems, valve issues, and process inefficiencies.

Table 1: What it takes to achieve NSR 30 in a combined-cycle plant

1. Keep the plant positioned to start
- Drums at light-off levels
- Machines on turning gear
- Required BOP systems in service
- Maintain vacuum (if your plant has an auxiliary boiler)
- Delete unnecessary permissives

2. Remove certain gas-turbine starting and loading constraints
- Implement purge credit
- Install adequate steam vent valves and control logic
- Install final-stage (terminal) attemperators for HP and hot-reheat steam temperature control

3. Simplify control-room operator actions
- Implement single step functions
- Use sequencers

Siemens Energy Day

Siemens Energy Day at CCUG gave users plenty to think about to keep their plants "relevant" as renewables continue to claim a larger share of generating capacity. Presentations covered the more immediate options for upgrading, optimizing, weatherizing, and cyber-securing your plant, but also longer-term options like adding green hydrogen capability, battery storage, synchronous condensers, and other equipment for grid stabilization.

Dilshan Canagasaby, head, Inte-

Table 2: Risk-reward proposition

Modification	Reward(s)	Risk(s)
Purge credit (pressurized pipe method)	Improperly implemented purge credit system resulting in premature ignition event	(1) Reduction of five to 15 minutes in engine start time. (2) Elimination of HRSG energy loss due to purge. (3) Reduction in HRSG life expenditure
Final-stage attemperators	(1) Steam-turbine water induction event. (2) Excessive temperature transient. (3) Quench damage caused by leaking spray valve	Provides ability to bifurcate the Brayton cycle from the Rankine and still start the steamer
Hot-reheat steam venting to atmosphere	(1) Loss of energy caused by leaking valve when closed. (2) Insufficient demin-water inventory	Provides a means to achieve NSR 30 for plants that do not have an auxiliary boiler
Steam-heavy control logic	(1) Increased wear and tear on bypass valves. (2) Increased wear and tear on condenser	Provides ability to load gas turbines uncoupled from the steamer while maintaining HP drum pressure/temperature ramp
Delete boiler-feed-pump in-service permissive to start gas turbines	Inability to start a BFP in time to prevent a drum low-level unit trip	(1) Reduction in parasitic load while keeping the plant in a ready-to-start condition. (2) Reduction in pump and valve wear and tear

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☐ Hot steam-turbine (ST) start on fly	☐ HRSG IP pressure control	☐ Optimized HRSG flexibility	☐ ST hot standby
☐ Fast gas-turbine (GT) ramping	☐ 1 × 1 min load in 2 × 1 plant	☐ Fast duct firing (DASH)	☐ Fast cooling of ST for maintenance
☐ HRSG thermal optimization	☐ Off-peak charging of storage system	☐ Clean ramp for SCR	
☐ Early ST seal steam		☐ Battery integration	
☐ Fast bypass close			

11. Generic performance goals are delineated around the typical combined cycle's start, ramp, load-following, and shutdown cycle. Solutions identified are designed to accommodate requirements for operational flexibility

Layer 1: Improved automation	Layer 2: Advanced controls	Layer 3: Optimization
☐ Equipment automation	☐ Engineered applications	☐ Mathematical modeling
☐ Subsystem automation	☐ Dynamic adjustments	☐ Stress modeling
☐ Automatic sequencing	☐ Controls decoupling	☐ Predictive algorithms
☐ Startup display operator guidance	☐ Adaptive control	☐ Self-learning algorithms

12. Modifying controls for faster starts can involve simply improving control, adding advanced features, or automated optimizing with model-based controls, stress calculations, and predictive algorithms. A suggested three-phase approach for achieving optimal starts is outlined here

REDUCE COST	INCREASE REVENUE
☐ Auxiliary power: Optimize the amount of power imported from the grid when the plant is not operating.	☐ Capacity market: Battery can deliver additional energy capacity to the grid to help maximize revenue.
☐ Energy arbitrage: Charge battery during off-peak periods, discharge on-peak.	☐ Black start: Battery provides power to start the gas turbine with no external (grid) power supplied.
☐ Reduce startup cost: Replace low-load/short-duration gas-turbine starts with the battery, thereby reducing startup costs, fuel consumption, and emissions.	☐ Increased operating range: Enables plant to offer output higher than baseload and lower than minimum turndown by using the battery as both a source and sink.
☐ Extended turndown: Charge the battery with gas turbine at min load to reduce power supplied to the grid.	☐ Grid balancing services: Provide grid balancing services by delivering or consuming megawatts.
☐ Supply startup loads from the battery to eliminate grid dependency, reduce energy costs for starting.	☐ Regulation: Instant battery ramp rate can help increase revenue from the regulation market independent of GT operation.
☐ Faster warmup: Shorten the steam-turbine warmup period with the battery before increasing speed.	☐ Spinning reserve: Battery is synched to the grid and can provide output instantly.
☐ Regeneration: Reuse steam- and gas-turbine coast-down energy.	☐ Enhanced peaking: Battery provides power on top of GT output to help meet a peaking need or respond to scarcity pricing.
	☐ Fast start: Battery output can be available immediately, bridging the gap between grid demand and GT startup.

13. Batteries can enhance a simple- or combined-cycle plant in a variety of ways, although no cost-reduction factor or revenue stream tends to prevail in actual project assessments

grated Product Solutions, kicked off the day with a few slides underscoring what the Siemens Energy "brand" stands for on the global stage. Then the technical content started flowing. What follows here are the highlights.

James Loiselle, principal engineer, Integrated Product Solutions, and Anil Peravali, project engineering manager, Plant Solutions Engineering, covered plant assessments for flexibility, upgrades, performance, and operational reliability—such as weatherization (Fig 11).

The presentation included several combined-cycle use cases from customers with different GT frames seeking individual or a combination of the above assessments. One underlying message was that such assessments are good for evaluating the plant operational and design limitations and developing tailored solutions addressing specific market needs and maximizing asset value.

Weatherization is top of mind these days after the catastrophic loss of the Ercot grid in Texas this past February. Loiselle and Peravali gave statistics on this event, including the astonishing one that lack of weatherization and auxiliary system maintenance led to shutdown of 14,000 MW of gas-fired generation in the state.

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Fair warning: Most plants' operating envelope may be unsuitable for extreme weather events, they said. Siemens Energy is issuing a white paper on this topic which addresses the approach to identify site-specific limitations and develop solutions to increase operational reliability during extreme weather.

Continuous monitoring of critical thermodynamic, mechanical, and electrical parameters supports this objective. If your plant is not well-equipped for M&D, Siemens Energy can help, with a diagnostics level of service (limited amount of feedback) and a continuous optimization level of services (regular communication about performance and solutions).

Christopher Bonilha, manager of plant optimization, noted that renewables are expected to account for 50% of generation by 2030 and 67% of decentralized power. He stressed having a multi-year optimization plan, rather than conducting a single plant assessment. That way, you can make the best maintenance decisions continuously to remain in optimal performance.

The presentation includes several individual examples of sustaining top performance accompanied by return-on-investment estimates: Adding HEPA filters to slow GT compressor degradation, tuning for cold weather, changing compressor control logic to avoid a pressure-ratio limit from causing GT unloading, quantifying and validating losses in the HP bypass attemperator, optimizing LP drum-pressure set point, monitoring condenser backpressure for efficiency loss, and optimizing cooling water pump operation.

In response to an audience question, the presenters noted that Siemens Energy performs continuous monitoring for 10,000 MW of customer capacity, although that includes sites where only the GT is monitored.

Galen George, director of business development and marketing, covered startup optimization and cybersecurity (Fig 12). He noted that some customers will start up their units 30 minutes early to meet anything from a 30-min to 3-hr start time. While control mods for faster starts usually mean greater automation, Galen stressed that "control is not taken away from the operator." For example, the system may tell the operator when to do something, but the operator actually has to do it. In other words, they still have to pay attention. The slides included a project executed in the USA Midwest that reduced startup times and fuel costs by 50%.

Cybersecurity. George's cyber-related slides quantified what we all know implicitly: Connected industrial digital devices have increased eight-fold since 2011, which means the "threat environment" has also grown exponentially. Most of the slides were intended to make the case for including an industry expert like Siemens Energy as service providers in your vulnerability management programs.

Audience questions addressed how to back up, save, and test systems (Siemens Energy recommends at least once a day, a function which can be automated, though older units may have manual only); then storing the backup files on a drive within the system, then transferring to long-term storage within the DMZ. Another attendee inquired about wireless devices and mesh networks. George said these are "much more vulnerable" and suggested continuous intrusion monitoring and detection.

Beyond the GT and CC. Jim Badgerow, senior project manager, Expanded Scope Solutions, covered battery solutions to reduce costs and/or add revenue streams. One of the more interesting use cases is to avoid paying demand charges for the electricity needed to frequently start up combined cycles as well as provide black-start capability (Fig 13).

The day concluded with Thorsten Wolf, product manager, plant innovations, presenting on opportunities for green hydrogen and grid stabilization. Main points:

- Surplus (often "spilled" or wasted) renewable energy can be harnessed to produce and store "green" hydrogen for later use.
- Hydrogen substitution for methane in natural gas does not lead to a linear reduction in carbon—for example, a 30% hydrogen mix by volume reduces carbon by 10%.
- Even low percentages of hydrogen may require changeout of carbon steel for hydrogen handling and transport, because of embrittlement risks, in plant fuel handling equipment depending on site-specific variables.
- Hydrogen storage has many considerations as it has to be compressed to 2400-2600 psig and unlubricated reciprocal compressors may be necessary.
- Steam turbine/generators at shutdown fossil plants can be converted into synchronous condensers for grid stability by adding a clutch and other equipment.
- Siemens Energy is developing static voltage compensator (SVC) technology to respond instantaneously for frequency stabilization.

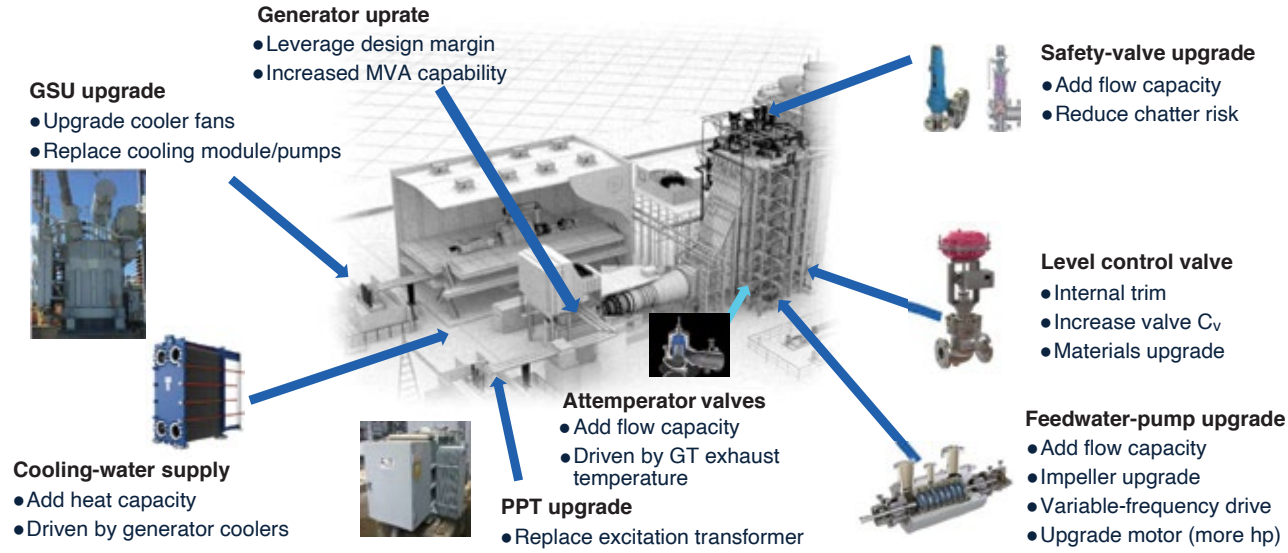
GE Day

The OEM's program at CCUG 2021 began with a glimpse into the *next* 20-30 years of combined-cycle facility operations and ended with a tutorial in using historical data to trend the *last* 20 years of a plant's operation. In between were deep dives into BOP plant impacts from gas-turbine technology upgrades and aggressive operating tempos, followed by solutions for those impacts on HRSGs, generators, and steam turbines.

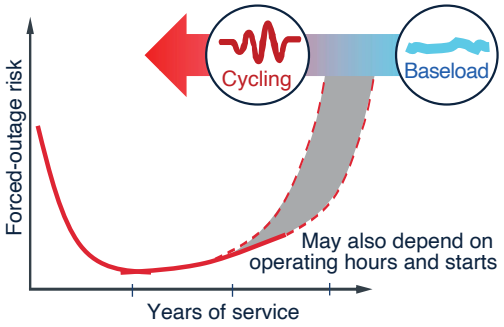
The overarching message was that GE has the depth and breadth of expertise to, essentially, be your partner and keep you on-mission, in-market, and thriving, regardless of what challenges your plant faces in the coming years.

Think of it this way. If your primary-care physician designed your body and manufactured its components, you'd probably have a high level of trust that he/she could maintain it. As the OEM for the GT/generator, HRSG, and steam turbine (ST)/generator at many combined-cycle facilities worldwide, GE wants you to know that they have the fleet performance data, specialists who can analyze your plant-specific operating data, diagnostic capabilities, manufacturing capacity for replacement components, repair procedures, and technology upgrades to keep your plant surviving and thriving into the future.

Jeff Chann, business intelligence leader, talked about the realities of "obsessive carbon management" in the political and cultural realms and the inevitability of converting some of today's GTs to burn different levels of hydrogen. He gave a candid review of the pros and cons of hydrogen and the



14. All major BOP systems should be reviewed when the gas turbine is uprated, such as for winter peak-load extension



Cyclic loading
- Additional stresses
- Increased forced-outage risk and probability of rewind

Historically, rewind risk increases for rotors 15 to 25 years old, stators 25 to 30 years old

Unplanned rewinds increasing
- 26 root causes for rewinds, some driven by starts, some by hours
- Insufficient data to create individual failure-mode distributions, so years after COD is optimal gauge

15. Unplanned generator rewinds are increasing without a common root cause driving them, other than aggressive cycling accelerating the lifecycle

need for carbon capture and storage if the hydrogen is produced through steam reforming rather than electrolysis powered by surplus renewable electricity and "really clean water."

Example: The largest installed hydrogen storage facility in the US would be emptied in eight hours by an H- or J-class GT. Takeaway: The accompanying hydrogen production, storage, and delivery infrastructure need to be built out.

Chann rallied the audience by noting "existing plants will have to stick around longer to help" with the transition to a low-/no-carbon electricity future and that "we're the ones with the technical expertise to enable hydrogen." Queen's "We are the Champions" could have been playing in the background.

Evaluating plant impacts. John Sholes, principal engineer, divided plant impacts into short-term (this year), mid-term (next major outage), and long-term (game-changer GT technology infusion). Examples:

- Short-term—modifying controls and upgrading the attemperator to achieve 80% turndown (60% is considered typical for low-load operating plants today).
- Mid-term—upgrading the combustor with advanced gas path (AGP) technology and extended-turndown valves for the attemperator.
- Long-term—full AGP upgrade for hot-day peaks and cold-day performance, along with identifying and addressing BOP (cooling tower, GSU/transformer, attemperator valves) limitations (Fig 14).

Matt Matthews, project engineering manager, delivered a case study of a winter-peak plant upgrade, timely given the catastrophic Ercot grid-wide winter outage this past February. Objective for this Ercot-based plant customer was a risk assessment targeting cold-plant operation. Matthews described the uprate as involving relatively small changes, such as boosting generator output by increasing hydrogen coolant pressure and higher horsepower motors for the boiler feedwater pumps. The plant will begin operations with the upgrades in the first quarter of 2022.

Harp replacements. Vasileios Kalos, platform leader, HRSG Services, cautioned the audience that off-spec operating conditions like sustained low-load operation and aggressive cycling accelerate life consumption of HRSG pressure parts. PPs operating under such conditions require more inspections and more repairs. Users considering replacing pressure parts need to think in terms of 12-month lead times and planning for "intensive field resources," such as large cranes, and even temporary preservation of PPs onsite for up to 12 months.

Kalos supported his presentation with four case studies:

- Working with a user to create a "value story" for an HP evaporator replacement.
- Replacing HP evaporator and economizer harps damaged by a hydrotest. (Lesson learned: You can't perform a 10-yr hydrotest on an older unit as if it were brand new.)
- Replacing HP superheater and reheater harps during a GT upgrade to extend HRSG life. Extensive cracking was discovered after 20 years of operation and daily start/stops.
- Replacing HP and IP economizer and evaporator harps damaged by corrosion because of improper preservation of pressure parts. User anticipated tube leaks and frequent forced outages as a result.

Generator lifecycle. Ian Hughes, principal engineer, Fleet Management, reviewed recommended maintenance and rewinds to avoid generator forced outages. To drive his main points home, Hughes noted that a *planned* stator rewind typically takes 28 days. Double that for an *unplanned one.*

Unplanned rewinds (Fig 15) are increasing, having doubled since 2011, he said, because of, you guessed it, larger load swings, more load swings, greater number of starts/stops, and time units are on turning gear. Generally, GE is not able to pinpoint the

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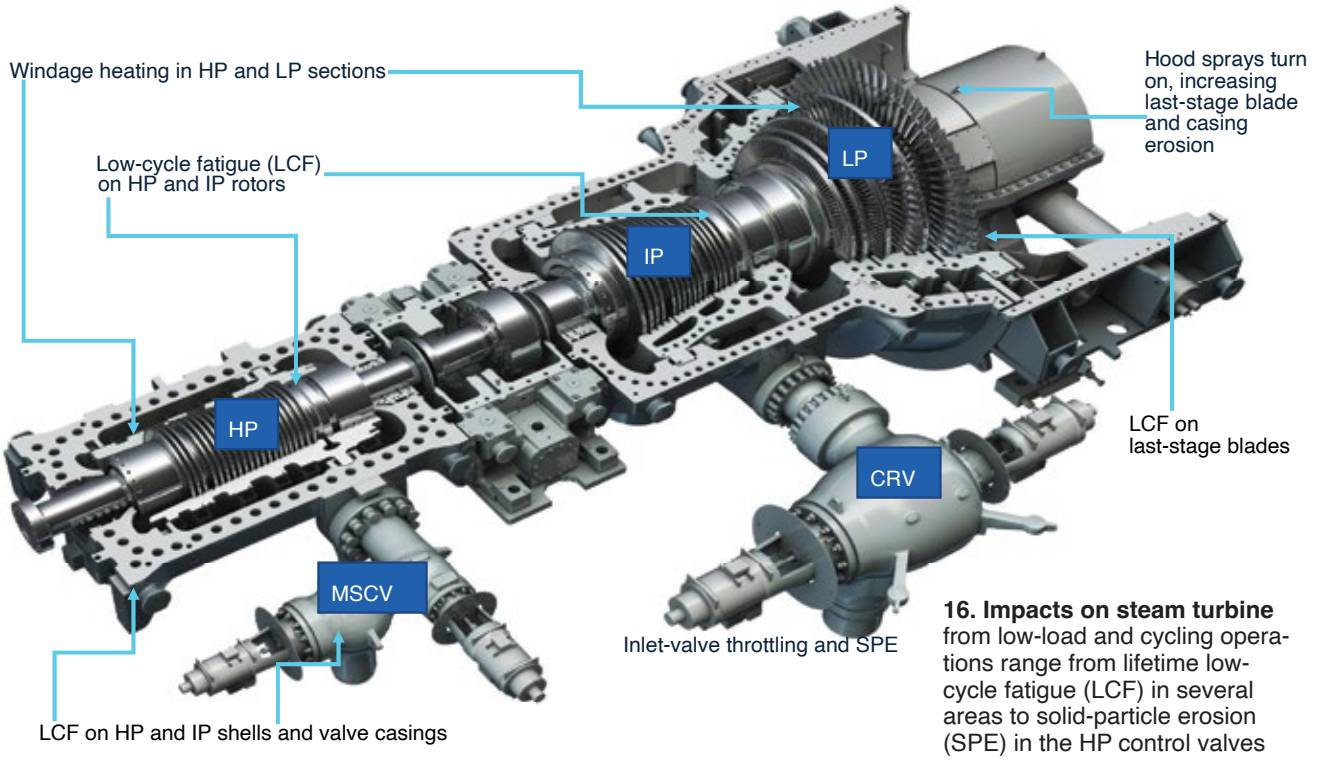


16. Impacts on steam turbine from low-load and cycling operations range from lifetime low-cycle fatigue (LCF) in several areas to solid-particle erosion (SPE) in the HP control valves

Fig A

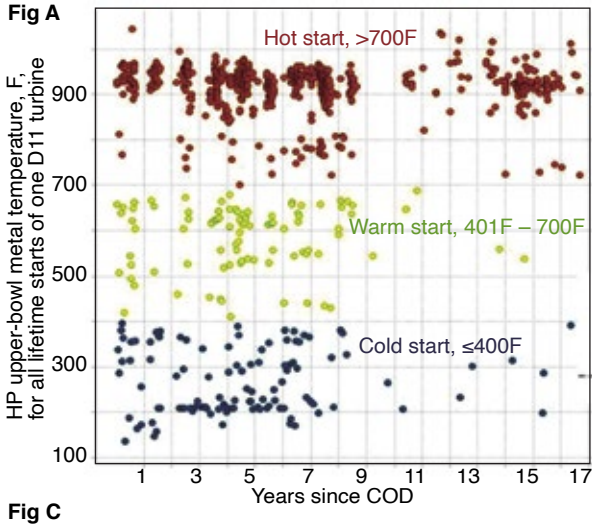


Fig B

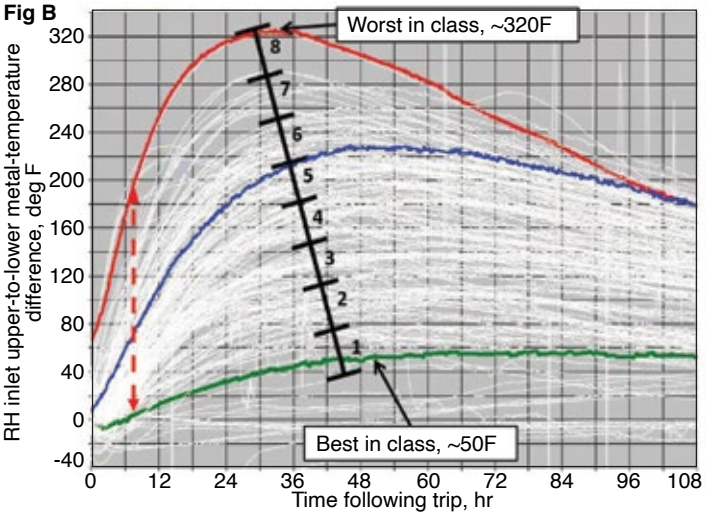
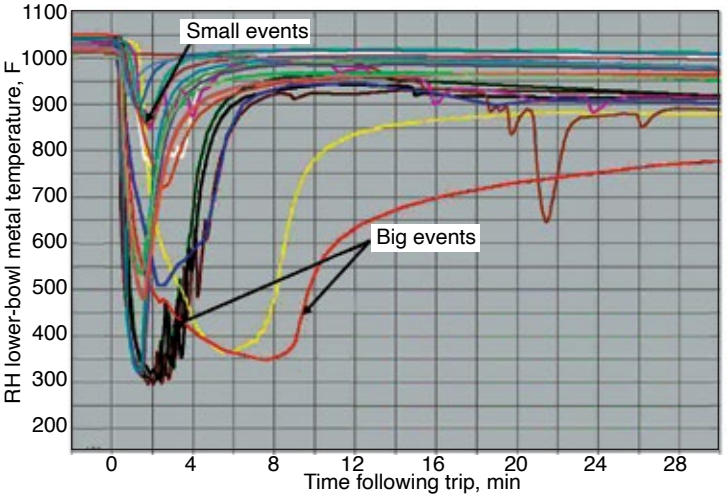


Fig C



17. Mining plant data assists in identifying issues, tracking them, and planning maintenance activities based on evidence. For example, lifetime HP steam-turbine bowl-metal temperatures provide a quick overview of changes in mission (**A**).

Upper-to-lower turbine-shell metal-temperature differences during cooldown can indicate shell distortion, risk of blade rubs during hot starts, and the quality of turbine insulation (**B**). Having a fleet's worth of data as a basis for comparison allows owner/operators to assess the relative quality of their insulation. The illustration shows that for the 8-hr hot start identified by the dashed line, the most common type of start for the D11 fleet, the worst delta T is as much as 20 times greater than the best delta T. Thus, the importance of insulation quality cannot be overstated.

Transient metal temperature profiles can help distinguish small water induction events from big ones (**C**)

root cause of these rewind outages; years in service is the best predictor of need for a rewind.

Hughes dwelled on core step-iron damage at the turbine end for 7FH2 units shipped between 2001 and 2003, the subject of TIL-2260, including some outlier finds of missing teeth. These units represent 6% of the fleet. This type of damage is generally found on the GT generators, not the ST unit. He further noted that there are eight different design versions of the 7FH2 generator, and some of the components are not interchangeable.

Perhaps the most important part of Hughes' talk was that the 1999-2002 GT supply bubble has led to a "rewind bubble" currently. By 2024, rewinding needs will exceed industry capacity, Hughes warned. GE has some exchange rotor fields for swap-outs but not many. He advised users to have stator and rotor bars "on-hand" as GE cannot, from a business perspective, carry too much inventory. "We have to shave the peak of this bubble," he cautioned.

GE recommends flux-probe and PDA tests prior to an outage to detect potential damage and at least a one-year planning cycle for rotor/stator rewinds. GE also offers several M&D packages for generators which range from twice yearly inspections to 24/7/365 remote monitoring.

Cycling impacts on steamers. Matt Foreman, platform leader, Combined-Cycle Steam Turbine Services, carried on by reviewing the many ways cycling operations impact the steam turbine lifecycle (Fig 16). Major takeaway: Most ST components are "made to order," only the last-stage blades have commonality, few components are stocked, and you should figure on an 18-month planning cycle prior to an outage. Regular inspection and maintenance are key to avoiding outage-inducing surprises.

Caught early, minor cracks, such as found in highly stressed components like main steam control valves, can be addressed through "grind and blend" repair techniques. As for a current common issue, diaphragm dishing," GE has been dealing with dishing for a long time in the D11 fleet," Foreman said.

An important aspect of Foreman's slides came at the end, when he showed several graphs (Fig 17) of long-term operating data (from the inception of commercial ops), and how data analysis also can identify minor issues before they become big ones. "Each unit has a unique operating history, and data mining can reveal trends important to a predictive maintenance strategy," Foreman said. CCJ

Challenges to SCR performance and NO_x compliance just keep growing

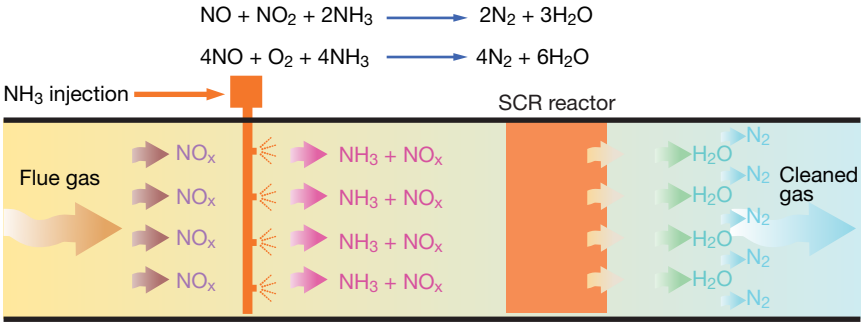
Whether you have the meanest, baddest advanced gas turbine in your plant, or technology dating back to the GT installation boom of 1997-2002 or before, you probably recognize that the challenges to maintaining selective catalytic reduction (SCR) performance and NO_x compliance just keep growing. This situation is causing some owner/operators to consider a long-term service agreement (LTSA) around the SCR just like they have for the gas turbine and other critical plant subsystems.

Goals are to shift the risk to where the greatest expertise lies for managing that risk and keep the unit performing the way it should. One of the goals of an LTSA program is to achieve O&M cost *predictability*. This is why debt-financed projects usually are required by their banks to have LTSAs at least during the debt-service years.

"SCR and CO-related costs are rising," Jeff Bause, president/CEO Groome Industrial Service Group and a leading expert on powerplant emissions control, told the editors. There are a few different reasons for the increased costs, he said, focusing on the following:

- Catalyst and assets are approaching end-of-life and require replacement or retrofit to extend life expectancy.
- Plants are re-permitting and requiring additional capability from their emissions control systems.
- Plants are operating with different load profiles than previously, at least some requiring more catalyst to accommodate the new emissions profiles.

Recall that an SCR is relatively simple from a chemical process point of view. In combined-cycle plants, ammonia is injected into the gas turbine exhaust inside the HRSG within the proper temperature range for the chemical reduction of NO_x to harmless nitrogen and water (Fig 1). However, today this reaction has to be incredibly precise, because the compliance NO_x emissions levels are approaching zero, and ammonia slip—unreacted ammonia—exiting the stack also is regulated. In addition, the ammonia reagent has to be evenly distributed throughout the exhaust gas volume, even as the temperatures across the plane of injection may vary (Fig 2).



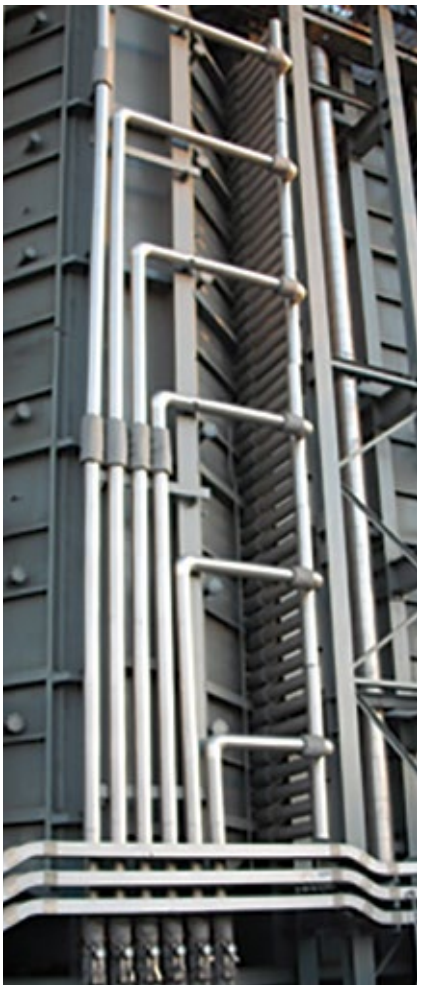
1. Chemical reactions between the NO_x emissions and the injected ammonia convert NO and NO_2 to inert nitrogen gas and water vapor. The catalyst is merely a facilitator of—not a participant in—these reactions

SCR challenges converging on owner/operators, several of which go beyond the SCR, are legion:

Staffing. Onsite staff at combined-cycle plants continues to shrink. Less and less does it make sense to maintain a resource on staff with the chemistry and engineering expertise to properly attend to the SCR. Even if you wanted this, persons with the right credentials and experience are hard to find and often resist locating at facilities remote from urban and suburban areas. Plus, today's digital and communications capabilities allow M&D data to be viewed and acted upon virtually anywhere.

HRSG impacts. One of the most popular topics when HRSGs are being discussed is tube surface cleaning. And one of the questions that frequently arises when cleaning options are being evaluated is, "Will it work on ammonia salts?" Although these salts make up a small proportion of the total deposition on surfaces, they are among the most difficult to dislodge (Fig 3). Adverse performance of the SCR leads to impaired heat-transfer efficiency in the HRSG and other ills.

Cycling. Most plant components are negatively affected by the deep daily



2. Job of the ammonia injection grid is to evenly distribute reagent throughout the exhaust gas stream

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3. Ammonia will react with sulfur compounds in the fuel and/or in combustion air to form ammonium sulfate and/or ammonium bisulfate, which can foul finned-tube heat-transfer surfaces in the coolest sections of the HRSG

and weekly cycling and startups/shutdowns combined cycles are subjected to these days as they "follow the wind."

SCRs are no exception. Like the other subsystems, the SCR system probably was designed for baseload operation; chemical processes work best when they operate steady-state. One consequence of cycling is that GT exhaust-gas temperatures will vary; however, you can't very well shift the ammonia injection grid so you compensate in other ways.

Even deeper cycling. Unfortunately, many plants are going to face even deeper cycling and are asking their turbine OEMs and non-OEM service firms, "How low in output can I go?" More and more, profitability depends on capturing higher and higher electricity prices over shorter and shorter operating periods. Thus, combined cycles will

4. When inspecting the SCR be sure to inspect for shifting of catalyst bricks. Regular repacking of insulation is recommended to minimize the potential bypass associated with shifting

stress the SCR even further beyond the bounds of the original design. Anything done to the system upstream–gas-turbine upgrades, uprates, etc–which changes GT exhaust characteristics–NO_x levels, mass flow, temperature profile, contaminants (from air or fuel), etc—must be evaluated for impacts on the SCR.

Aging equipment, latest equipment. Plants with legacy SCR systems face obvious repair and replacement costs but also non-obvious ones from cycling stresses. SCR experts have noted that plants with the most advanced GTs–the G, H, and J engines–generally have to meet a final NO_x limit of 2 ppm but with several orders-of-magnitude higher NO_x levels exiting the turbine.

While many sites with advanced gas turbines are operating at high capacity factors (that is, close to steady state) because they are more efficient, industry experience suggests this won't always be the case. When these plants cycle, it may be even harder for them to meet NO_x limits across the load range. If they were supplied originally with the absolute minimum catalyst volumes (typical, to keep capital costs low), they will require more frequent tuning and hardware and control adjustments.

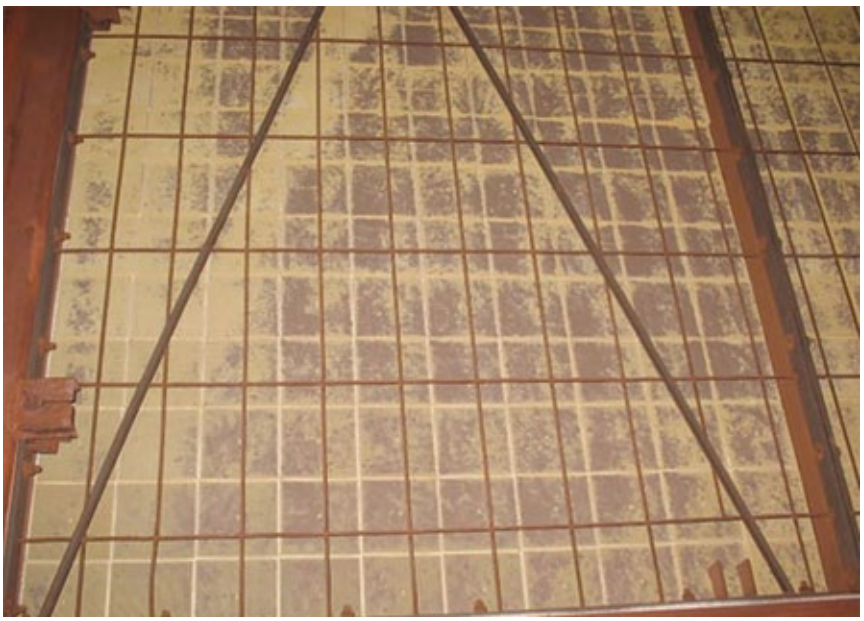
Catalyst deterioration. Even plants which do operate as designed for most of their lifecycles face normal catalyst deactivation and deterioration (Fig 4). Other operating impacts such as HRSG tube leaks and debris from upstream (insulation, for example) which can blind catalyst surface will affect performance over time (Fig 5).

Over the years, many plant operators have been surprised when ammonia slip suddenly rises, a prime indicator of catalyst deactivation. Keeping the system tuned, especially the ammonia injection grid (AIG), will improve catalyst life, but the testing required for AIG tuning is laborious and slow. Assessing catalyst condition and optimizing for catalyst cleaning, regeneration, replacement, and/or even upgraded formulations may be best left to the experts.

Duct burners. Supplementary firing in the HRSG can cause stratification of the inlet NO_x profile, which complicates the operation and tuning of the SCR. Yet duct burners are firing longer and harder these days to achieve overall unit flexibility.

Safety. Ammonia in aqueous or anhydrous form is toxic and the ammonia handling equipment is a key area for personnel safety.

Violations and penalties. It's almost impossible to find data on penalties paid for NO_x non-compliance or fines for not delivering the power output your plant had agreed to contractually. Such data usually are held confidential. But everyone agrees the fines can be significant. One thing's for sure: You'll pay mightily if your SCR causes an inopportune outage, failure to start, or premature shutdown. CCJ



5. Plugging by insulation fibers and other contaminants in the exhaust-gas stream increases backpressure and SCR performance drops

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Performance is Key on the Path to Net-Zero

Jeff Schleis, Gas Turbine Product Manager at EthosEnergy

Unless you've been living on an island alone and completely disconnected from society, the topic on many people's minds is the push for a cleaner world. It's in the news, on social media, and on the front page of every corporation's website. In particular, a number of high-profile (and high energy) users have pledged to attain net-zero greenhouse gas emissions in coming years.

While several big utilities across the country (Southern Company, Dominion Energy, Duke Energy, PSEG, Xcel Energy) have made the pledge to get to net-zero by 2050, there are significant energy consumers in data storage and petrochemical who are also making a commitment. Schlumberger, BP, Shell, Suncor, and others pledged for a 2050 goal. Some of the big data companies (Google, Vantage, and Microsoft) have set their target to 2030.

As we all know, it's one thing for business to make these pledges to satisfy public demands, but are they really taking action? According to the 2020 Black & Veatch (B&V) Strategic Directions Electric Report, the answer is "yes." A poll from over 800 utility stakeholders, the large majority of those surveyed said investment is increasing for renewable generation (solar and wind). Alternatively, 61% of participants expected a stagnant or decrease in investment for natural-gas-fired generation.

Meanwhile, pressure is mounting to electrify anything that is related to fossil fuel use. California has already pledged to have all new vehicle sales as electric vehicles (EV) by 2035. The Biden Administration has a similar goal of zero internal-combustion-engine (ICE) sales by 2030. Several big cities are pledging the elimination of natural gas for household use. These include Berkeley, San Francisco, San Jose, Seattle, Denver, and New York City to name a few that have set somewhere between 2030 and 2040 as the goal.

Where is all of this taking us? If we electrify everything, a conservative estimate would be more than double our load requirements by 2035, adding another 1,300 GW to the grid!

But is this even possible? There have been numerous studies on this topic, with some of the more detailed ones considering the various pledges and determining where new power plants would need to be located and the necessary infrastructure to do so. While results differ somewhat, there are some interesting conclusions that they confirm:

- Coal-fired power plants are gone from the US grid by 2035.
- Demand on the grid is at least double by 2050.
- Renewable power generation exceeds fossil-fuel power generation before 2035.

That last point is the startling one. Currently, renewable power generation is about 20% of our total power consumption according to the US Energy Information Administration (EIA). We need almost triple that amount in less than 15 years to achieve net-zero goals. This combined effort is leading us down a path where the increase in power needs will exceed the rate at which we can add renewable power generation. That begs the question: How do we build a grid in thirty years that is twice the size of the current capacity and entirely on renewables?

The power generation industry knows all too well that the switch to renewables has already led to a significant impact on gas turbine generators that have switched from baseload to peaking service:

- Increased maintenance due to cycling.
- Greater need to turn down further and ramp up quickly.
- Power market prices becoming increasingly unstable; smaller stressors generate bigger events.

As the use of variable renewable power generation hits that majority tipping point, there is a significant need to

Hidden problem with inlet fogging causing decreased plant output	Fouling of nozzles caused loss of 2.3 MW per unit and was unknown to the plant Over the course of a year, a potential loss greater than $800,000 USD
OEM "repaired" bearing oil leak that was causing compressor fouling	Following repair outage, 5 MW loss in output after one month of operation Proof was required to force vendor to fix the issue (more than $60,000 USD lost for every offline water wash)
Slow degradation in turbine performance during peak generating season	Plant generating loss of 2.5 MW (1.5%) over first four months If left unchecked, this would have been a loss greater than $400,000 USD
Lean blowouts caused forced outages	Root cause analysis required to determine 18-year-old TIL never performed Opportunity of cost of greater than $50,000 USD
Forest fires increased airborne particulate matter, fouling gas-turbine inlet filters	Turbine performance was slowly decreasing over 10 days Waiting seven months for planned outage would have lost $290,000 USD

Examples of latent issues found by PHD Advance

stabilize the grid with spinning inertia. Frequency stability will become a bigger factor. Energy storage has technology to help, but won't completely solve problems like riding through significant faults on the grid. With all this turmoil, it is likely that industrial power generation will become even more critical to isolate themselves from this chaos and keep their processes running.

Looking back to that B&V study, some utilities do see the need for increased spending in natural-gas-fired assets in this environment. The remaining 38% of those surveyed see this increase. Whether this is for increased maintenance spending, or additional assets, we don't know, but it is fair to say that these units are not going away immediately.

Natural-gas-fired units are not going away in the short term, but how do we find the investment needed to keep these necessary units running? EthosEnergy's Plant Health & Diagnostics (PHD) products can find the latent or hidden issues costing the plant every day. PHD can also reduce maintenance costs by converting reactive work to targeted/predictive work.

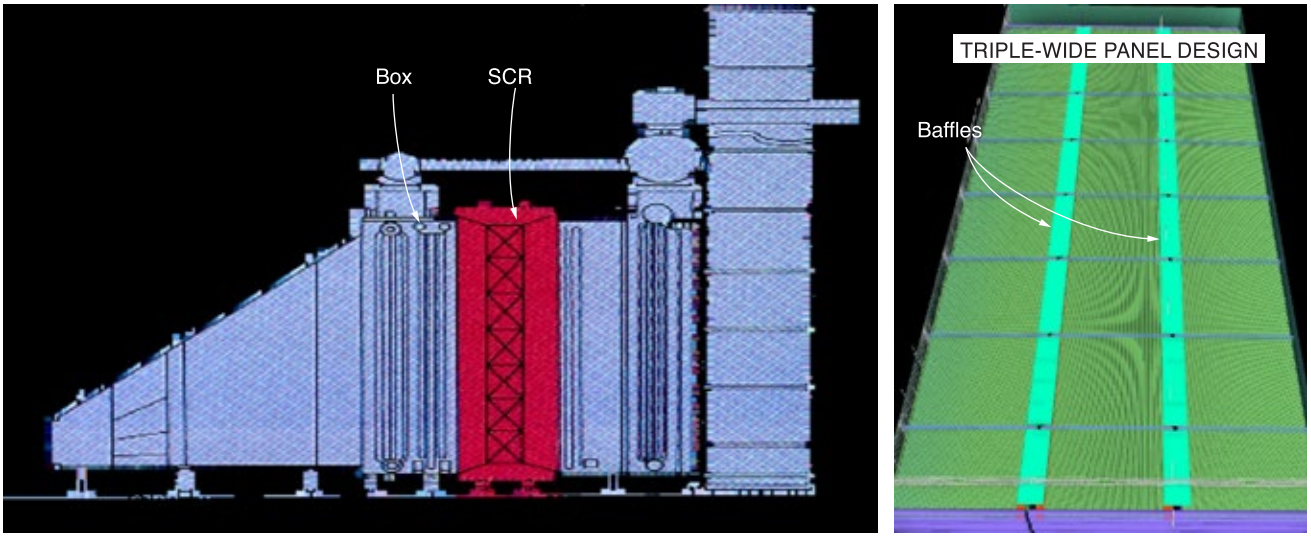
For plants with limited engineering resources or a lack of experienced operators, PHD Advance's artificial intelligence engine is working 24 × 7 for the plant (figure). By utilizing the plant data that already exists, PHD is trained on what normal behavior is, and the AI engine finds issues before they create forced downtime. Maintenance can spend less when issues aren't as time-sensitive and before major failures occur.

The issues alerted by PHD are not always simple to solve. That is why the program is backed by EthosEnergy's depth of knowledge and engineering. Whether it is related to the steam turbine, gas turbine, generator, control systems, or balance of plant, the engineering resources are just a button away. All the troubleshooting is logged through our web interface. In addition to making collaboration with EthosEnergy easy, it keeps track of all issues from diagnosis through resolution.

A key step before monitoring live data is a Thermal Performance Audit (TPA). This engineering report benchmarks each of the plant's assets and systems against industry performance targets to find latent issues. While this is included with the PHD program, a TPA can be performed annually to look for underperforming systems. Included with the TPA is a gap analysis at the end of the report. It provides the data to understand the impact each underperforming system has on plant output and heat rate. From this information, the owner can decide if the expense to correct the issue is worth the gain to the plant. Many times, the impact of degraded systems is much greater than expected.

Interestingly, a side benefit to the TPA is the ability to evaluate the impact of upgrades or changes to the plant in terms of overall plant performance. For example, scenarios like expanding the cooling water system that will improve the steam-turbine condenser can be modeled. The return on investment can be an easier decision when the impact to the plant performance is accurately modeled using current plant conditions and data.

Whatever your situation is with investment in your plant, EthosEnergy is there to assist with the journey and help keep your assets running longer and improving performance. Rest assured that gas-fired assets are needed for us to make the transition to net-zero. Don't let the uncertainty of the future stop your plant from improving and retaining importance, that is of course, unless you are alone on your very own island.



1. HRSG is characterized by a heat-recovery section (a/k/a box) just upstream of the SCR. Baffles are located between adjacent tube panels in the triple-wide design

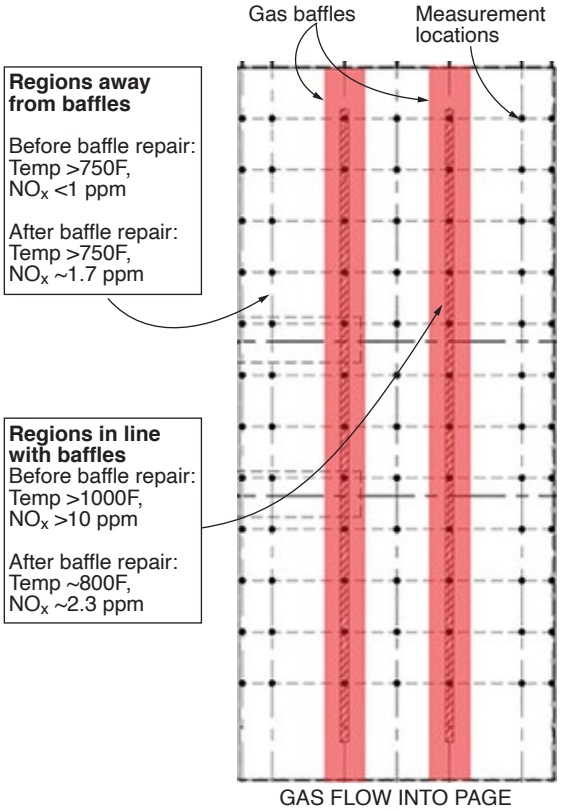
Repairs to gas baffles between HRSG tube panels restore SCR performance

A 480-MW 1 × 1 combined cycle was experiencing NO_x emissions above its 2-ppm stack permit limit. The problem was more pronounced with supplementary firing, so the plant was restricted both in its level of duct firing and overall output. This HRSG, which incorporates a heat-recovery section directly upstream of the SCR (the "box" in Fig 1), is of the triple-wide panel design with baffles between the panels.

2. In the top-traverse test method, a weighted probe is lowered to desired locations in the inlet and outlet flow planes, identified in Fig 3, to measure NO_x, NH_3, and temperature

SCR Solutions LLC was engaged to help the plant determine the cause of the emissions excursion. Principal Consultant Bill Gretta, who specializes in SCR testing and optimization, and AIG (ammonia injection grid) tuning, began his investigation by gathering gas-path data at the catalyst inlet and outlet using the company's proven top traverse method (Fig 2). Temperature and NO_x were measured at 12 elevations via each of the HRSG's seven roof ports (total of 84 data points), as shown in Fig 3.

Initial results revealed very high NO_x (more than 10 ppm) at the SCR outlet in locations directly in line with the baffles separating the tube banks. Temperatures in those same locations exceeded 1000F when duct firing. By contrast, SCR outlet NO_x readings in regions away from the



3. Locations for measuring NO_x and NH_3 are shown on a front elevation drawing of the SCR along with results of measurements taken before and after baffle repair

baffles, where temperatures typically were about 740F, were generally less than 1 ppm.

Thus, ammonia had to be over-injected to reduce overall stack NO_x to permit limits. This led to high ammonia slip and high ammonia consumption (524 lb/hr), and the plant could not maintain its stack NO_x limit when duct firing.

SCR Solutions determined that the baffles were not designed properly and failed. Thermal expansion was a contributing factor. The resultant openings in the failed baffles allowed a significant amount of high-temperature gas to sneak through the box and get to the SCR, damaging some of the catalyst.

The baffles were repaired and testing was repeated in the same locations. As shown in Fig 3, the downstream temperatures in line with the baffles were reduced to about 800F. Important to note is that no changes were made to the system beyond baffle repairs.

NO_x values at sampling locations in line with the baffles were closer to the stack average post repairs and typical of NO_x values in regions of the catalyst away from the baffles.

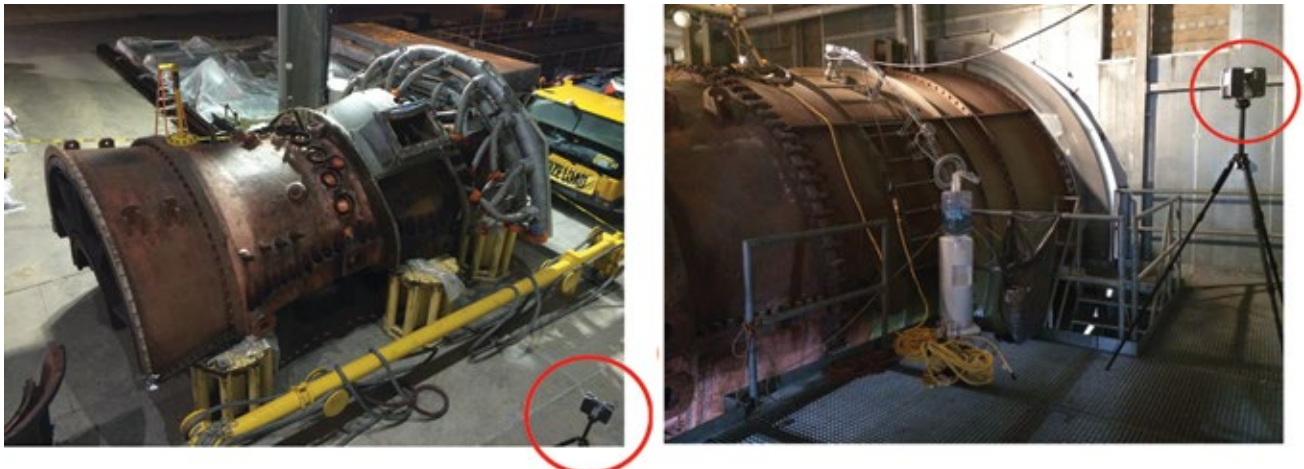
Ammonia flow was reduced to 417 lb/hr—a 20% reduction—allowing the plant to operate with duct burners at 100% capacity. **CCJ**

Boost performance with an upgraded insulation system

User-group meetings, virtual and in-person, afford the opportunity to expand your knowledge of gas and steam turbines, generators, HRSGs, and plant auxiliaries and controls. Presentations by Arnold Group at the 2021 meetings of the 501F Users Group (forum.501fusers.org) and Alstom Owners Group (www.aogusers.com) illustrate the level of detail you can expect from many vendors discussing their areas of technical expertise.

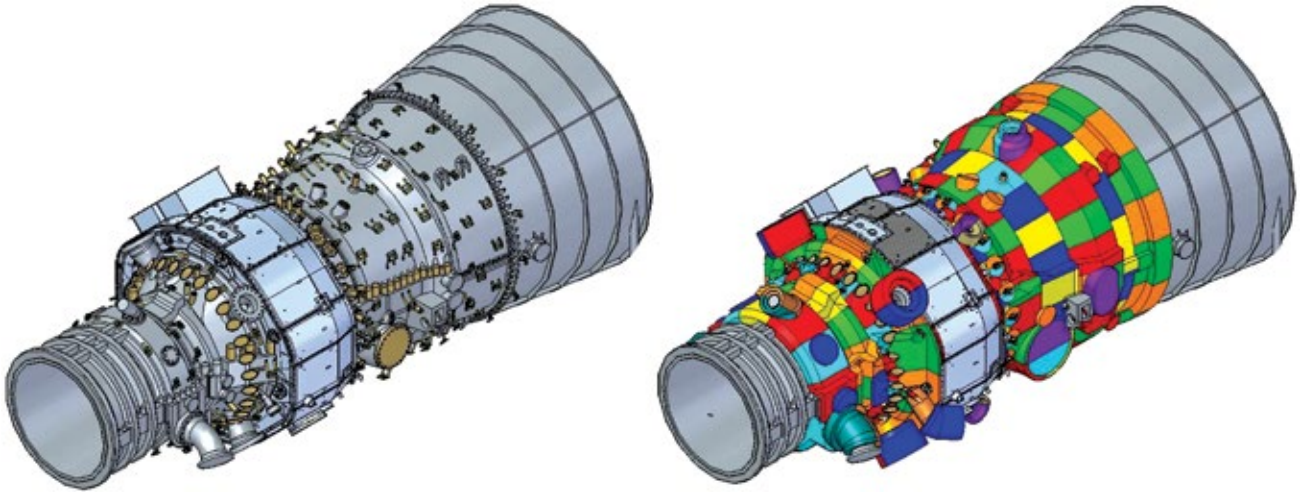
1. Engine inspection revealed degraded insulation that the owner's engineers concluded should be replaced

2. Decision to re-insulate made, first step is to strip clean the unit of old insulation and prep for new insulation



3. Laser scanning of the casing provides the surface data required by design engineers to assure a perfect fit with the new insulation. This step may be omitted in cases where data are available from previous scans of the same engine model

4. Back in Arnold Group's shop, the scans are compiled and processed into a 3D model as the progression of illustrations above shows



5. Next, Arnold engineers design the support structure and insulation system and incorporate it into the model

You can learn a great deal by simply listening. Case in point: Casing insulation systems for steam and gas turbines. Insulation is an afterthought at many plants until the gas-turbine package temperature exceeds best practice or someone inadvertently is burned by contact with a very hot turbine shell.

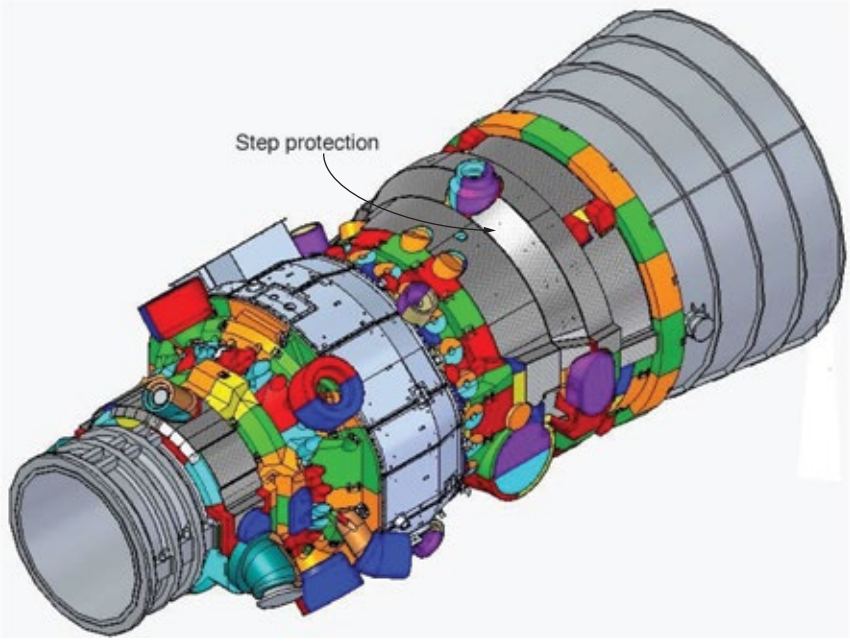
Questions you might ask to help decide if a new insulation system is in your plant's future:

- How would you inspect your unit's insulation to determine if it is beyond its useful life and replacement with an upgraded system would improve both performance and safety?
- What are the key steps in the replacement process?
- How long does such a project take from inspection to determine current condition to restart after installation?

You're sure to have other questions as well—most of which can be answered during the Q&A or discussion session after the presentation or when visiting the supplier's booth (virtual or in-person) at the end of the conference day.

The photos here walk you through the re-insulation of a GT24, a process similar for all gas-turbine frames, as well as for steam turbines. Spending a few minutes looking at the images will likely raise questions in your mind about things you want to know more about to make better decisions for your plant in the future.

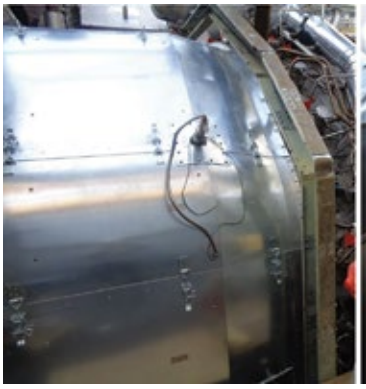
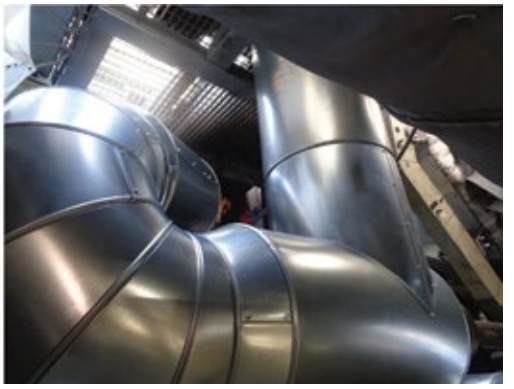
Contact Arnold Group's Pierre Ansmann (pierre.ansmann@arnoldgroup.com) directly for more information. CCJ



6. The final engineering step is the addition of step protection on the model. It is fixed to the support structure and protects against damage to insulation during inspections, package maintenance, etc


7. Back in the field, after the model is complete, the M10 studs shown in the left-hand photo are welded to the casing. The insulation support brackets at the right are attached to the studs with Nord-Lock hardware and a hex nut


8. Installation of insulation is next; note step protection in the right-hand photo

9. Following step is installation of C-MAS insulation with quick-release fasteners (left) and flexible galvanized-steel cladding to protect piping (right). Note that C-MAS is a secondary sheet-metal casing wrapped around the combustor/turbine section. Low-pressure air flows in the annulus between D-MAS and the primary casing to help the latter expand uniformly


10. Best practice: If the gas turbine is exposed to atmosphere during the work described above, be sure to protect the insulation installed from the elements (left). The completed job is shown at the right

Alstom Owners Group Fifth Annual Meeting

Virtual: February 7 – 11 and 14 – 18, 2022

The Alstom Owners Group, born of necessity to help owner/operators navigate the O&M challenges arising from GE's purchase of Alstom in November 2015, looks ahead to its fifth annual meeting in February 2022. Although work on the conference is just beginning as CCJ No. 68 goes to press, there is some information that can be shared at this point. Most important: Registration is now open at www.aogusers.com and there is *no charge* for users. Stay tuned to the organization's website for the latest information. Questions? Contact Ashley (ashley@aogusers.com).

AOG 2022 begins Monday, February 7, at 9 a.m. with introductions and keynote presentation. A two-hour end-user session follows at 10. Tuesday is GE Day. Wednesday, Thursday, and Friday are arranged similarly with a 30-min presentation, case study, or best practice from an owner/operator at 9:30, followed by four half-hour presentations by solutions providers from 10 until noon. The next hour is reserved for users to meet virtually with the day's solutions providers. Adjournment is at 1 p.m.

Focus of conference activities on Wednesday and Thursday is the gas turbine. The Friday program covers steam turbines, generators, auxiliaries, and controls.

The second week of the meeting is dedicated to training, with two two-hour modules each of the five days. The first training session runs from 10 until noon, the second from 1 to 3.

AOG 2021

The fourth annual (2021) AOG conference was live-streamed from PSM's global headquarters in Jupiter, Fla. This location made possible a virtual tour of host's 105,000-ft² workshop and repair facility, complete with demonstrations at work stations of interest to owner/operators—including blade and vane repairs, additive manufacturing, flow testing, brazing of cobalt and nickel alloys, welding, and machining.

Recall that AOG is a private user organization that enables owner/operators of Alstom gas and steam turbines to communicate directly with each other, and with third-party services providers, in a secure setting. Membership is limited to individuals directly involved in the construction, operation, and/or maintenance of Alstom turbines and who are employed by companies with ownership and/or operational interest in those turbines.

Content for, and conduct of, the conference was organized by the steering committee, which remains the same for 2022:

- Brian Vokal, Midland Cogeneration Venture.
- Pierre Ansmann, Arnold Group.
- Robert Bell, Tenaska Berkshire Power.
- Jeff Chapin, Liburdi Turbine Services.
- Chris Hutson, Southern Company.

The 2021 meeting opened Monday, March 1, at 8 a.m. (Eastern) with a two-hour user-only session focusing on the repair, service, and maintenance of GT8, GT11, GT13, and GT24/26 engines. The goal: Help owner/operators increase reliability and control costs. Program featured a formal presentation by an owner/operator, followed by open discussion.

The OEM's two-hour session, focusing on generator maintenance and associated recommendations, followed the end-user program and completed the day's activities. The remainder of the conference was as follows:

Day Two, Tuesday, began with a keynote presentation on cybersecurity by Mark Uggett of IGI. The topic: Evolving attacks threaten electric-system reliability. MD&A followed with a 30-min presentation on its generator capabilities. Half-hour sessions hosted by Pioneer Motor Bearing, TRS Global, Camfil, Doosan, and Power Services Group (PSG) followed. A two-hour vendor fair for the day's presenters closed out the Tuesday program.

Day Three, Wednesday, featured half-hour presentations by solutions providers Liburdi Turbine, EPRI, Emerson, Rochem, Hughes Technical Services, and AGT Services, followed by a two-hour vendor fair for the day's presenters.

Day Four, Thursday, featured the same program arrangement as Wednesday, with the following companies participating: PSM, Arnold Group, Major Tool and Machine, National Electric Coil, GCMS, and Noxco.

Training Day, Friday, began with a virtual shop tour of PSM's facilities. Six concurrent two-hour training sessions followed. The hosts were Liburdi

on gas-turbine condition assessment (two presentations, one in Spanish language), Camfil on GT inlet filtration, Pioneer Motor Bearing on bearings, Emerson on control systems, AIM Power Consulting on long-term service agreements, and Hughes Technical Services on P13/blueline control system training.

Visit https://forum.aogusers.com to access the presentations.

End-user session

The program opened with a presentation by Chris Hutson, Georgia Power, "GT11N Series OEM-Recommended Schedule Maintenance and Inspections," which was divided into three sections: Inspection methodology, mechanical work, and commissioning work.

Hutson began by (1) highlighting critical action items in a suggested planning cycle which starts 29 months prior to the outage, and (2) discussing the key factors influencing maintenance and inspection scheduling. The latter includes plant priorities, availability requirements, onsite maintenance capability, duty cycle, cost of downtime, type of fuel, etc. Next came a review of A, B, and C inspection scopes and their scheduling for both gas and liquid fuel.

Pre-shutdown checks was the first segment of the mechanical-work portion of the presentation. Having operational data is important because the information recorded can be used in combination with condition assessment to identify any underlying issues. To illustrate the point, Hutson noted that a short coast-down time with high bearing metal temperature can be an indication of a bearing or shaft misalignment.

Taking accurate disassembly measurements is important—such as radial rotor position, compressor blade and vane clearances, and labyrinth and oil-seal measurements—and he provided details on the proper procedures for doing this. Certainly of value to someone with limited experience on Alstom 11N machines.

Work scopes followed for the inspection and repair of SB burners and combustors, and EV burners.

Discussion of steps involved in cold commissioning provided valuable checklists in these areas:

- Preparational checks.
- Instrumentation re-commissioning.
- Auxiliary-systems re-commissioning.
- Systems associated with the GT block—including ignition, compressor blow-off, variable-inlet guide vanes, flame monitoring, pulsation monitoring, fuel distribution.
- Turbine protection.
- Hot-commissioning instrumentation.

A review of hot commissioning work closed out Hutson's presentation.

Interactive discussions among users followed on these points:

- Recommendations related to the installation and operation of dehumidification systems, plus lessons learned.
- Experience in the 11N1 fleet with the hardwired pressure switch for starting the emergency dc lube-oil pump. User seeking guidance said he was not getting sufficient pressure drop across the manifold while simulating this low-pressure event to perform an emergency dc lube-oil function test.
- Rotor life management—repair or replace?
- Operating experience with replacement rotors manufactured by a third party.
- Sharing of experiences with third-party vendors, especially in component repair (delivery issues, lag

time, lack of availability, etc).
- Review of recent Technical Information Letters and other OEM notifications.
- Inspection methodology.
- Maintenance challenges.
- Inspection experiences (bearings, burners, etc).
- Re-commissioning challenges—cold and hot.

One of the discussion topics receiving great interest concerned third-party rotors. The example shared was Doosan Turbomachinery Services' experience at Midland Cogeneration Venture, which, at the time of the meeting, had three new 11NM Doosan rotors in operation and had experienced no issues with them. Two more engines at the 12-unit site were said to be receiving new rotors in 2021. Plus, three rotors removed from the Midland units were slated for life extension.

OEM session

GE's two-hour session on Day One of the meeting focused on generator maintenance and recommendations. Presentation opened on the theme that enhancing reliability to support life extension keeps fleets relevant. Reliability impacts were said to involve thermal, ambient, electrical, and mechanical factors, and that as the years tick by, the risk of a forced outage increases—more so for units in cyclic service. The speaker said that rewind risk for rotors increases after about 15 to 20 years of service, for stators after 25 to 30 years.

Owner/operators can reduce the risk and impact of unplanned rewinds, the group was told, by taking these steps:
- Follow GEK103566 (Rev M) recommendations.
- Consider continuous monitoring for rotor and stator (shorted turns, PD, shaft voltage, flux, etc).
- Consider stocking long-lead-time parts (rotor rewind kit, stator bar set, brushless exciter, etc).
- Consider a rotor exchange to reduce out-of-service time.

A review of Technical Information Letters to guide upgrades was next, followed by several suggestions for reliability improvements. Included were the following:

New TIL 2256, concerning top-turn deformation, pertains to air-cooled 60-Hz machines manufactured after 1996 (WX/Y 21Z and WX/Y 23Z). The background: Evidence of rotor insulation damage was identified which could lead to a ground fault, although no unit in service has experienced this yet. Root causes based on analysis are plastic deformation from stress during over-speed, and creep over time leading to further plastic deformation.

Recommendations are to replace both the top two turns (with the latest configuration) and cover channels during a partial or full rewind. For details, access this TIL and other support material at https://mydashboard.gepower.com.

New TIL 2241, "Rotor Winding Connection Inspection and Replacement," applies to air-cooled WX/Y 21Z and WF 21Z generators, as well as to hydrogen-cooled WT 21H units. Background: The two winding connections connect the inner-most coils of the rotor winding with the radial. Cracks have been found; in most cases only one lamella was affected. No forced outages have been attributed to this issue at this time. Crack indications can be found with a visual (borescope) inspection. If so, replacement of the winding connections likely would be necessary.

TIL 2119, regarding rotor pole-to-pole connector cracking, applies to generators manufactured between 1996 and 2015—air-cooled WX/Y 18Z, 21Z, 23Z, and 25R; hydrogen-cooled WT 21H and 24H; and water-cooled WT23E and 25E. The problem: Cyclic

load during start/stop operation causes low-cycle material fatigue and can lead to cracking. Recommendations:

- Replace the pole-to-pole connectors (requires a rotor pull) with upgraded configuration at the next scheduled major or robotic inspection for machines with 700 starts or more.
- Visually inspect units with 1000 starts or more within one year. For all other units, visually assess the condition of the pole-to-pole connection during each inspection until a replacement is performed.

Improvement 1: Rotor blocking for air-cooled 60-Hz generators. Implementation of this improvement reduces the possibility of displacement of the tangential spacers impacting generator availability and reliability.

Improvement 2: Retaining-ring liner upgrade to prevent direct contact between the rotor top turn and the retaining-ring liner, thereby avoiding a ground fault and subsequent forced outage. Applies to WX/Y 16L/Z, 18L/Z, 21L/Z, and 23Z 50- and 60-Hz air-cooled machines.

Improvement 3: Damper fingers upgrade to speed up retaining-ring removals during inspections, thereby increasing outage efficiency. Applies to WX/Y 16L/Z, 18L/Z, 21L/Z, and 23Z 50- and 60-Hz air-cooled generators.

For a deeper dive into the OEM's topics, visit GE's MyDashboard website at https://mydashboard.gepower.com.

Vendor presentations

AGT Services Inc

Generator high-voltage connection, bushing box, and bushing inspections

Jamie Clark's well illustrated presentation focused on these three areas:

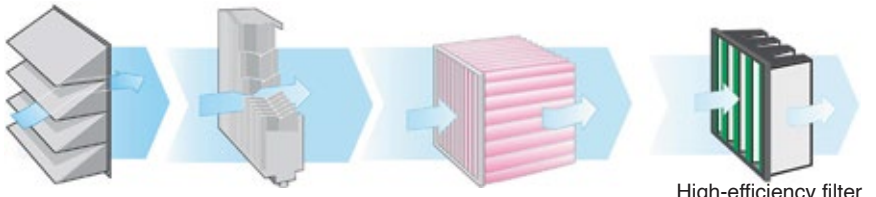
- High-voltage connection inspections, answering the questions most often asked by users: How/why do HV connections overheat? He covered flexible connections, the importance of tight surface contact, hardware (bolt/nut, washers, etc) selection, and connection restoration.
- HV bushings for pressurized gas-cooled generators: What to look for in bushing inspections and how to locate gas leaks.
- Main-bushing construction methods—addressing porcelain insulators, flange designs, and conductor designs.

Asked what type of bolts AGT Services uses on HV bushing mounting flanges, Clark responded thusly: Typically carbon steel but sometimes duronze. Stainless-steel bolts are avoided because they tend to gall on aluminum or stainless terminal plates or nuts/hardware.

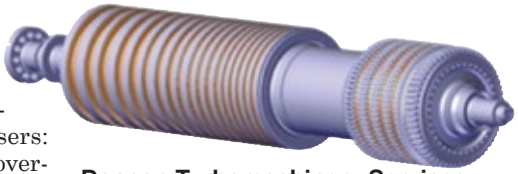
He went on to say that tight connections are critical for keeping HV bushings cool, recommending the blue-checking of electrical connections at disassembly and reassembly and verifying proper alignment.

When bushings must be replaced, Clark said pre-planning is key to a successful project. For example, be sure to arrange for access to both the inside and outside of the bushing box and be familiar with plant auxiliary equipment removal and lockout/tagout requirements, scaffolding needs, foreign material exclusion, etc.

AGT Services Inc: High-voltage connection inspections, HV bushing types for pressurized gas-cooled generators, main bushing construction methods



Camfil: Primer on gas-turbine air inlet filtration systems covers impact of filter performance on GT performance, how filters work, rating standards and testing, lifecycle cost analysis, and much more



Doosan Turbomachinery Services: Rotor lifetime extension and new welded rotors for Alstom gas turbines

Arnold Group

Steam-turbine warming systems for startup improvement

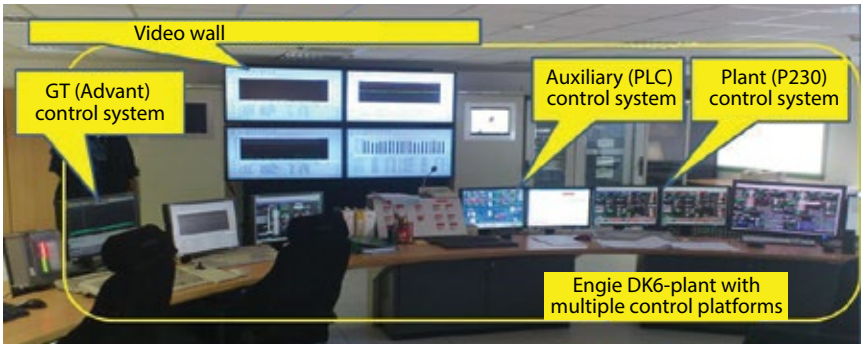
The highlights of Pierre Ansmann's presentation were summarized last issue (No. 67, p 86) in CCJ's report on the 2020 meeting of the Steam Turbine Users Group. Elsewhere in this issue, please see Ansmann's recommendations on how to "Boost performance with an upgraded insulation system."

Camfil

PowerEye™: Squeeze more power out of thin air

Project Manager Malcolm McClintock, Regional Manager Brock Hamlin, and GT Product Manager Gautam Marwaha reviewed what Camfil says is its most innovative product yet, PowerEye, a predictive analytics engine to help you transition from a condition-based maintenance mode to a predictive mode. The purpose is performance optimization.

PowerEye, said to be installed in many plants, is designed to help you understand the impact that environmental conditions, changing weather patterns, and filter status has on engine health and performance. It pulls information from these sources:



Emerson: Control solutions for Alstom Heritage gas turbines and combined cycles; case history for an Engie DK6-plant HMI

- Site historian.
- The air monitoring station installed on the dirty side of your filter house, which captures temperature, humidity, and the concentration of particulates in ambient air.
- Online weather services.

The information is analyzed for decision-making critical to maximizing revenue—such as the optimal time to clean/replace filters. Case histories are included.

Doosan Turbomachinery Services

SangJoo Lee focused on Doosan's component and rotor repair centers for large gas and steam turbines in La Porte, Tex (near Houston). He then described the company's GT11NM welded-rotor technology and lifetime extension program for gas turbines and its D11 drop-in solution for steam turbines, said to offer performance and reliability benefits over the existing machine. D11 improvements include a reduction in startup time, an increase in output, easier maintenance of HP valves, and elimination of casing-cracking and diaphragm-dishing issues.

Emerson

Control solutions for Alstom Heritage gas turbines and combined-cycle powerplants

Dave Cicconi reviewed Emerson's lineup of gas-turbine control systems for retrofit applications and new-build engines (including AE94.3A, GT26, and GT36). The company's experience list encompasses over 850 gas turbines (frame and aeroderivative models) with Emerson controls—including units manufactured by GE, Siemens, Alstom, Mitsubishi, and others.

The case study involving a GT13E2-powered 2 × 1 combined cycle in France illustrates the third-party vendor's capabilities. Project involved replacing legacy GT controls with an Ovation system during a 13-day outage.

Hughes Technical Services: P/13
BlueLine control systems training

This was the first time a company other than the turbine OEM had been selected to retrofit the controls on this model gas turbine.

Flexibility was a factor in the owner's decision. Ovation is an open system, allowing plant personnel the opportunity to modify applications or adapt the controls to accommodate future plant expansion.

Electric Power Research Institute

GT24/26 outage plan and technical support manual overview

Technical Executive Leonard Angello, well known to US generation professionals, presented on the research organization's GT24/26 "Outage Plan and Technical Support Manual," designed to help owner/operators plan, manage, and document major overhauls. It includes custom-built databases with details on the numerous maintenance tasks necessary to complete a gas-turbine major inspection. Note that this is a "living document," updated as new issues evolve.

Volume 2 (Assessment and Inspection) of the three-volume work features 44 Inspection Assessment Data Sheets (IADS forms in EPRI lingo) arranged in four parts categories: combustion, rotating, stationary, and structural. Examples of forms in the rotating category are LPT blade row 1, HPT blades, and HPC blade row 20. A similar format

is used for all IADS forms, which are unique to specific component features, issues, and inspection criteria.

The form illustrated by Angello was for HPC blade row 20. Assessment findings are defined by condition (such as chip, crack, bulging, erosion, etc), severity (minor moderate, substantial), and location (leading edge, trailing edge, platform, etc). There are corresponding Field Guidance (FG) documents for each component. They provide corrective actions and recommendations.

Global Consulting & Mechanical Services

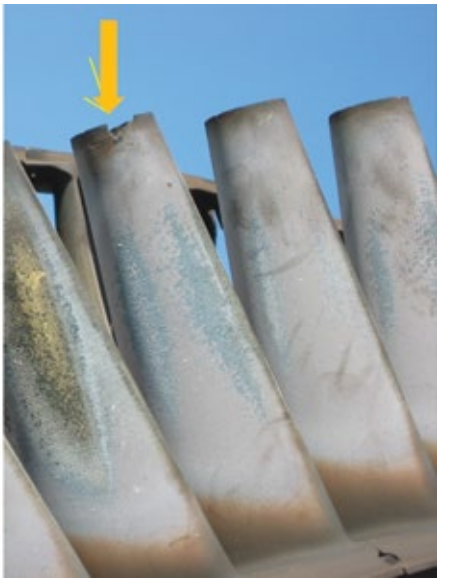
The road to mechanical malfunction paved with good intentions

Andy Smoak's presentation is a brief case history of a gas-turbine bearing oil leak that led to a fire. Plant staff believed an increase in vacuum and frequent checks of the drain pot would allow operation with minimal risk of fire until permanent repairs could be made. That was not the case. Others can learn from this experience.

Hughes Technical Services

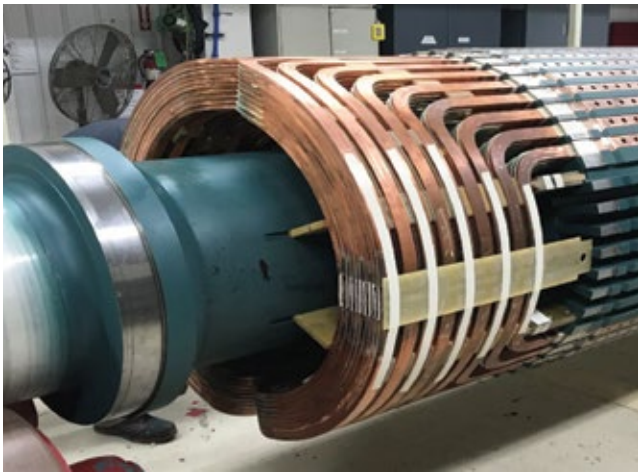
Advanced power plant services and solutions

If you want to know what HTS can do for you regarding plant commissioning and maintenance, listen to Fernando Velez's presentation. The company specializes in control system service, upgrade, and retrofit, and excitation and frequency conversion. Gas and steam turbine services also are offered, along with balance-of-plant solutions. Presentation, in effect, is a "laundry list" of HTS's offerings.



Liburdi Turbine Services: Gas-turbine durability improvements through repairs, plus a training session on GT condition assessment

Major Tool & Machine: Stationary repairs and replacement parts for legacy Alstom gas turbines



MD&A: Discussion of issues affecting Alstom generators—including pole-to-pole connector failures, slot-armor cracking, top-turn deformation, etc

National Electric Coil: Stator rewinds and maintenance for large Alstom WX/WY generators

TRS Services: Comprehensive O&M support and asset performance management for GT8, GT11, GT13, GT24/26 engines

Liburdi Turbine Services

Gas-turbine durability improvements through repairs

Doug Nagy began by quantifying the benefits of going beyond standard repairs on two GT11N2 gas turbines over a period of 10 years. The benefits of so-called durability repairs were the following:

- Availability increase from 92% to 98.5%.
- Repair yield of 98.3%.
- Service interval extension of 25%.
- Extended lives on airfoils.
- No reduction in power output.

Here were some of the actions taken:

- Leading edges of compressor airfoils were re-profiled in lieu of blade replacement.
- Rejuvenation heat re-treatments to re-strengthen superalloy components to resist deflection and cracking.
- TBC coating optimization: (1) Full-area TBC coverage on more components and surfaces. (2) Stress-relieved, thicker TBC layers to reduce temperatures at the bond/coating interface.
- Geometric stiffening of components to prevent buckling.
- Upgraded honeycomb alloy reduces oxidation.
- Design improvements to eliminate high-cycle fatigue.
- Airfoil wall-thinning correction using Liburdi Powder Metallurgy (LPM).
- Vane salvage: (1) Use of custom filler metal to reconstruct vanes badly cracked from cyclic duty. (2) Use of LPM tape to repair and hard-face wear points.

The speaker closed by explaining the company's repair engineering and validation process.

Pioneer Motor Bearing: Training session covers the role of bearings in machines, hydrodynamic film degradation, information for a successful refurbishment, bearing refurbishment, inspection of a refurbished bearing

Major Tool & Machine

Source for legacy Alstom stationary repair and replacement parts

Hans Lissman introduced MTM to users, several of whom might not be familiar with the privately owned non-union company and its considerable fabrication and machining

capabilities in more than 620,000 ft² of environmentally controlled shop space. The Indianapolis-based firm employs more than 375 personnel, many highly skilled.

MTM has compiled an enviable reputation in the power-generation and oil-and-gas industries worldwide over the last three decades. It has done repair and new-build work for GE, Siemens, Ansaldo/PSM, Solar, and other gas-turbine OEMs and contract manufacturers. Experience in the fabrication and machining of superalloy hot-section components raises MTM's profile among third-party specialty suppliers to the industry.

The company has participated from concept to design to manufacture of stationary components for several Alstom gas turbines—including the GT11 series of high interest to AOG attendees. Regarding the various GT11 models, it has fabricated pressed parts, collars, and other components for hot-gas casings; liners for the lower combustor; tile carriers for Rows A through D; swirlers; shield cones; air mixing nozzles, and other parts. Plus, it has experience in a wide range of repairs.

Power Services Group: Steam-turbine diaphragm dishing and its correction

Mechanical Dynamics & Analysis

MD&A capabilities on Alstom generators

Mark Crittendon, MD&A's Generator Div engineering manager, summarized the key issues affecting Alstom's legacy gas-turbine fleet. He noted that this fleet of air- and hydrogen-cooled generators is comprised of many different arrangements, some with unique designs manufactured by legacy companies.

Points to keep in mind as you read through the key issues affecting the fleet (italics below): The majority of legacy Alstom generators in North America are air-cooled and the manufacturer has relied on air-cooled technology for some relatively high-output machines.

Pole-to-pole cracking issues can be identified by borescope inspection during a generator minor or major inspection. Crittendon said the 60-Hz 23Z and 50- and 60-Hz 21Z legacy fleets have experienced quality issues with the pole-to-pole connectors. Specifically, indications have been found on the braze interface and the connectors themselves. If not addressed, serious damage to the generator could result.

Slot-armor cracking. One of the field components impacted by cycling is the slot armor, which insulates field coils from the rotor forging. Spe-

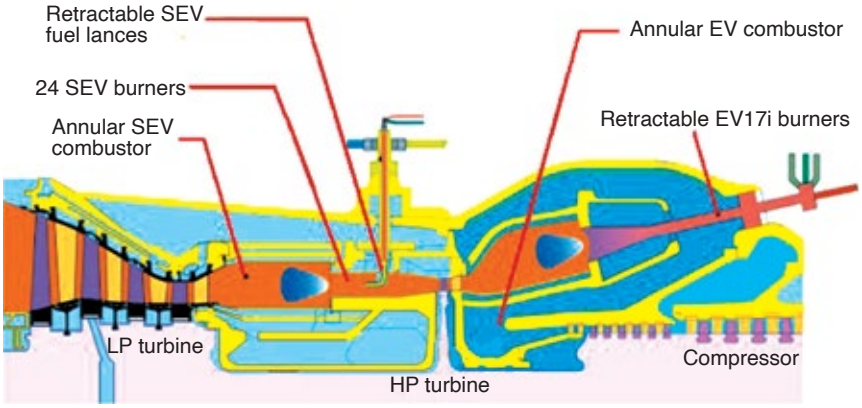
cifically, cracks in the slot armor have been found in the slot exit region in the 60-Hz 23Z and 21Z fleets. If this condition is not addressed, serious damage to the generator can occur. Cracking can be found by borescope inspection during a generator minor or major. MD&A's solution involves a field rewind, including replacement of the original slot armor and armor caps.

Bar corona protection. Crittendon said the legacy 50- and 60-Hz 23Z fleets have experienced quality issues conducive to corona activity in the end-winding region where the stator bar exits the slot. Specifically, damage to the grading tape has been observed. Failure to correct can lead to damage of ground-wall insulation. The speaker explained MD&A's solutions to address corona activity in both the slot and endwinding regions.

Phase connection lugs. Phase connection failures in the 60-Hz 21Z fleet have exposed quality issues with the lugs. MD&A offers a redesigned replacement to correct the problem.

Stator slot side filling has migrated axially outward at the ends of the slots on both 50- and 60-Hz generators—in particular, those in cycling service. Recall that side filling helps keep stator bars secure in the slot and ensure there is electrical contact between the stator bars and the stator core. Crittendon explained his company's repair to address the issue.

Top-turn deformation can occur because of quality issues with field coils in the 60-Hz 18L/Z fleet. An MD&A repair procedure is available to address the deformation problem.



EPRI: Outage plan for GT26 engines

National Electric Coil

Key considerations for large Alstom WX/WY generator stator rewinds and maintenance

Howard Moudy opened his presentation saying that significant contributing factors to a stator rewind are spark erosion and endwinding looseness and resonance. He focused on spark erosion—what it is, how it occurs, the damage it causes, etc, then explained how the damage is corrected and the time and cost associated with returning the machine to service.

Moudy explained, with the help of high-quality photos, important steps in the rewind process and the advantages of upgrading the winding with slot side packing and other design enhancements to enable a "permanent" solution. Stator maintenance and repair considerations discussed include the following:

- Borescope spark-erosion inspec-

tions.
- Bump test.
- Robotic inspections and electrical testing.
- Critical parts.
- Partial-discharge maintenance/repairs.

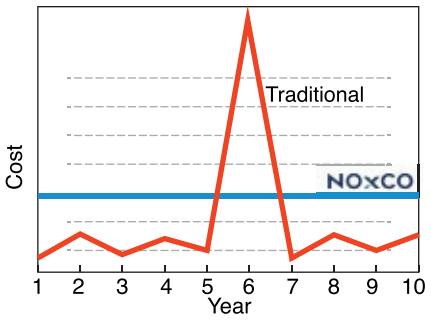
Noxco

Guaranteed emissions compliance for your aging plant

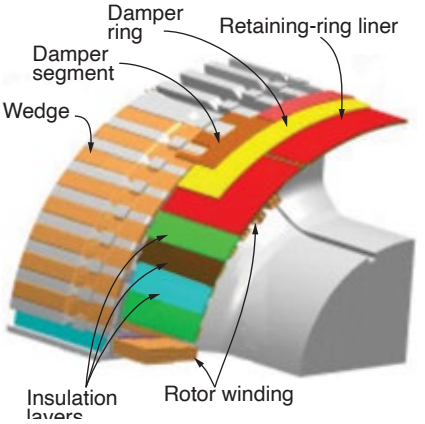
CEO Jeff Bause opened his presentation by explaining to turbine users how Noxco is raising an industry bar with the first LTSA (long-term service agreement) for emissions compliance. He said that by removing the burden and responsibility for protecting and managing complex systems from owner/operators, Noxco delivers performance, predictability, cash flow, and 100% risk mitigation through a turnkey solution.

Bause is well-known to many CCJ readers for his deep knowledge of catalyst system maintenance, gained over the years as CEO of Groome Industrial Service Group. He is a frequent speaker at industry events on SCR and CO catalyst cleaning, repacking, and replacement, plus the cleaning of ammonia vaporizers and injection grids, as well as of HRSG tubes.

Noxco's turnkey solution, Bause says, increases the operational flexibility and performance of the SCR, CO catalyst, and ammonia injection system (AIG) to deliver sustained peak performance at the lowest lifecycle cost. LTSA benefits include all system maintenance, inspections, tuning, optimization, catalyst testing and cleaning, catalyst replacement with the optimal product for your site and operating conditions, spent catalyst disposal, AIG design optimization and tuning, and performance upgrades.



Noxco: Comparing the traditional aftermarket catalyst spend to the annual cost of Noxco's guaranteed emissions compliance program for aging gas turbines



GE Gas Power: Upgrade solutions for owner/operators of D11 generators

Pioneer Motor Bearing

Keeping track of endless mods to legacy turbine equipment

The presentation by Robert Swisher and Juhani Karhatsu had a simple message: It's important to keep track of the changes and updates to your equipment to avoid a maze of potential problems during overhauls and when repairs are required. Virtually everyone involved in plant operations would agree with this, the editors assume, yet given today's reduced staffing, multiple vendors onsite during inspections, information coming from many different directions at once, increased intervals between outages, and other challenges, don't bet on the accuracy of record-keeping. It's not your fault.

The speakers offered the following

formula for success:

- Concentrate on the last two to three outages.
- Review OEM reports from onsite work, if any.
- Concentrate on parts that have a competitive marketplace.
- Embrace a secure cloud system, accessible by anyone, to maintain a virtual paper trail.

They later explained the robust CRM system Pioneer uses to track everything.

A case history on incorrectly bored pocket bearings is included in the presentation.

PSM

Introducing PSM and Thomassen: Innovative service solutions for Alstom legacy-fleet turbine operators

President Alex Hoffs and his technical staff brought owner/operators up to date on what PSM and its sister company Thomassen Energy had to offer the global Alstom fleet, focusing on clean energy solutions. Today these two companies operate as part of Hanwha Impact, a division of Hanwha Group's gas-turbine services organization. They were purchased from Ansaldo Energia in July 2021.

The presentation began with a review of PSM's capabilities in field service, repair, upgraded components, and global M&D with digital and service engineering. The initial focus was on the company's platform for enabling digital solutions for plant optimization—FlexSuite, including FlexStart, FlexRamp, minimum plant load, and HRSG stress evaluator.

A deep dive into enhanced controls flexibility underpinned by PSM's AutoTune product was next, with mention of its Peak+, Power+, transient tuning, FuelFlex capabilities, among others. Collectively, they reduce the risk of trips, eliminate manual tuning, enable turndown to low levels, mitigate combustion dynamics, and optimize hardware life and performance.

Upgrades for the GT26, the next major discussion point, reviewed PSM's engine performance and flexibility enhancements proven by experience on 29 units owned by 10 customers in 10 countries and based on more than 300,000 operating hours and more than 2500 starts. The gas turbine's ability to burn hydrogen was explained and the increase in inspection intervals touted. Details provided to illustrate the last point: standard GT26 interval, 28k EOH (equivalent operating hours); GT26 XL, 32k; and GT26 MXL2, 40k).

Reconditioning of GT24/26 fuel-injection burners and lances to improve the performance of the EV (EnVironmental) and SEV (Sequential EnVironmental) components was explained next. Fuel and air-flow calibration, sealing-surface restoration, and lifetime extension were key topics. PSM has reconditioned more than 250 SEV and 150 EV burners, reportedly with a low rejection rate.

A virtual tour of PSM's workshop in Jupiter (Fla) was included in the AOG program and is described in the training section later in this report.

Power Services Group

One reason owner/operators attend user-group meetings is to identify service providers beyond the obvious that are capable of providing solutions conducive to a more robust bottom line—like PSG Power Services Group, formed a few years ago by combining the capabilities and assets of Turbine Generator Maintenance (TGM), Airco Power Services, and Orbital Energy Services (OES).

Mike Lake, VP sales, focused on PSG's diaphragm-dishing analytical and repair capabilities, stressing that a viable repair must correct both the dishing prevalent in the diaphragm while mitigating future occurrences. The company's process for dish removal was discussed and illustrated by way of photos. Diaphragms with dishing up to 180 mils were said to have been repaired successfully. A diaphragm-dishing bridge repair case history also was presented.

Real Time Monitoring for Generators, Motors, and Transformers

Electro - Magnetic Interference Monitoring

The NEW and improved Algorithm Assessment tool maximizes the detection of potential failures before they occur. This long term planning tool allows plants to reduce their O&M budgets, while having fewer catastrophic outages:

Monitors and trends failures within

Motors and Generators:

- Arcing
- Dirty Stator Windings
- Broken Rotor Bars
- Partial Discharge
- Defective Bearing Insulation
- Defective Motor Lead Insulation

Transformers:

- Water Intrusion and Insulation Breakdown
- Cracked Insulators
- Damaged Wedges
- Isophase Bus Failrues
- Contamination on Windings

- **Benefits of EMI Monitoring:**
  - Early Detection Saves Money
  - Non - invasive installation - NO outage required
  - Lower costs compared to third party services
  - Fewer forced outages due to equipment failures
  - Automated data collection
  - Plants have remote access to data
  - Integrates into NI InsightCM™ to make analytics easier

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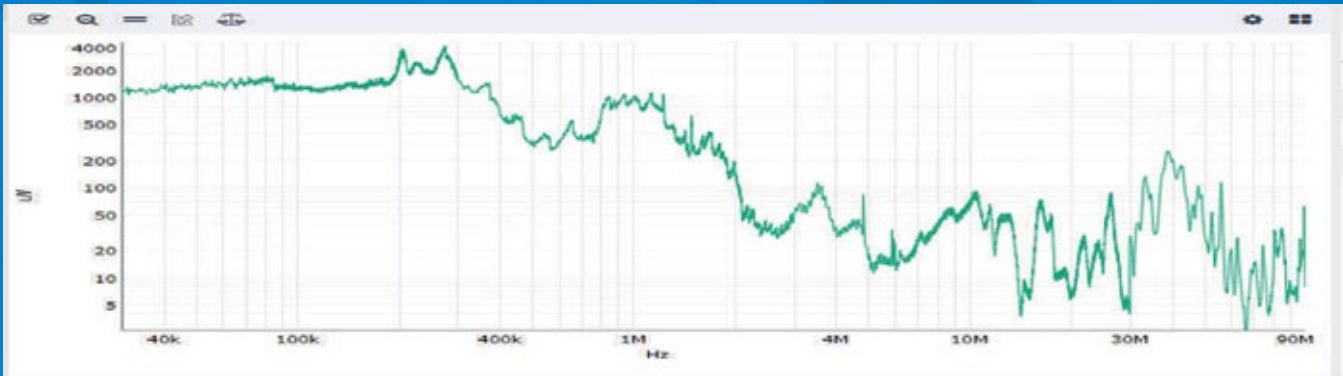
NO OUTAGE REQUIRED - EASY INSTALLATION

Power Spectrum



Assesment Table

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

- **Cutsforth Enhanced EMI system:**
  - » Classifies signals associated with defects in transformers, motors, and generators
  - » Identifies specific failure modes without the need for experts to review the data
  - » Archives data including time domain waveforms
  - » Easily creates trend plots for future analysis

ANAB ACCREDITED ISO/IEC 17021 MANAGEMENT SYSTEMS CERTIFICATION BODY

nqa. ISO 9001 Registered Quality Management

For more information, contact us:
Cutsforth.com/Contact
800.290.6458 x.1
info@Cutsforth.com

Rochem

The dozen most frequently asked questions about gas-turbine compressor cleaning

Martin Howarth and Steve Egelhoff answered the following questions during their recorded presentation, which the editors believe would have value for generating discussion among plant personnel during a lunch-and-learn in the break room.

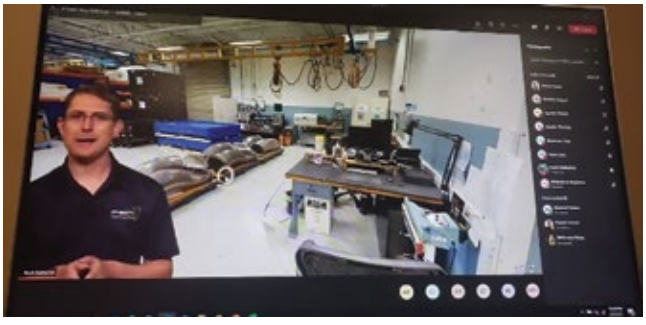
- What are the options when cleaning a gas-turbine compressor?
- What do I do with the offline wash waste?
- Is online washing effective?
- Why do we need to clean the compressor?
- What are the benefits of compressor cleaning?
- Water versus chemical cleaners?
- Is water-only washing effective?
- How do compressor cleaning chemicals work?
- Where should we locate the compressor cleaning nozzles?
- What if the foulant redeposits in downstream compressor stages?
- Must the washwater be heated?
- I have HEPA filters; do I still need a compressor washing system?

TRS Services

Comprehensive Alstom O&M support and total asset performance management

Greg McAuley of TRS and Siraj Taj of ST Power Services told attendees their companies have joined forces to provide Alstom owners and operators with a comprehensive portfolio of parts and services solutions that are more competitive and reliable than the OEM's current offering.

Recall that TRS provides turbine component repair, new-parts manufacturing, and consulting services geared to reduce fleet downtime and O&M costs. STPSC offers pragmatic solutions to extend equipment service life, reduce lifecycle costs, and increase profitability using its asset, obsolescence, and business-process management skills and a wide array of O&M support services.



1, 2. Lonnie Houck, director of shop operations, directs workshop tour from PSM's studio (left), shoots a segment on the shop floor (right)

Focus of the partnership's solutions are Alstom's GT8, GT11, GT13, and GT24/26 gas turbines. Specific solutions include the following:

- Parts repair and refurbishment.
- New and refurbished parts.
- Engineering and technical O&M support.
- Planned and unplanned inspections.
- Outage planning and management.
- Electrical and control systems (including AVR, SFC, generator protection, Egatrol, P13 Blueline).

Training workshops

Two of the distinguishing characteristics of annual meetings hosted by the Alstom Owners Group are its training workshops and facility tour. The 2021 program featured seven two-hour training sessions on the last day of the event (one in Spanish language) and a virtual tour of PSM's Jupiter (Fla) workshop. Plant managers were encouraged to select the topics of greatest interest and assign plant personnel to monitor each of those sessions, then gather in the break room for a round-table discussion of the highlights, best practices, lessons learned.

If you were not able to listen in on one or more the training programs described below, you can access them when convenient at https://forum.aogusers.com. The session summaries follow:

- **Gas-turbine condition assessment,** *Doug Nagy, Liburdi Turbine.*

Hot-section capital parts are life-limited and require periodic replacement. The repair versus replacement decision is an age-old debate containing facets of risk, technical, commercial, and schedule. Regardless of the decision, capital-parts condition upon delivery has a significant impact on gas-turbine reliability, efficiency, and availability. To verify suitability for service, engineering has a role to understand the manufacturability of new parts and the repairability of used parts.

This presentation helps you understand the limits of what can—and cannot—be done based on condition assessments. Numerous real-world examples of the good, bad, and ugly are included.

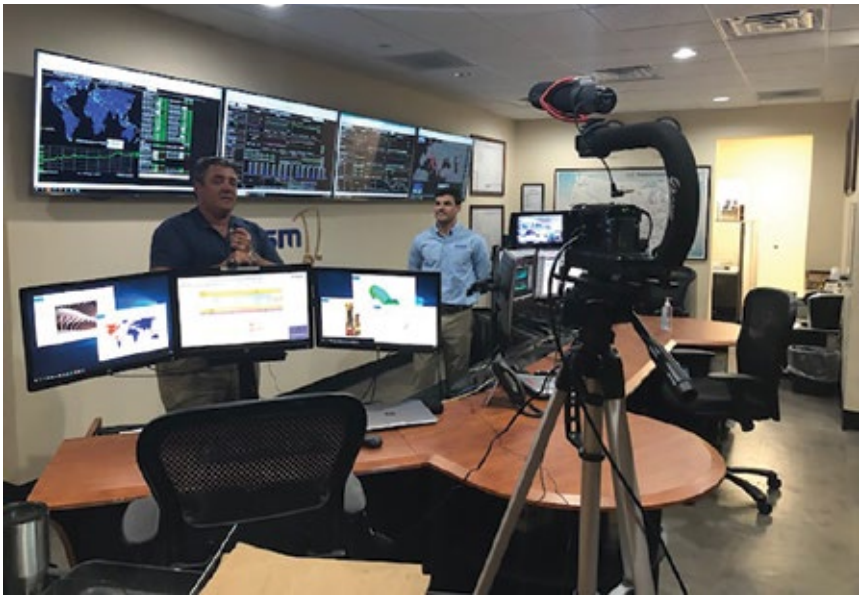
- **Recubrimientos contra la corrosion y la oxidation a altas temperaturas para components de turbinas a gas,** *Miguelina Curcio, Liburdi Turbine.*

Esta charla está orientada a que el participante visualice los criterios principales para la selección de un recubrimiento para proteger las partes capitales de una turbina a gas contra los mecanismos de degradación de su proceso de operación, así como, su importancia para reducir costos de reparacion y operatividad del equipo. Entre los temas a tratar, se analizaran las funciones del recubrimiento y cuáles son los principales mecanismos de degradación dependiendo de las condiciones de operatividad de la Turbina a gas. Se discutirán problemas de erosión, oxidación, corrosión en caliente, fatiga térmica, entre otros y como afectan estos mecanismos de degradación en la funcionabilidad de un recubrimiento para que sea eficaz,y mantenga su estabilidad mecánica y metalúrgica durante la operación del equipo.

- **Introduction to gas-turbine air filtration,** *Jim Benson, Camfil.*

Goal is to provide plant personnel information about filters and their impact on turbine operation. Beyond providing basic engine protection, inlet filters can impact plant performance. Trends in filtration (increased efficiency) and plant operation (fewer

3, 4. Segments of the shop tour are taped by roving camera crews (left and right)



5. M&D Center was included in the tour to illustrate PSM's global customer-support capabilities

service hours) are included in the presentation. Plus, software and IoT tools that can provide operational personnel greater insight on filter selection and performance.

■ **Industrial hydrodynamic bearings: Facts without friction and reliability without regrets,** *Dr Lyle Branagan, Pioneer Motor Bearing.*

Learn fluid-film bearing fundamentals—from operational theory to damage mechanisms. Plus, the intricate details of Alstom, Brown Boveri, Stal, and ABB bearing designs. Pioneer has more than 100 years of experience to share, as well as nearly 30 years as a licensee of ABB/Alstom/GE.

■ **Control-system training,** *Laurence O'Toole, Emerson.*

Focus of this session is on upgrade options available to users with legacy Procontrol and Alspa control systems for Alstom gas and steam turbines. Using a case study of a recent upgrade project, the presentation explains the options available to customers facing obsolescence and support challenges on the original systems and discusses lessons learned and issues to avoid to ensure success in managing your upgrade.

■ **Long-term service agreements, what's under the hood?** *Craig Nicholson, AIM Power Consulting.*

Topics included: LTSA negotiation/renegotiation, asset due diligence, gas-turbine performance benchmarking and evaluation, technical-issue resolution, commercial and technical support for major maintenance and controls upgrades, and onsite technical and quality-assurance services for outages and upgrades.

■ **P13/BlueLine control system training,** *Tom Douglas, Hughes Technical Services.*

Presentation is for operators, engineers, and managers who want to better understand their P13/BlueLine control system. Course covers hardware and software used to work with the system. Examples of how to follow signals through the system and logic blocks used are discussed. Also, additional details on the speed modules, Modbus communications (serial and TCP) and fiberoptic data transfer (70DH01 and 70DH02) are provided.

Shop tour

The virtual shop tour of PSM's facilities was an informative and interactive way to see some of the advanced technologies the company employs for the manufacturing and repair of gas-turbine hardware.

The tour was conducted from the PSM Studio by Lonnie Houck, director of shop operations (Figs 1 and 2). He walked viewers around the 105,000-ft² workshop using the latest 3D facility modeling technology, highlighting processes and capabilities along the way (Figs 3 and 4). An overview of the company's remote capabilities from its Monitoring & Diagnostics Center was included (Fig 5).

Two live segments from the workshop tour were of particular interest to attendees. One provided specific information on the thermal spray coating booths, the other on laser cladding equipment used for single-crystal component repair. CCJ

Ask the Chairman

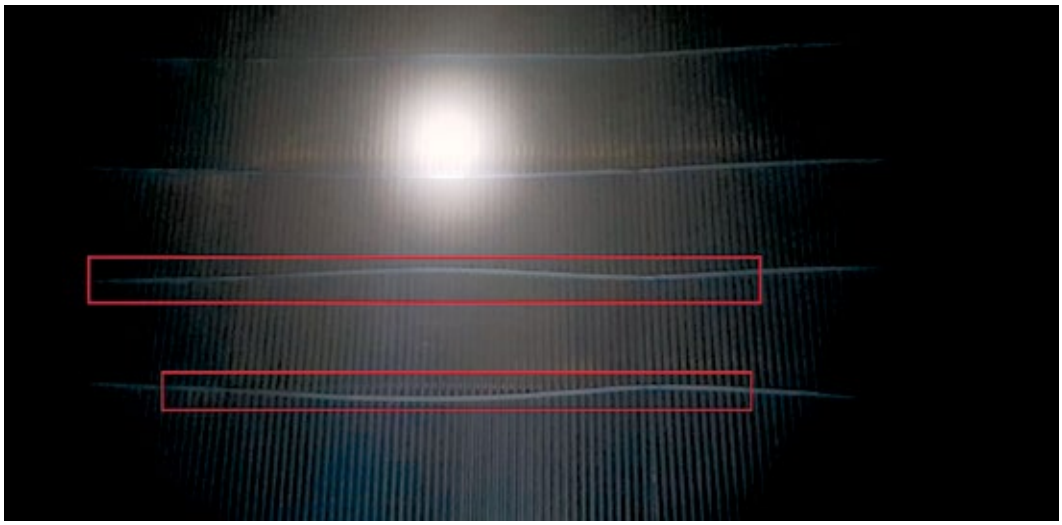
What is an acceptable amount of sagging/deflection for superheater tubes?

Submit your HRSG questions to
Bob Anderson, anderson@hrsgforum.com

An international user writes via the forum, *We have a horizontal dual-pressure HRSG (Alstom India) with bypass stack and diverter damper. A recent inspection of the HP section found that some tubes and face plates were "sagging" (photos). Those tubes are misaligned because of this. The same observation was made during the previous inspection, with no further deviation observed.*

Kindly review the pictures and advise if there is any standard or comparison document to benchmark the acceptable level of sagging/deflection in HRSG superheater tubes.

Thanks for the help in advance, **HB**.



HB: The bowing (you called it sagging) of tubes such as this is caused by water passing through and quenching (shrinking) these tubes while other tubes remain dry and hot. The water typically arrives from the attemperator, but can also come from undrained pipework or headers (manifolds in the case of the Alstom HRSG). There is no standard that I am aware of regarding the acceptable degree of bowing.

When bowing is severe, it creates large gaps between tubes, allowing bypass of exhaust gas, or permits adjacent tubes to contact each other. In such cases, the bowing generally is considered in need of correction. However, the degree of bowing in your photo does not look severe.

It is also typical not to be concerned about future problems being caused by bowing if it is moderate *and* not getting worse over time (as in your case). However, consider that the water causing the bowing may accelerate thermal fatigue damage in welds between interconnection piping and headers/manifolds. This can be a particular problem in the Alstom design.

The more important issue is where did the water come from and during what operating condition. A common source of the water is leaking attemperator spray when the tubes are hot with little or no steam flow (such as during startup and following shutdown).

Another source/event is overspray of the attemperator during startup, shutdown, and/or during low-load operation. If the steam temperature downstream of the attemperator drops below 50 deg F above saturation, overspray is occurring. The closer the steam temperature downstream of the attemperator is to the saturation temperature, the more damage that occurs in the tubes, headers, manifolds, and interconnecting piping.

Another source of water is the owner failing to ensure that superheater and reheater pipework, manifolds, and headers are completely drained of condensate and leaking spray water prior to initiation of steam flow during *each* startup.

Repeated water-quenching events may not result in increasing degrees of tube bowing if later thermal transients are not more severe than the initial transient that first caused the tube to bow. However, each repeated thermal transient *does* cause additional thermal fatigue damage in pipework to manifold/header welds and will eventually result in cracks. Thus, it is very important to identify why and when the thermal transients occur and apply corrective actions promptly.

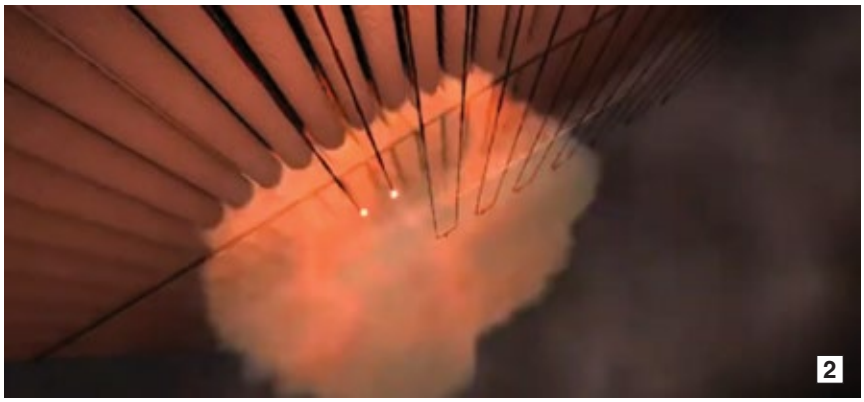
I routinely identify thermal transients and their causes, then suggest the necessary corrective actions for owners of HRSGs around the world. To dig deeper, find several papers and articles on the subject on my website at www.CompetitivePowerResources.US.

KinetiClean presents new option for HRSG tube cleaning

GC UG 2021

Calling it "safer, faster, and deeper" than dry-ice blasting, Jeff Bause, CEO, Groome Industrial Service Group, introduced participants in the 2021 virtual conference of the Combined Cycle Users Group to KinetiClean HRSG tube cleaning, a patented kinetic shockwave technique widely used in other industries but new to combined cycles. It was developed by Explosive Professionals Inc (ExPro), a detonation-based


1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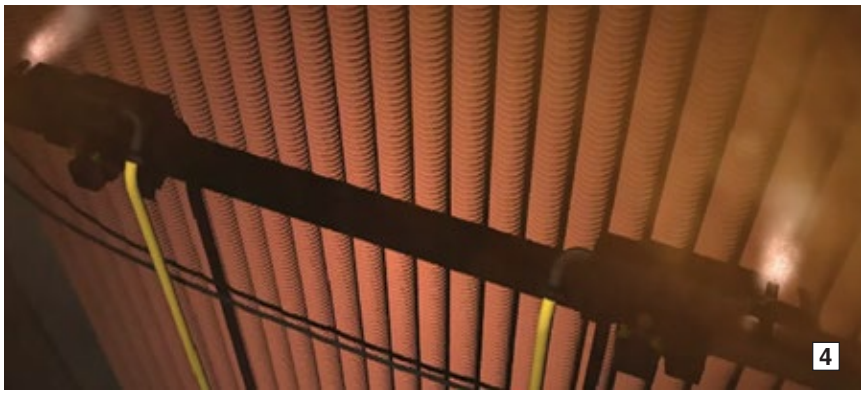
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5

Key steps in the KinetiClean tube cleaning process are described in this sequence of photos. A continuous length of detonating cord (Fig 1), hung between tube bundles from the top of the HRSG and extending the full length of the heat-transfer surface, is arranged similar to a festoon system typically used for electrical cables (Fig 2). This photo, extracted from a video clip, reveals two light spots which indicate where the cord is burning at the moment. The "curtain" of cord to the right has yet to be ignited; the dark space to the left is where the cord already has been detonated.

Following the explosive cleaning step, compressed air provided by a truck-mounted compressor (Fig 3), is delivered to a patented, automated distribution system to remove any loose debris. The air nozzles shown travel across the face of the bundles from the top of the tubes to the bottom (Fig 4). Liberated foulant falls to the floor of the HRSG and is vacuumed up (Fig 5).

KinetiClean

The most effective way
to clean a HRSG

KinetiClean is safer and faster with the deepest cleaning effect

of any method currently used to clean HRSG fin tubes.

Groome's patented technology uses a proven Kinetic Shockwave cleaning method to remove unwanted foulant. An innovative and automated air system then distributes high-pressure, high-volume air to liberate remaining debris.

- **No manual tube movement**
- **Minimal-to-no scaffolding**
- **Other projects can continue in tandem**
- **No additional moisture**
- **Highly-trained and fully-licensed professionals manage explosive process**

GROOME
Industrial Service Group

WWW.GROOMEINDUSTRIAL.COM | (800) 505-6100

cleaning services firm with decades of industry experience.

Only a few weeks after his July 27 CCUG presentation, Bause announced on September 7 that Groome had acquired ExPro, uniting the latter's patented processes and Groome's 50-plus-year history in providing premium powerplant services—many identified with the hot-gas path in gas-turbine-powered simple- and combined-cycle plants.

ExPro executives Brad McGinnis (president/CEO) and Rod Hall (executive VP) have transitioned to the Groome team, bringing the skills and expertise honed at the 26-yr-old company to increase the number of critical service options available to owner/operators.

One of the stated competitive advantages of KinetiClean over alternative tube-cleaning techniques is that some of the work involved—such as the placement of detonation (a/k/a det) cord—can be performed while other outage work proceeds in parallel. Additionally, limited to no scaffolding is required for this process.

KinetiClean is a three-step process. First, the shock waves created by the det cord curtain dislodges deposits from the HRSG's finned tubes, then compressed air removes any loosened deposits that remain, and finally, the floor of the HRSG is vacuumed clean.

The process begins with the installation of det cord, described as a flexible textile jacket encasing PETN which is an extremely stable powder plastic explosive. Simply, a curtain of det cord, spaced 12 to 18 in. apart between tube bundles, extends the length of the finned tubes to be cleaned (photo montage). Det-cord spacing is based on the nature and volume of foulant as determined by ExPro. The det cord curtain is only armed when the blasting caps are introduced.

When the cord detonates along its length at a velocity of about 23,000 ft/sec (optimal for hard deposits), the ensuing shock waves remove debris from tube surfaces and fins. Importantly, no detonation material or tools touch any HRSG internal surfaces.

Next, patented air vestibule machines remove loosened debris that settled on fins below with high volume/high pressure air. The machine is digitally programmable to ensure full tube-bundle coverage. Once all debris has been removed from the fins, vac trucks are utilized to collect the material from the HRSG floor. The primary focus of this turnkey operation is to mitigate the chance of any opacity issues upon startup. A typical job takes six to eight 12-hr shifts to complete, meaning the cleaning of an F-class HRSG is a three- or four-day project.

Knowing that the mention of explosives was likely to send palpitations to the collective heart of the audience, Bause included as one of his first slides a record of the industry's safety and training record—specifically, no reportable incidences, lost time, or fatalities over the last three years, each representing close to 30,000 hours of work. A crew of seven typically does the work, including one licensed blaster.

Bause gave several case studies to wrap up, each exhibiting four to six tons of material removed and a 4- to 5-in.-H_2O differential-pressure improvement. During one site's work, damper repair work was conducted in parallel. Other slides quantify the general benefits of tube cleaning, although few combined-cycle personnel need any convincing on that front.

During the Q&A, attendees learned that 30 minutes following detonation, workers can enter the HRSG; noise levels are not expected to impact neighbors; that the technique is effective at removing ammonium bisulfate deposits; and the technique is not recommended for catalyst cleaning, although the patented air vestibule machine could be adapted for non-scaffold cleaning of the SCR catalyst at some point in the future. **CCJ**

HRSG FORUM

This year's annual HRSG Forum is being conducted virtually in monthly installments. The first was held May 3, 2021. The report here is a compilation of the presentation and discussion summaries from the virtual meetings conducted in August, September, and October. Access the recordings of all presentations made to HRSG Forum attendees in 2021 (May through October) by simply scanning the QR code at the right with your smartphone or tablet.

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

Global organizations supporting the HRSG Forum are the following: International Association for the Properties of Water and Steam (IAPWS), Australasian Boiler and HRSG Users Group (ABHUG), Power Users Group, EPRI, European HRSG Forum (EHF), Film-Forming Substances Forum, and Combined Cycle Journal (CCJ).

Bob Anderson, Competitive Power Resources Corp, and Barry Dooley, Structural Integrity Associates Inc, share responsibility for both content development and the conduct of HRSG Forum sessions.

Monitoring for proper water chemistry poses big challenges to users

Owner/operators can be forgiven if they feel like there's nowhere to turn when it comes to ensuring proper water chemistry in their water/steam cycles and, by extension, HRSG reliability. The challenges of water chemistry were obvious in the three presentations at the fourth monthly meeting of the HRSG Forum, August 19. But what was not said directly is probably as important.

Despite decades of research since the 1960s, said Barry Dooley, who was first presenter, flow-accelerated corrosion (FAC), the leading chemistry-influenced tube failure mechanism, continues to be responsible for 40% of tube failures in HRSGs.

Dooley re-iterated many points from prior presentations, including how to prevent single-phase FAC, the importance of optimizing pH in a range up to 9.8 to minimize iron in the cycle, and inadequate feedwater and lower-pressure circuit chemistries leading to corrosion product transport (CPT), which is more prevalent in frequent/fast start (FFS) operating scenarios.

Many of Dooley's slides were devoted to so-called "repeat cycle-chemistry situations." Worldwide, most failures and damage can be attributed to plants operating with two or more RCCSs (see "Trends in HRSG reliability, a 10-year review," CCJ No. 61, 2019, p 44). Inadequate sampling and monitoring, as well as alarming and control based on these readings, appears on many slides.

Thus, the real challenges seem to lie in sampling and monitoring. "Continuous steam and water monitoring is vital," Dooley said, "grab samples are inadequate." He characterized grab sampling as being like driving your car with eyes closed and only opening them once every 30 minutes. Dooley went on to say that measuring CPT is difficult when units undergo FFS. This set up the next two presentations, one by Ken Kuruc, Hach Co, on monitoring iron in HRSG drums, and the other by Kirk Buecher, Mettler Toledo, who covered "Online Instrumentation Overview for Healthy HRSG Operation."

It's well established that, unless you are a chemist or maybe a chemical engineer, the vast majority of plant staff are electrical or mechanical types who have a knee-jerk aversion towards chemistry. The goal of continuous monitoring also is mitigated by a few other realities.

One was illuminated by comments from audience members, one from a 2 × 1 combined cycle which "ran like a peaker" two to three years ago, but now starts daily and shuts down around midnight. "Getting steady-state conditions [needed for good sampling and monitoring] is non-existent today," the user said, "an 'abnormal' sample is where the unit is operating." Specialists responded that watching the trend is what's important, not the actual numbers; you can benchmark against the steady-state conditions. That may be true as long as you are sure the raw data are accurate.

Another attendee echoed the sentiment: With flex operations, systems don't run more than 10 hours, so how do you get a good sample? If it's any consolation, this has been the challenge with all monitoring towards some level of predictive, trending capability to anticipate and avoid failures. Whether manual or automated, the raw data are usually more accurate and "cleaner" (and more predictive of anomalies) at steady-state conditions.

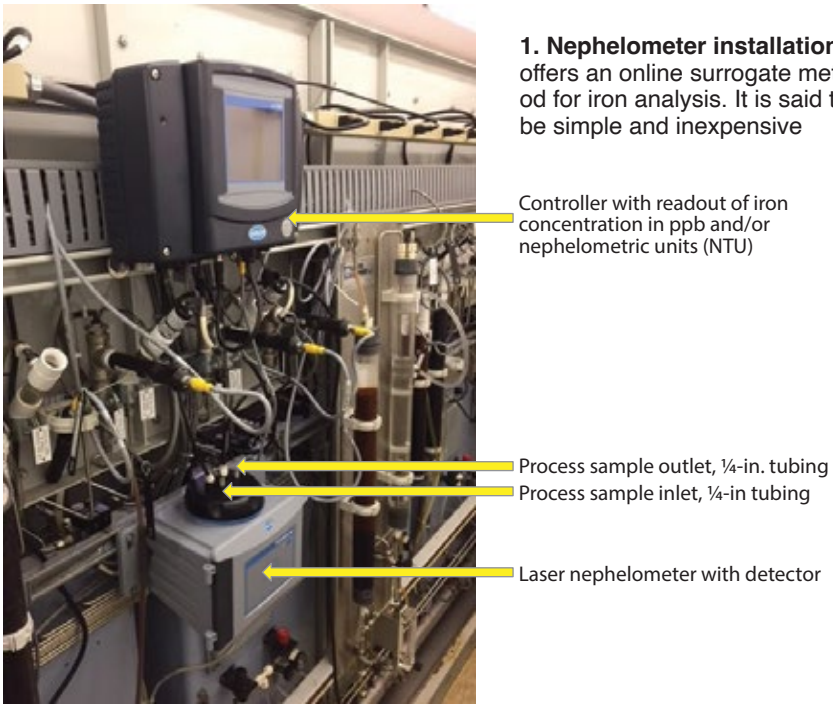
Another implicit reality is that doing better sampling or adding continuous monitoring devices takes resources and money. Yet resources get even more scarce when a facility's total operating hours decline.

The good news in Buecher's presentation is that today's online instrumentation is more reliable and less maintenance-intensive than in the past. For example, dissolved O_2 meters based on luminescence are available today which do not use membranes and offer faster response times. One plant, Buecher said, avoided 400 maintenance man-hours annually by making the switch. New phosphate analyzers have a much better reputation than the old ones, he added.

Buecher urged the audience to

download and read the following technical guidance document available at no cost from IAPWS: TGD2-09(2015), "Instrumentation for Monitoring and Control of Cycle Chemistry for the Steam-Water Circuits of Fossil-Fired and Combined-Cycle Power Plants" (www.iapws.org/techguide/Instrumentation.html). It describes the minimum level of instrumentation (MLI) necessary today. Important to note is that many instruments in the ML require redundancy at different locations to assess sensitivity throughout the entire cycle.

In discussing iron monitoring, Kuruc stated that grab sampling is not ideal, but if that's what you've got, make sure it's done properly. He referenced and reviewed a 10-step methodology available as a standard, emphasized the importance of proper pretreating and digesting of the sample, taking five to six samples to weed out anomalies, and a new online laser nephelometer (Fig 1) which can detect iron down to less than 1 ppb. A continuous ppb reading of total iron should be added to the DCS displays, he insisted. Total iron level in HRSG drums is the key indicator that FAC is active in the unit.



1. Nephelometer installation offers an online surrogate method for iron analysis. It is said to be simple and inexpensive

Responses to other audience questions could be boiled down to: (1) spend quality time at the IAPWS site to get a better handle on water-chemistry impacts and what to do about them, and (2) every plant's chemistry impacts are unique and therefore it is inadvisable to answer questions about specific impacts—such as why one out of eight HRSGs at a site is showing high conductivity, or how to get rid of O_2 corrosion in an LP drum already at discharge limits—without a deep understanding of site-specific conditions, metallurgical examinations, and the like.

In response to an OEM representative asking what can HRSG manufacturers do to "solve these problems," there seemed to be consensus from the presenters on refusing to install

oxygen-scavenger injection ports in all-ferrous systems, and making sure there are opportunities, such as isokinetic locations and sampling nozzles, to do proper sampling.

The use of an oxygen scavenger in an all-ferrous system was long ago identified as a major driver of FAC. Unfortunately, around 40% of powerplant operators continue to inject it an inflict FAC damage on their HRSGs.

A final reality is explicit in the IAWPS monitoring document: Continuous monitoring equipment involves its own maintenance issues which are aggravated under flex operations—including regular calibration of pH monitors (at least monthly) and other instruments, keeping instruments on a constant refreshing cycle with demineralized water during offline or shutdown periods (except sodium), maintaining the peristaltic pump which may accompany a phosphate monitor, replenishing reagents, conducting offline grab samples occasionally to confirm satisfactory operations and/or diagnose deviations from targets (that is, you can't avoid some grab sampling and competent analysis), and ensuring adequacy and reliability of extraction, conditioning, and delivery subsystems. This last point is so vital it is covered in a separate IAWPS document.

Acoustic monitoring proves worth for early detection of HRSG tube leaks

Boiler tube leaks have been plaguing fossil-fired powerplants for decades. HRSGs, especially those which cycle frequently, are no exception. Plants experiencing recurring tube leaks should analyze for root cause and make the necessary modifications. If that's too expensive, another option is to install a sophisticated acoustic monitoring system (AMS) to at least detect leaks earlier, locate them faster, and repair them at the earliest outage opportunity.

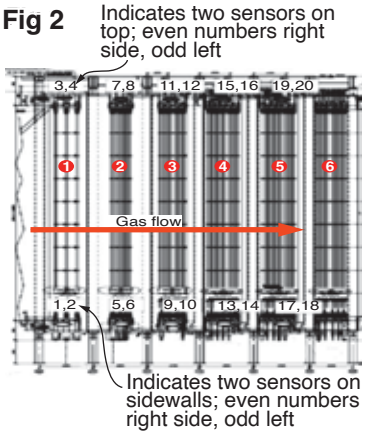
This was the situation presented by Tham Chelvan, Siemens Energy, at HRSG Forum 5 (Sept 24, 2021), hosted by Bob Anderson (recording at www.HRSGforum.com). A 2 × 1 combined cycle at a government-owned plant in South America with V94.3A gas turbines (supplied by Siemens, along with the controls) and triple-pressure, natural-circulation, drum-type heat-recovery steam generators began to have serious tube leaks three years after commercial operation began at the end of 2009. Because they were detected late in the game, the leaks caused collateral and expensive damage to adjacent tubes as well.

Although a root cause of the leaks was determined, owners considered the recommended modifications too expensive at $3.5-million. So, the plant installed a Mistras AMS system instead for about 15% of that investment. Siemens was unable to identify a system comparable to Mistras, Chelvan told CCJ in a follow up conversation.

Basic idea behind the technology is that noise created by tube leaks (distinguishable from other noises inside the boiler—such as attemperator sprays—using sophisticated signal processing) travels through the exhaust gas, hits the inner liner, causing a sounding rod to vibrate. The sensor converts the vibration energy into electrical signals.

Hundreds of fired boilers and feedwater heaters are equipped with AMS these days, but only 20+ HRSGs serving combined-cycle facilities because of the need to filter out ambient noise generated by the gas turbine. Perhaps this latest success will encourage HRSG manufacturers, EPCs, and/or owner/

Fig 2



Tube sections in direction of gas flow

1. Fourth-stage HP superheater
   Third-stage reheater
   Third-stage HP superheater
2. Second-stage reheater
   First-stage reheater
   Second-stage HP superheater
   First-stage HP superheater
3. HP evaporator (three sections)
   Third-stage HP economizer
4. IP superheater
   Second-stage HP economizer (three sections)
   IP evaporator (two sections)
5. LP superheater
   First-stage HP/IP economizer (three sections)
   LP evaporator (two sections)
6. Preheater (five sections)

Fig 3

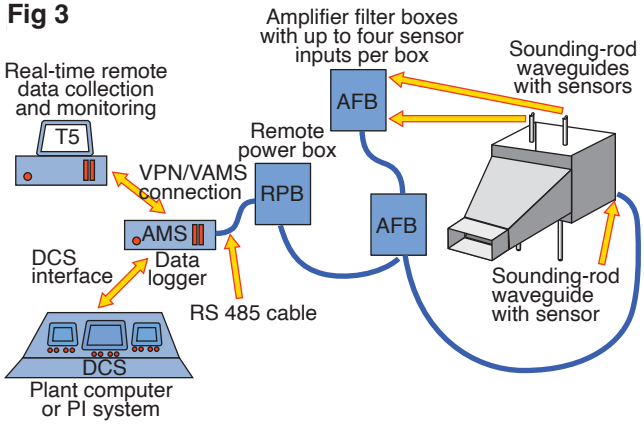


Fig 4

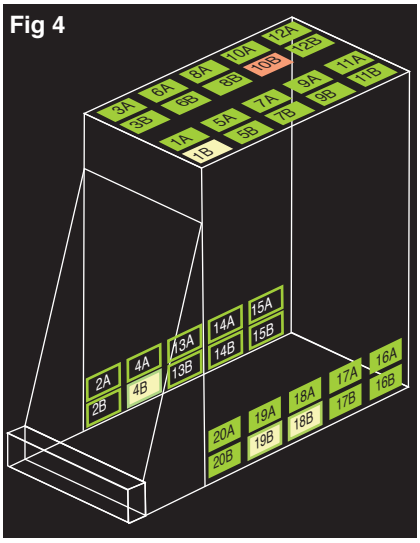
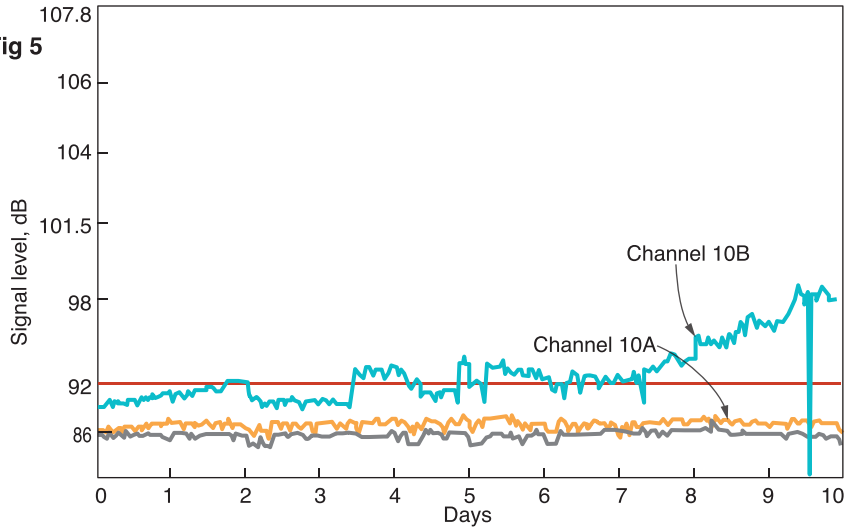


Fig 5



Each of the 20 sensors identified in the **Fig 2** AMS covers an area with a radius of from 20 to 30 ft and is positioned where leaks are most likely to occur. **Fig 3** shows sensor signals are amplified/filtered, directed to a remote power box, then to a data logger with an interface, if desired, to the DCS and plant data network. The case history illustrated in **Figs 4 and 5** indicates a leak in the area covered by Sensor 10B (red), with the progression and size of that leak described by the Channel 10B curve (blue). By comparison, the Sensor 10A is shown in green (normal activity) and the companion Channel 10A curve (yellow) relatively flat over the 10-day period monitored and well below the alarm line. Recently, the owner/operator has decided to add sensors (two on top, two on lower sidewall) to monitor the tube bundles in Section 6

operators to consider AMS as standard for unit monitoring and diagnostics.

According to Chelvan, the AMS was installed in 2016 on both boilers, and since then has successfully early-detected 10 tube leaks, almost all of them in one unit. Chelvan also told CCJ that this facility isn't penalized much, if at all, for tube leaks at the wrong time.

However, users in the US have said that, because of penalties assessed to sites not available in markets when they are committed, as well as lost revenue, a Mistras system can pay for itself with the first tube leak detected. Plus, because the data collected by the Mistras system are tracked in the company's central monitoring center, no additional work is required from a time-challenged plant staff.

Chelvan includes numerous slides showing the AMS equipment, installation of sensors, trends pre- and post-leak, and weld repairs made to the tubes, all required viewing if you are contemplating an AMS. Perhaps of most practical importance is how the sensors (attached to sounding rod wave guides) are arrayed outside the boiler casing and where the amplifier boxes, power boxes, data logger, computer, and monitoring screens are positioned relative to each other (Figs 2-5). Several slides clearly show how the data are measured, trended, and interpreted.

EPRI touts carbon initiative

A second presentation at the HRSG Forum gave EPRI an opportunity to pitch its Low Carbon Resources Initiative (LCRI), billed as an independent assessment of the work going on worldwide to modify gas turbines and duct burners for natural gas/H_2/ammonia fuel blends, which could have repercussions for other sub-systems, such as emissions control.

Give level gages the respect they deserve

Most plant folks are aware that faulty level readings on pressure vessels and poorly maintained, improperly operated, and inadequately designed level-gage equipment can only lead to bad outcomes. But if you haven't thought much about level indicators recently, here's the good news: There's a great deal of reference material and, because level gages are subject to Code requirements, much of it is free.

And the place to start is the presentation by Jim Kolbus, Clark-Reliance product manager, at the virtual HRSG Forum No. 6, held Oct 21, 2021 (listen to the presentation at https://

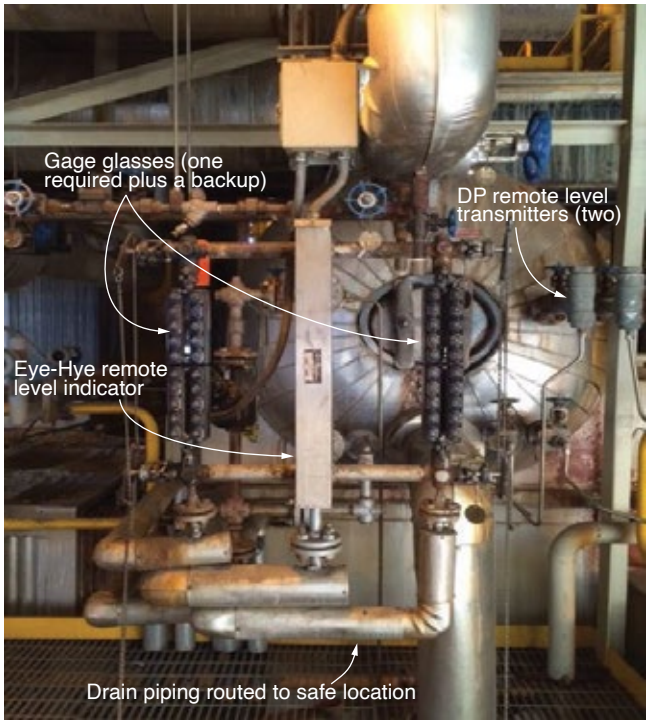
HRSGforum.com).

Powerplants have a significant number of level indicators since they are required not only on the HRSG boiler drums but also blowdown tanks, feedwater heaters, deaerators, and condensate tanks. And they typically have more than one to meet requirements for backup, independent verification of measurement, local and remote (control room, for example) readings, etc (Fig 6).

Kolbus takes a "just the facts, ma'am" approach in reviewing the four main categories of level indicator technologies and the ASME (PG.60.1) and European (EN12952-7) Code requirements governing them. In particular, you'll want to view the slides towards the end; Kolbus gives a few common Code violations, maintenance tips, and photos from the field of "what not to do" and how to remedy the violations.

As just one maintenance example, if your blowdowns exceed 20 seconds, you're doing it wrong; there's a video animation of a proper blowdown on the Clark Reliance website at https://youtu.be/mcD1pbgf_ek. From a design point of view, if the piping to the level gage is more than 6 ft, you are violating Code. As Kolbus intimates, lots of things can go wrong with small-bore piping, so frequent inspections and maintenance planning are musts.

Attendees had many practical questions such as frequency of calibrations or function tests, which codes to follow for specific technologies, impacts from cycle chemistry, and startup issues, several of which were addressed by Bob Anderson and Barry Dooley, the hosts and organizers of the monthly HRSG Forums.



6. Code-compliant installation of level indicators includes additional instruments for backup

Tame attemperator cycling impacts using clamp-on ultrasonic flowmeters

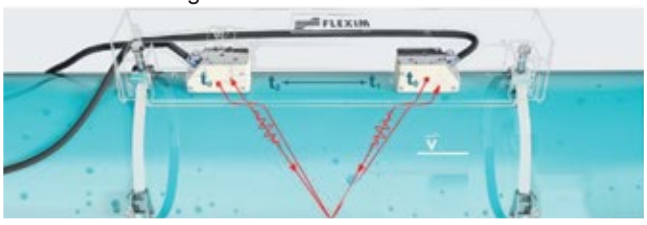
Impacts on attemperators from deep cycling continue to vex plant owner/operators, and Duke Energy is attacking the problems head on, conducting field trials of a novel atomizer that uses high-pressure steam to disperse water droplets (CCJ, No. 67, 2021, p 50), and, as reported at HRSG Forum No. 6, testing out portable, clamp-on ultrasonic flowmeters to detect attemperator block-valve leakage (Fig 7).

HRSG Engineer Eugene Eagle's presentation is replete with the problem statement (piping and liner damage caused by thermal quenching of leaked water), P&ID of the attemperator spray system, theory of how ultrasonic flowmeters work, installation and transducer photos, details of the Flexim Americas Corp devices selected (and now standard in Duke's combined-cycle fleet), graphs of field trial data from the reheat spray piping after the block valve (including a sustained period when the gas turbine was operating at 40 MW), comparisons of data from existing differential-pressure spray-water meters versus the ultrasonic meters, and connections with the DCS, servers, and laptops.

Next steps for Duke are to optimize the valve replacement/repair strategy based on the leakage trends and troubleshooting to determine why the Flexim meters show negative readings when the HP attemperator block valves at one site are fully closed.

A robust Q&A session followed Eagle's slides. One attendee asked if Duke considered a second actuated block valve in series to prevent leakage, and Eagle responded "yes," but was too costly with added complexity, control logic, and drain lines. Another attendee asked whether the temperature control valve downstream of the block valve closes tightly and HRSG Forum Host Bob Anderson quipped "never trust a control valve to remain tight."

A third attendee asked whether a fluid couplant was necessary between the transducers and the pipe and the response was that a permanent coupling pad is used. In other words, the gels or greases often used in these applications are avoided. Finally, one attendee asked the holy grail question: Did they confirm that pipe/liner damage was reduced by eliminating leakage? Response: No failures since the meters were installed, but it's too early for such a conclusion. CCJ



7. Detecting block-valve leakage using clamp-on ultrasonic flowmeters (below) is key to avoiding damage from thermal quenching in attemperator liners and piping. Actual installation is at right

Latest thinking on seals, pre-outage audits, ACC cleaning, extended turndown, outage planning

MD&A focuses on upgrades to support aging turbine fleets

■ Hydrogen seal upgrade with custom fit

Key takeaways

- Bolted seals reduce the probability of oil ingress into the generator.
- Bolted seals are proven to be millwright-friendly and less problematic during assembly.
- Rapid modification and housing exchange programs are available.

■ Understanding steam-path efficiency and structural audits

Key takeaways

- A list of recommended maintenance actions with the corresponding improvement in power output, heat rate, and efficiency, quantified on a stage-by-stage basis.
- Root cause of the damage, important for identifying a long-term solution capable of sustaining high levels of performance.
- Structural steam-path audits should be done early in the outage to allow maximum time for repair or replacement of components during the project schedule. Audits point to reliability issues with steam-path components and offer options for corrective action.

■ Performance improvements through advanced steam-turbine sealing technology

Key takeaways

- Information required to reverse-engineer steam-turbine seals.
- Engineering process to duplicate (or modify to Guardian design) steam-turbine seals.
- Installation process for steam-turbine seals.

Realize gains from converting to bolted generator hydrogen seals

Bolted hydrogen seals for large GE generators (of the Lynn or Schenectady design) are reliable, millwright-friendly, and easy to assemble, and replacing unbolted seals with them easily fits into a planned outage, said Wes Sneek, engineering manager, MD&A's Bearings, Seals, and Hydraulics Div, during the first of three webinars offered by the company to the industry in early September.

Each large GE generator is unique, Sneek noted. Older versions of the generators for 7FH2 and D11 turbines (derived from the Lynn design) employ a two-segment, babbitt-steel, unbolted design, but newer units are bolted. The traditional "Schenectady" design features unbolted four-segment bronze seals. Sneek distinguished between the seals, which are converted, not modified, and the housing, which is modified to accept the bolted seals; "windows" are added to access the bolts.

Those responsible for such equipment will want to watch the recording at https://bit.ly/3aI3ORc to get a good idea of how conversion to a bolted seal is accomplished. The upgrades for both types of generators are shown separately, with details you could only get if you visited the shop—such as how the windows are manufactured and installed for the traditional design.

Attendees were told during the Q&A that the upgrades maintain the GE recommended clearances and that the upgrades work for the Canadian ATB generator design as well. When asked if the new seals could create a hydrogen leak path, Sneek replied that they've received no customer complaints about this. Dowels could be a problem, he added, but they've developed a procedure on how to properly install and torque the bolts.

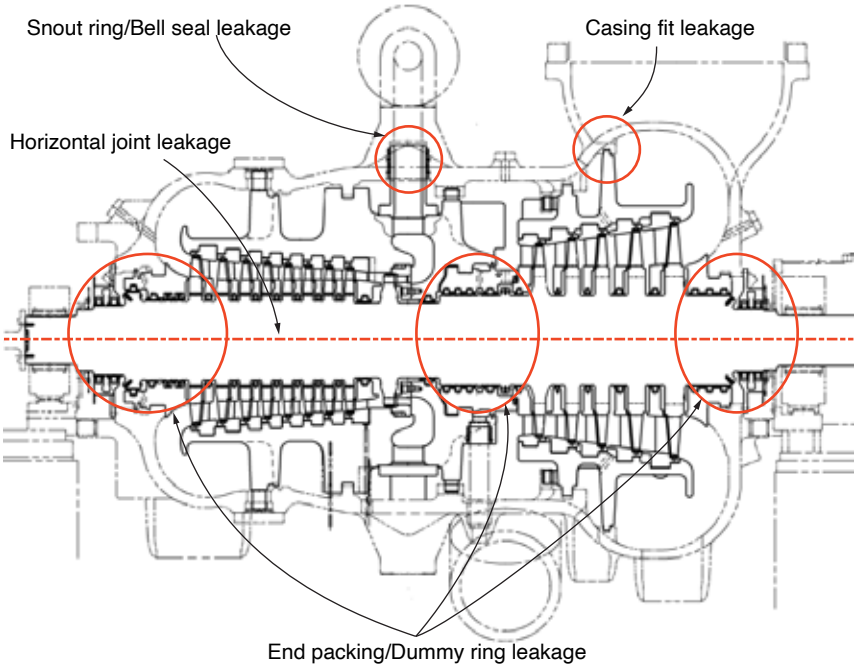
Pre-outage audits help you plan—and purchase only what you need

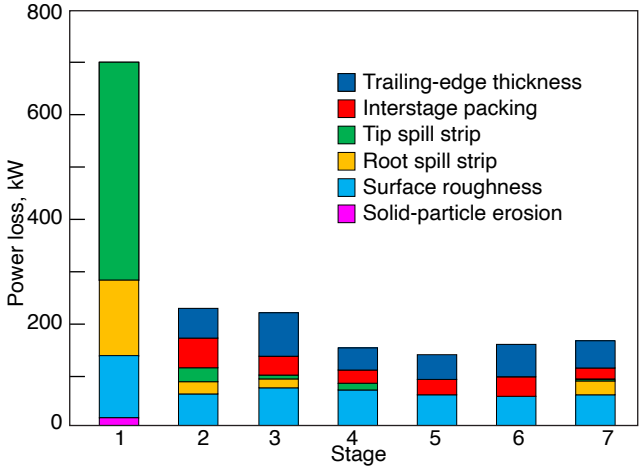
There's a really annoying insurance company commercial on TV that promotes an app that helps you "pay for only what you need." Minus the annoyance, steam-path audits can accomplish the same thing. Jeff Newton, steam-path engineer, and Deborah Cioffi, of MD&A's Repairs Div, tag-teamed during the second of three webinars the company offered in early September. Newton handled "structural audits," primarily aimed at reliability gains, while Cioffi handled "efficiency audits." Both are highly experienced steam-path engineers.

The structural audit is a visual assessment when the unit is opened for inspection and after blast cleaning; it includes limited dimensional checks but, stressed Newton, is not a substitute for NDE testing. Generic fleet issues are often identified before the outage, based on MD&A's multi-decades of experience with steam turbines.

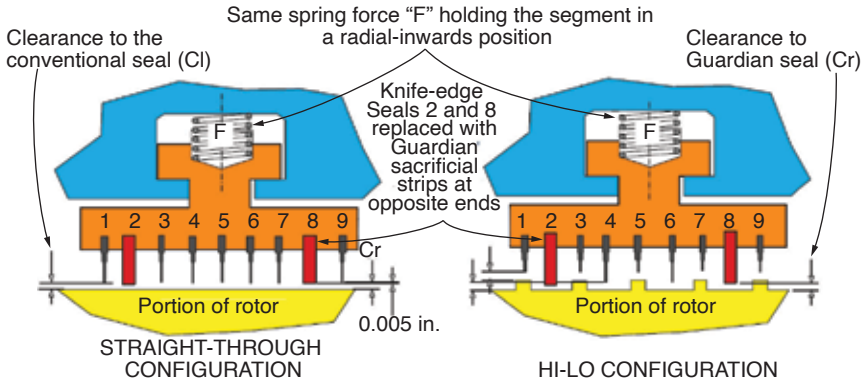
During bucket/rotating blade inspections, MD&A experts look for solid-particle erosion (SPE), moisture erosion, foreign object damage (FOD), rubs, notch lifting, cover lifting, and corrosion. Newton's slides are replete with before-and-after photos of damage and how it was repaired for various components. Diaphragm/blade ring inspection includes SPE, FOD, moisture erosion, and rubs, and also seeks evidence of dishing.

Examples of results (presented in tabular format), repair recommendations, and options form the basis for the report which supports outage planning and purchase orders. Newton





1, 2. Major HP turbine loss categories are quantified after inspection data are taken (above), with results tabulated stage by stage (left)



3. Guardian gland rings show arrangement of the Guardian strips for both the straight-through and the Hi-Lo labyrinth arrangements

urges that such an audit be performed every time the turbine is opened for inspection.

As part of the efficiency audit, findings on primary-loss categories identified in Fig 1 are converted into estimates of heat-rate degradation and annual fuel costs incurred (Fig 2). MD&A deploys a "powerful chart/calculator" to optimize options around a limited maintenance budget. For example, you can play "what if" scenarios for replacing, upgrading, or sharpening interstage packing—an example finely detailed in one of Cioffi's slides.

Other decision points could include:

- Major or minor weld repair, or new nozzles, to address SPE damage.
- Standard grit, fine grit, or polishing of blade surfaces.
- Increase or decrease turbine flow capacity.
- Repair, replace, upgrade, or do nothing to steam seals.
- Repair, replace, or wait until next outage to fix snout ring leakage.
- Repair now or wait until next outage to address casing distortion.

You'll want to take 30 minutes to view the Newton and Cioffi recordings at https://bit.ly/3aI3ORc for a complete picture of how audit findings are translated into recommendations with specific dollar figures attached to them.

Advanced steam seals can restore up to 4.5% of turbine efficiency

On the strength of retrofits for more than 300 steam turbines globally, MD&A's Jacques Amyot and Drew Spears, manager of Onsite Seal Services, told attendees during the company's September webinar series that Guardian® and Vortex Shedder® steam-sealing technologies, applied as a system, can both recover efficiency and maintain the performance gain longer than traditional replacements.

The two explained that Guardian is applied to the shaft packing seals, Vortex to the blade tip seals. Guardian minimizes seal wear by providing sacrificial strips of Nitronic 60 in place of two of the normal knife-edge teeth in each seal segment (Fig 3). Importantly, noted Amyot, the strips do not ride on the rotor, but maintain a clearance of 5 mils less than the seal teeth, which are protected and stay sharp longer.

The Vortex shedder (Fig 4) requires no stationary-fit modifications and maintains design radial clearances. The shedder is added only on the upstream tooth and uses circumferential velocity interfacing with axial disturbances to create a low-pressure zone upstream of the tooth, reducing pressure drop across the seal, and concurrently seal leakage.

The balance of the presentation reviewed the various measurements necessary, the reverse-engineering process, design radial and axial clearances, opening and closing clearances, alignment data, packing-coil spring design, installation steps, and other aspects you'll hear when you view the recording at https://bit.ly/3aI3ORc.

The critical parameter, underscored Amyot, is the radial design clearances; those given by the OEM "tend to be generic for a specific model, but not optimized for operations, and are sometimes too large. That's why they have to be measured, rather than inferring them from design or previ-

ous data."

MD&A brings a portable machine-shop-in-a-box to the site, complete with all supplies, HVAC, office space, and a desk to handle the turbine inspection and dimensional analysis.

In response to a question about clearances for cycling units, Amyot responded that clearances are designed in the same way regardless of unit cyclic operation.

CONCO. Air-cooled-condenser cleaning and leak detection, *Gary Fischer, national sales manager, Conco Services LLC*

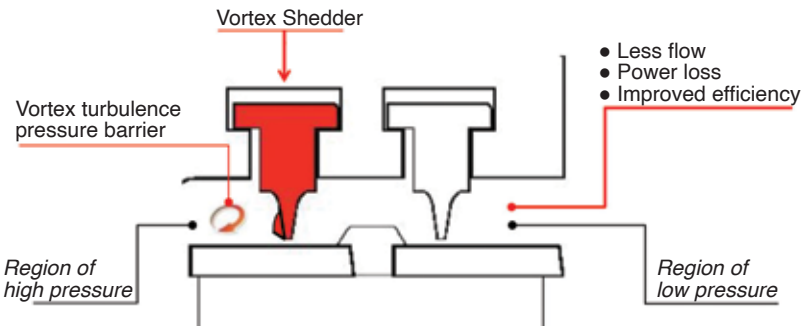
Whether you call it "weather" or "climate," severe weather events are increasing in both number and severity, which means hot and cold days may be more intense and more frequent, regions surrounding your plant may be ravaged by fires and smoke, and ice and snow events may be more prolonged. Remember, your air-cooled condenser (ACC) is inhaling whatever is in the air and, like your lungs, bad stuff is being deposited on its heat-transfer surfaces.

All these are excellent reasons to spend an hour viewing the Conco webinar conducted in late September on ACC cleaning and leak detection. Fouled tubes can rob a plant of performance, especially on hot days; a 20% loss of air flow across the tubes leads to a 33% increase in turbine backpressure on a vacuum steam system, reminded Gary Fischer, national sales manager and presenter.

Thoroughly cleaning tubes (Fig 5) with an automated water wash system (amply detailed in the presentation) can add 15 to 18 MW of output for the example given. One plant in the UK pegged its weekly savings at over $18,000.

Regarding leaks, Fischer told his audience that higher levels of tube leakage are observed at sites prone to freezing conditions, especially when the winds come from the same direction most of the winter. Ercot's catastrophic grid meltdown in February, focusing the industry's attention on winterization, should be motivation enough to make sure your ACC is ready for winter. Consider helium-based tube leak detection done by pros to be part of that preparation.

Fischer's presentation is available in the recorded webinars section of CCJ's website (www.ccj-online.com/onscreen). For prep, you may want to quickly review the summary of last year's Conco presentation on the same subjects in CCJ No. 65 (2021) p 66.



4. Shape and spacing of the Vortex Shedder are optimized for each unit design

EthosEnergy. The extended turndown phenomenon, *Christopher Chandler, chief technologist, turbine optimization, EthosEnergy Group.*

If industry trends continue the way EthosEnergy's Chris Chandler laid out in a Sept 30, 2021 webinar, future profitability belongs to gas-turbine-powered generating plants that can achieve even greater load flexibility, both at the low and high ends of the range. And by the end of this year, EEG will have demonstrated a new

product for that, EcoMax Extended Turndown+. Chandler, described it as "bowling with guardrails in the gutters."

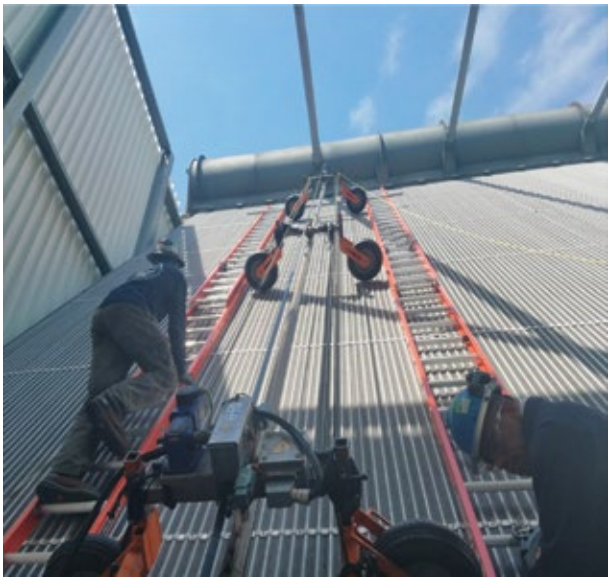
For those who haven't been in a bowling alley in a while, guardrails are used to avoid gutter balls and keep young kids and others motivated to learn. With respect to a gas turbine, what Chandler means is that EcoMax software predicts the GT's "low sustainable limit" (LSL) and automatically tunes combustion fuel/air ratios and fuel splits to achieve it. Similar tuning is conducted to achieve higher-than-normal max output (though sacrificing heat rate).

In both cases, the software accommodates ambient conditions, while still meeting NO_x and CO emissions, keeping combustor dynamics stable, and remaining within HRSG operating limits. In other words, the software keeps the unit from going off the rails.

Regarding industry trends, Chandler said that the combination of policy drivers towards (1) more renewables; (2) displacing natural gas for residential, and commercial, and industrial uses; and (3) converting transportation to electric vehicles mean that gas-fired powerplants will have to work even harder "chasing renewables" to keep grids stable.

The consequences are already evident in Ercot and CAISO, Chandler insisted, such as Ercot's catastrophic grid meltdown in February 2021 and instability events on June 14, 2021, and CAISO's shedding of load Aug 14-15, 2020. Renewables over 40% impact grid stability, he said. Both ISOs are planning to add more renewables "at significant rates." The slides Chandler showed suggest "we ain't seen nothing yet."

In response to audience questions, Chandler noted that low-load operation has a positive impact on turbine component lifecycle because the unit is operating at lower firing temperature, but HRSG component lifecycle may be impacted. He also cautioned that 7FA.03 and .04 units may have to pay special attention to lean blowout.



5. Automated online cleaning sytem is set up on a typical air-cooled condenser

TRS Services. Five ways to make or break your turbine outages, *Greg McAuley, CTO, TRS Services.*

Imagine putting your turbine back together after an outage only to find that you've lost 8 MW because the clearances were grossly out of spec. Or adding three days to the outage because someone didn't check the capacity of the bearing repair shop. Or losing time because the lifting and laydown plan that worked flawlessly for a dozen previous outages isn't effective for the current one because the scope expanded and laydown area was lost.

These and other situations can be avoided, said Greg McAuley, during an Oct 5, 2021 webinar, by having an independent expert, a/k/a/ technical field advi-

sor (TFA), help develop and implement the outage plan. In every step of the plan, McAuley advocates, "Ask what could go wrong and develop contingencies and options."

Whose specs are referenced when the document says, "all clearances within spec"? Does the contractor provide evidence of experience in meeting the schedule? What do you do when you have an incapable crew onsite? Are the pre-bid work scopes vague and incomplete? Are you putting too much trust in what the OEM is telling you?

Contingency planning checklists

Compressor section

Inspection scope
Borescope service provider
Do we have the labor to assist?
Blending service provider
Thrust-bearing shim-grinding resource
Spare rotor availability
How do we deal with shim migration?
Blade/vane availability
Bleed-valve scope and who is responsible
What if I can't remove all my borescope plugs?
Dry ice and/or heating resources for stator-vane removal
Vane pinning resources

Turbine section

Consumable hardware availability
What to do if my clearances are too tight or loose?
Exhaust static or flex seals
Exhaust cylinder or diffuser cracking:
- Weld procedures and welders
- Spare rotor availability
- Parts don't fit
- Parts found contaminated

Interstage-seal field-alignment issues (Siemens units)
Blending service provider
Bucket sequence chart availability
Fuel-nozzle flow-test results
Non-capital-parts condition

Generators

Test work scope
Test and inspection service provider
What if my field megger is low or grounded?
Wedge, blocking, and ties
Cooler gaskets
Cooler leaks
Alignment jacking fixtures
Bearing availability and repair resource

Make sure your plan follows a checklist and guidelines that are customized for your site, and accommodate current adverse factors (Covid, supply-chain issues, etc) which can affect parts and service availability, timing, delivery, etc. Don't rely on "generic" checklists from the OEMs or assume that the upcoming outage will go just like the last one.

See contingency planning checklists in the sidebar for gas-turbine compressor and turbine sections, plus generators. McAuley also has developed checklists for safety, craft labor and engineering, logistics, etc. To get your copy, write gmcauley@trsglobal.com.

But even the best plan may get thrown out when the battle begins, so the saying goes. McAuley embraced the analogy of a football team's offense built around a quarterback who gets injured during the first game of the season. That's when it really helps to have someone onboard with deep outage experience and a network of resources to develop options on the fly.

In response to the question, "What controllable items unexpectedly extend outages in your experience?" McAuley gave the example of a contractor team which did not fully understand LOTO procedures; when

the site had to unexpectedly turn the turbine lube-oil system back on to roll the rotor, the outage was prolonged an extra shift to train the team on those procedures.

Outage planning and implementing is aggravated today, McAuley notes, because sites push outages as long as possible, then take them all on top of each other, stressing all the OEMs and services firms.

McAuley began his presentation with a safety minute, but ended by cautioning that during recent work at a site, he observed that only 50% of the outage team was wearing safety glasses.

RMS Energy earlier this year acquired electromagnetic signature analysis (EMSA) technology developed by Richard LaDroga, PE, in particular an online 24/7 monitoring version RMS calls "Watchkeeper." In a Webinar back in March, LaDroga, now RMS Chief Technical Officer, explained how the technology benefits powerplant owners when making maintenance decisions on generators, transformers, large motors, isophase busses, switchgear, and any other high-powered electrical components.

Failures of these components can be catastrophic in terms of safety, public relations, and financial loss. Watchkeeper continuously monitors for and detects defects which may involve electromagnetic interference (EMI)—including noise, arcing, corona, partial discharge, gap discharge, sparking, micro-sparking, and others.

Basic system includes one or more split-core radio-frequency current transformers with signals directed to a spectrum analyzer, the "command module." Data are uploaded to the cloud, analyzed remotely at a central monitoring facility, and trended. Elements of the technology's value stack include failure avoidance, optimized maintenance planning (for example, not pulling rotors when you don't need to and shortening outage periods), strategic operations (operating with knowledge of equipment condition), and adjusting insurance premiums.

Regarding the last, LaDroga noted that reduced premiums alone can pay for the technology and the subscription-based monitoring service. LaDroga's experience base is vast: He claims 5000 tests performed since 1980 and the discovery of 70 electro and mechanical defects in the last two decades, and underscores that he is a forensic expert in electrical systems. **CCJ**

Global suppliers tout upkeep, repair, upgrade solutions for GTs, HRSGs, BOP systems

Unlike many user-group events, the 2021 Combined Cycle Conference for the Middle East/North Africa (MENA) region began with a primer on combined-cycle facility design, which set the stage for detailed presentations on gas-turbine, steam-cycle, and balance-of-plant upkeep, repair, and upgrade techniques and technologies. (Access presentations at www.ccj-online.com/mena-ccgt-conference.) Perhaps the only major subsystem omitted was steam/water treatment for maintaining proper cycle chemistry.

Sponsors of the virtual meeting were GE, Allied Power Group, ARNOLD Group, CoreTech Industrial Corp, EMW filtertechnik GmbH, John Cockerill, Keck Group International, MD&A, and SPG Dry Cooling.

Joel Holt, operations manager at CoreTech's Plant Systems Div, kicked off the conference with a presentation on combined-cycle plant basics. The editors consider this must viewing for folks new to the industry and a worthwhile refresher for veterans.

As one example, Holt compared a 2005-vintage combined cycle to a 2020 facility, and the contrast is stark if you haven't thought about it for a while: A two-hour hot start versus less than 30 minutes today, around 50% efficient versus 62+%; steam turbines and HRSGs *designed* specifically for combined cycles (rather than designs lifted from other applications), and features like purge credit and system simulation not even available 15 years ago.

HRSG. Raphael Stevens, John Cockerill (formerly CMI), began with a review of his firm's 200 years of industrial experience and an install base of 800 horizontal, vertical, and once-through HRSGs (amounting to 120 GW and 10% of the world HRSG market, he claimed).

Stevens gave examples of recent projects, including HRSG modifications to match the boost in output from a GT upgrade at Kings Lynn Power Station in the UK (Fig 1), and a new low-pressure module added between the HRSG and stack to increase water production and reduce CO_2 emissions, by lowering the stack temperature from 352F to 273F, at one of the world's largest desalination plants (Fig 2).

Performance enhancements. Bob Johnston, Keck Group International (KGI, formerly GE Gas Turbine Upgrades), opened by saying "GTs may be 'forever' but customer needs change." KGI's services include engineering support to evaluate performance enhancements, including lifecycle evaluations, faster startups, efficiency improvements, controls upgrades, emissions support, and upgraded parts evaluation.

Johnston's presentation is replete with nuggets of insight (Sidebar). For example, he stated that exhaust thermocouples on GE units were biased high between 1980 and 1997 and can be corrected to improve performance. And some replacement hot-gas-path (HGP) parts are actually upgraded (superseded) components which can qualify for higher firing temperatures.

1. King's Lynn's HRSG was modified to match the gas-turbine upgrade (replacement of the existing V94.3 engine with an SGT5-4000F). HP superheater and reheater heat exchangers were removed (left) and replaced with ones able to recover heat from higher-temperature flue gas (right)

He also discussed a "tilted control curve" which can allow you to overfire on hot days to boost output and underfire on cold days. Normally, the GE control curve maintains constant firing temperature for all ambient conditions.

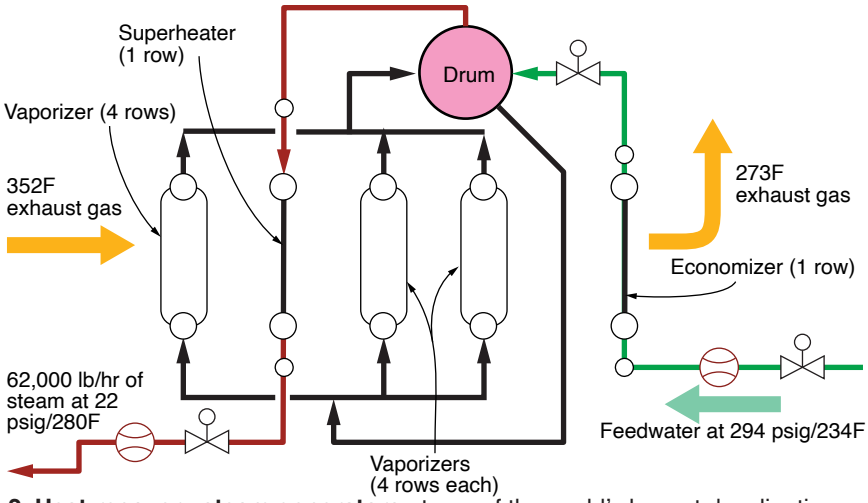
Steam turbine warming. Pierre Ansmann, global head of marketing for ARNOLD Group, presented on his firm's advanced single-layer turbine warming system (Figs 3 and 4). This is must viewing if you've never thought that hard about steam turbine insulation and their support and casing attachment systems, differences between bottom and top insulation (25% thicker on the bottom, removable on the top side), casing heaters and attachments, and advanced controls which ensure every heating zone is controlled to within 1 deg C. Arnold guarantees that surface temperatures do not exceed 15 deg C above ambient, and the unit is "hot-spot free."

Dry cooling. Frederic Anthone, aftermarket manager, SPG Dry Cooling (a member of Paharpur Cooling Towers) opened with his firm's 150,000 MW of air-cooled condenser (ACC) installations worldwide, and five basic designs – A-frame, Box Air, and Hexacool for plants less than 50 MW, and Module Air and W-style for large plants.

Because "performance always changes with plant cycling and ambient conditions," Anthone dwelled on the need for regular testing (for example, vacuum leakage test), inspections (including drones) by specialists, and/or an ACC360 continuous monitoring and diagnostics (M&D) service program so cleaning and repairs can be properly planned, rather than forced.

"Data-driven analysis combined with thermal modeling can detect failures before they occur," Anthone said, "which can increase reliability during adverse ambient conditions." He offered brief case studies, one of an 800-MW plant that increased ACC thermal capacity to accept higher steam loads, in which all motors/gearboxes were replaced and upgraded without changing fan blade geometry.

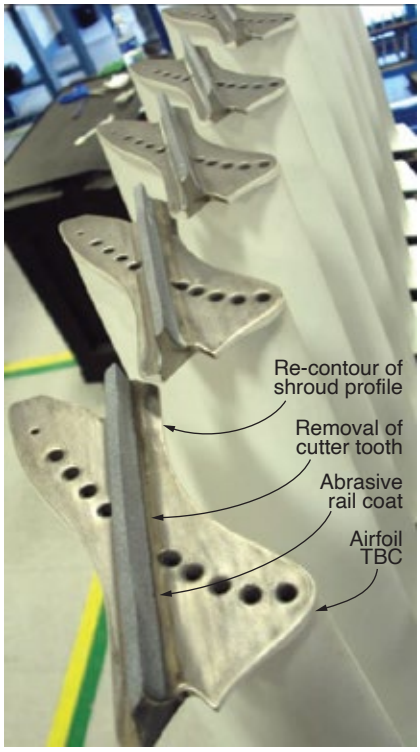
GT repairs. Jason Brown, senior VP of business development, Allied Power Group, called his firm the "largest independent GT repair company in the world" as a result of "many acquisitions over the last few years." He then noted the 3100 transition pieces sold for all GE frames through the 7FA.04, the 1900 combustion liners/CCP assemblies sold, and other components, some of which he said are better than the OEM's for repairability. Repairs, including rotors, can



2. Heat-recovery steam generators at one of the world's largest desalination plants were modified by adding low-pressure modules to recover more heat, thereby increasing steam production and reducing CO_2 emissions

3. Heating wires are permanently fixed below the steam-turbine split line

4. Heating zones in upper casings are removable



5. Repairs to F-class second-stage blades make these parts better than new

be conducted on most GE and Siemens/Westinghouse machines.

Coatings are a "primary competitive advantage" of APG's offerings, and are equivalent or superior to the OEM's, he added. "We have 12 coating booths in operation and each of them can handle all necessary components." The field services group can manage up to 10 outages at one time. One of the case studies presented involved the life extension of a crude-oil-fired GT, now expected to achieve a 12,000-hr inspection interval, whereas before it the interval was far shorter.

GT filters. Andrew Thompson, project engineer, EMW Filtertechnik (family owned since 1954), reviewed the important standards his company can test to and meet, including EN779, ISO 16890, ASHRAE 52.2, EN1822 (HEPA standard), and ISO 26463. Thompson underscored the importance of high-quality filters kept clean by showing photos of compressors after only 5000 hr of operation *after* online and offline cleaning. Spoiler alert: The photos aren't pretty.

High-end filter media are also easier to clean, too. No washing is necessary and compressors remain "completely clean" after 5000 hours. "Washing really only cleans the first-stage blades," he said. Changing from an F8 type filter to an E11 or E12 can "dramatically increase performance and reduce outage work," Thompson concluded.

6. One rotor-straightening option includes thermal stress relief to relax internal residual stresses

7. Piggyback wedge system is an option for medium- to large-size generators

Mechanical Dynamics & Analysis (MD&A, a Mitsubishi company) then delivered a series of presentations on gas and steam turbines, generators, turbine valves, and control and excitation systems. Jose Quinones covered GT component repair experience with 6FA, 7FA, 9FA, 7FA.03, and many other GE machines, totaling close to 1250 sets of F-class components (Fig 5).

Neil Jones spoke on steam-turbine inspections and repairs for what he termed "almost all OEM-manufactured equipment." He included a case study from 2020 in which a bowed rotor was straightened from 16 mils to 4 (Fig 6).

If you didn't realize that an inspec-

Eke out more perform

It's not often you get something for nothing, or in this case almost nothing. Pay for an expert review by a couple of top global gas-turbine consultants with man-decades of experience, have them tweak your controls, and you likely can squeeze out a few megawatts and/or efficiency gains from an older gas turbine. No capital costs involved.

According to Bob Johnston, president, Keck Group International, speaking at the MENA Combined Cycle Conference, the key is an integrated, system-wide evaluation of the components currently in your machine (Table 1). "Some replacement hot-gas-path (HGP) parts are actually upgraded parts which supersede their earlier versions, and could qualify for higher firing temperature," Johnston stressed.

This so-named "non-capital-parts uprate program" has been successfully applied to "many dozens" of GE machines and also can be applied to other OEM machines. Johnston explained that OEMs often supply upgraded parts as in-kind replacements but don't tell the customer that they've replaced enough parts to qualify for an uprate. In fact, this is the "likely" situation for older machines, typically those shipped before 2001. For example, most of the later-vintage HGP parts for the MS5002 and MS700EA are directly interchangeable with all prior vintages.

Tweaks identified by Johnston which can arise from the parts evaluation are:

- Inlet guide vane (IGV) angle change.
- Isotherm setting increase for power at higher ambient temperature.
- Exhaust thermocouple (t/c) corrections.
- Degradation correction to control curve.
- Tilted control curve.

Exhaust t/cs were biased high on machines between 1980 and 1997, and a straight-forward controls setting change can net up to an 11-deg-F increase in turbine exhaust temperature. Results for 11 gas turbines in the

tion and recommendations report for steam-turbine valves could run 60-120 pages, listen to Jason Wheeler's presentation to find out why. One of Wheeler's stats: 75% of overspeed events are caused by improper valve operation. Depending on the aggressiveness of service, these valves must be inspected every three to five years.

James Joyce covered generator stator and rotor repairs, and began with a primer on generator components. Much of his material addressed the question: "Should I re-wedge or not?" When the answer is "yes," MD&A can handle in-kind wedging or upgrades "which can be beneficial but very labor intensive." Several options and tradeoffs must be considered (Fig 7), why you need to call in specialists. Re-wedging takes 8-10 days and does increase outage costs. Core tightness checks and frequency bump tests should be included the project.

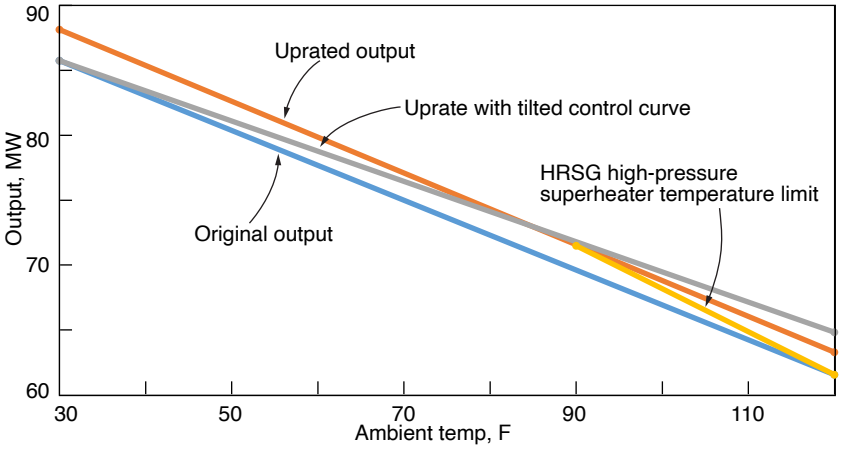
Michael Broggi addressed dealing with obsolescence of, and adding selective upgrades to, generator controls and excitation systems. Modern systems can include high-speed data

ance from your old machine

Table 1: Data required for non-capital-parts uprate review

Gas turbine serial number
Current firing temp, F
Drawing numbers for the following components:
- Stage 1, 2, and 3 buckets
- Stage 1, 2, and 3 nozzles
- Stage 1, 2, and 3 shrouds
- Transition piece
- Combustion liner
- Crossfire tube
- Inlet guide vane
- Exhaust thermocouple

Exhaust-frame blower motor, hp
Compressor water wash (yes/no)
Exhaust temp limit (Isotherm)



Non-capital-parts upgrade can squeeze a few more megawatts out of many pre-2001 units, but make sure to account for the impact on HRSG high-pressure superheat temperature

Table 2: Change in controls setting can boost turbine exhaust temperature, output

Parameter	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6	Unit 7	Unit 8	Unit 9	Unit 10	Unit 11
Current firing temp, F	1840	1840	1840	1840	1840	1840	1840	1840	1840	1840	1840
Firing temp increase, deg F	0	25	25	0	0	25	25	0	0	25	25
GT degradation exhaust temp correction, deg F	5	5	5	5	5	5	5	5	5	5	5
New tilted control curve	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Exhaust t/c bias correction, deg F	5	5	5	5	11	11	11	11	11	11	11
New firing temp, F	1840	1865	1865	1840	1840	1865	1865	1840	1840	1865	1865

Middle East (Table 2) show that not all the tweaks apply to every unit (Table 3). Output gains ranged from 2.4% to 10% for three separate groups of 56 engines without applying IGV angle-change tweaks.

Standard GE control curves maintain constant firing temperature at all ambient temperatures. A *tilted* control curve overfires the machine by 16 deg F on hot days, and underfires the machine by 25 deg F on cold days. This can give a 1.6% output boost on hot days, with no net impact on parts life or maintenance cycles. Again, only control setting changes are necessary. Most sites value an output boost during peak summer periods, and can sacrifice small decreases during cooler periods.

Control curves are based on a new machine, but as operating hours mount, non-recoverable performance degradation occurs, which reduces output, but also leads to under-firing the machine because the control curve hasn't been adjusted. "By applying a suitable correction to the control curve, you can gain 0.8% output," notes Johnston. This has been done for "hundreds of machines since the 1990s," he added.

Users are cautioned that the higher turbine exhaust temperatures which lead to the output gains could raise the HRSG's HP superheater temperature beyond its limit (figure). Two ideas here are to add desuperheater capacity or remove fins from the superheater tubes. Careful analysis could reveal other options as well.

Table 3: Performance improvement with non-capital-parts uprate program

Uprate option	Units 1-16	Units 17-24	Units 25-56
86-deg IGV setting	?	?	?
Exhaust t/c correction, %	1.8	?	?
GT degradation correction, %	0.8	0.8	0.8
2055F firing temperature (gas/distillate only), %	5.5	?	5.5
Tilted control curve, %	1.6	1.6	1.6
Heavy-fuel first-stage nozzle, %	0.3	?	0.3
Total estimated output gain, %	**10**	**2.4**	**8.2**

capture and storage for troubleshooting. "This goes beyond PI data because faults are often in the milliseconds range," he stressed.

Through an acquisition, MD&A now offers the IBECS® "fully integrated" control platform in which all HMI is encrypted and the system is "set up to be cyber-secure, with native drives and open-source protocols and features such as advanced alarming, pattern recognition, time synchronization, sequence-of-events recording, high-speed trending, and remote access and monitoring."

GE Day

The underlying messages from GE Day at the MENA Combined Cycle Power Plant Users Symposium was that, regardless of which region of the world you operate in, (1) mission and operating changes are coming to your plant, and (2) GE Gas Power specialists can help you analyze the impact of those changes on your equipment, recommend solutions, and implement them.

Jeff Chann, business intelligence leader, took the highest-altitude perspective and presented on the global industry transformation. The push to decarbonize a global economy essentially built on fossil fuels over a hundred year or more period will impact all gas-fired facilities.

As renewables grow, combined cycles not originally designed or built for cycling will have to be modified to do so. And unlike other regions, MENA's electricity demand is still growing at a rapid pace. "One-billion people on this planet still need electricity," Chann reminded his audience, and that need has to square with decarbonization.

John Sholes, principal engineer, then introduced Ahmed Gaber, application engineering leader, MEA Region (Middle East and Africa), who reviewed some of the mission outcomes that may be necessary as this transformation unfolds: higher peak load, more fuel flexibility, turndown to lower loads, faster starts, and higher cold-day or hot-day output.

Sholes noted that addressing the limitations on the balance of plant from a gas-turbine uprate will likely cost only a fraction of the GT uprate. He said GE specialists can analyze your plant's performance and goals and recommend upgrade options. One example: If your attemperator valves are topping out, analyzing the operating data could reveal that relatively minor modifications can address this and eliminate water hammer during load transitions.

Akram Ismail, senior solution architect, and Mohamed Hamdy, lead customer application engineer, presented a case study for a 9F.03 combined cycle, where the gas turbines had been upgraded with the OEM's Advanced Hot Gas Path, the steam turbine upgraded with GE's Advanced SteamPath, and the HRSGs upgraded to improve overall plant performance.

Akram and Hamdy showed the evaluations used by GE to identify potential impacts on plant systems and discussed solutions to fix identified equipment limitations and scope offered for implementing concluded resolutions.

The following presentations then drilled down to the generators, HRSG, and steam turbine. The GE presentations are posted on the company's MyDashboard website at https://mydashboard.gepower.com.

Generators. Karim Bakir, lead customer service engineer, EMEA Region (Europe/Middle East/Africa), reviewed generator maintenance practices and lifecycle issues, especially after the onset of cycling. Generally, he said, users need to consider

a rewind for the rotor after 15 to 20 years, and for the stator after 25 to 30 years. However, cycling duty may accelerate those schedules.

Bimpe Olubode, lead customer service engineer, EMEA Region, reviewed new developments in collector rings and brush systems. Janusz Bialik, principal customer service engineer, EMEA Region, spoke about generator health monitoring and recommendations. Benjamin Kreyssig, lead customer service engineer, EMEA Region, presented a forced-outage case study on a 7FH2 generator field.

The speaker explained how the field defect (ground fault) was ascertained based on GE diagnostic experience and fleet know-how. Detailed review of the observed findings identified what caused the ground-fault event. Plus, the presentation highlighted how GE as able to provide the field owner the best service option, including a spare field, to minimize generator downtime.

The HRSG presentation, led by Vasileios Kalos and delivered by Mohamed Hamdy, lead customer application engineer and Salim Kassis, senior sales manager, reviewed the replacement of pressure parts to extend life and reduce O&M costs—with an emphasis on upgrading from carbon steel to Gr11 alloy. Details were also given on GE's pressure wave plus technology to address HRSG tube fouling.

Recall that pressure wave is an offline cleaning technique which uses controlled acoustic shock waves, or "bangs," to knock debris off the tubes. A total cleaning on an HRSG serving an F-class unit takes about four to six shifts. For every inch water column of backpressure increase, the plant typically loses 0.2 MW of output and 0.1% heat rate. GE recommends that tubes be cleaned when backpressure reaches 3-in. H_2O above specification.

Steam turbines. Matt Foreman, combined-cycle steam-turbine fleet leader, and Salim Kassis, delivered observations and findings from the product service team on impacts when units shift to low load and cycling service. Sites need to understand what these impacts can be, monitor for them, and engage in long-term mitigation planning. A few examples cited:

- Erosion of valve components can increase when the valve is throttled to achieve lower loads.
- Highly loaded components, such as rotors and last-stage blades, will accumulate more LCF damage with an increase in annual starts.
- Leading-edge erosion of turbine blades is accelerated by low-load operation.

GE spoke to solutions that range from upgraded replacement components like NextGen Valves and Advanced SteamPath to basic repairs to mitigate impacts of low-load and cyclic operation, but monitoring, diagnostics, and planning are critical.

The last presentation reviewed how analyzing operating data can help diagnose and identify emerging steam-turbine issues, flag minor problems before they become big ones, and inform maintenance planning. For example, when tracking the difference between the upper and lower turbine-shell metal temperatures, a delta T trending high from shell top to bottom indicates a higher risk for rubs. This can be addressed by checking for quality of insulation and ensuring proper installation of insulation. Changes in transient vibration over the unit's operating life may help diagnose rotor bowing, as another example.

Such changes can be very gradual over time but nevertheless meaningful for diagnostics. The speaker suggested that users lacking the necessary expertise consider subscribing to GE's OSM monitoring service. CCJ

'Interesting' breaker events dictate stronger maintenance practices

"Interesting" doesn't do justice to the generator circuit-breaker failure events described by two utility users at the Combined Cycle Users Group's 2021 virtual conference, although that's the word they used. Threatening is more accurate. While the events themselves tend to be unique and site-specific, many readers can relate to the pain, and the "lessons from the field" they presented. Above all, it never hurts to be reminded that anything can take you out in a powerplant and everything needs to be checked, rechecked, etc.

Examples included new breakers and old breakers in variety of different plants but the most impactful event was an overheated breaker which took out a 7EA gas turbine/generator on the hottest day in August last year with no replacement power available for purchase anywhere. Root cause: A runback for unit output set higher than the 7EA could produce. Takeaways here are to check runback settings, make sure operators act on alarms, maintain fans, correct failing switches, and make sure spare breakers are available.

In another example, the presenters stressed that contractual issues can be as important as mechanical issues when it comes to maintenance. With non-utility owner/operators, FERC rules, markets, and state/regional ISOs, it's often not clear who pays for plant substation equipment. The "point of ownership" may not be the same as the "point of interconnection." Contractual language and accounting rules governing critical plant property can be confusing, but should be understood, not ignored.

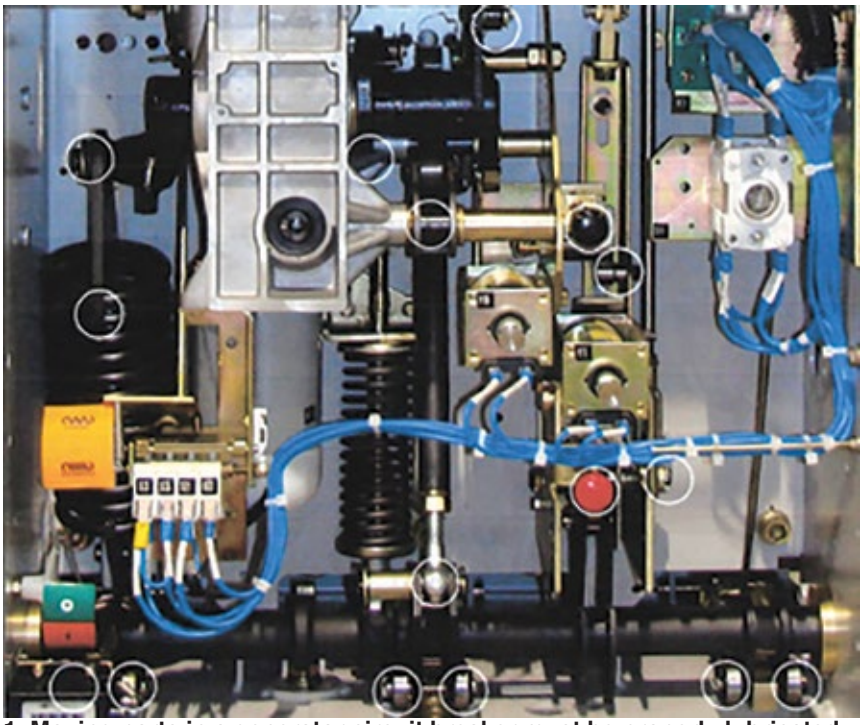
What's more, some breaker suppliers "played fast and loose" in the past with breaker ratings at ambient temperature, and it may be prudent to validate the rating. Some units are forced-cooled "to get more rating out of it." In this way, a 3000-amp breaker can be "uprated" to 5000 amps.

Age of a breaker has much to say about its failure likelihood. Annual failure probability at six years is 0.1%, but at 24 years, it rises to 2%. And if you want to address 50% of generic underlying performance failure causes (lubrication), make sure you are using the right lubricant, that it is applied correctly, and that it has not degraded (Fig 1).

The slides, available on the Power Users website at www.powerusers.org to registered owner/operators, detail some basic maintenance standards—such as conducting visual inspections every 12 months, minor maintenance every 24 months for 13.8-kV units, and 36 months for 480- and 4160-V breakers, and major maintenance (Fig 2) every 72 months, regardless of voltage. These are based on ANSI/NETA MTS guidelines.

If you're unfamiliar with these acronyms, NETA is for the InterNational Electrical Testing Assn and MTS for Maintenance Testing Specifications (for Electrical Power Equipment and Systems). MTS is an approved American National Standard.

But realize that established maintenance just tells you whether the breaker will work, not what might be wrong with it. Modern relaying can "speed up troubleshooting time after an electrical trip."



1. Moving parts in a generator circuit breaker must be properly lubricated and the grease checked for degradation. About half of the breaker performance failures are attributed to shortcomings in lubrication. In the photo, circles indicate recommended lubrication points

Finally, the presenters give critical suggestions for conducting opening time tests and measuring and trending contact gaps on the vacuum bottle for an indication of remaining life.

This is a presentation that you'll want to listen to, not just review the slides; the commentary adds valuable color and texture to the illustrations. CCJ

Visual: Contacts, bushings, controls, desiccant, gaskets, gauges, interrupters, timers, counters, trip/close coils, wiring, fuses, paint, etc. If possible and safe to do so, measure the contact cap on the vacuum bottle following the manufacturer's guidelines. This gap can be trended to determine end of life. If the gap is too wide, the vacuum interrupter has reached end of life

Minor: The visual recommendations above, plus the following:
- Timing tests (profile). Secondary current injection. It is critical to operate the breaker and capture the *first* trip time.
- SF_6 breakers require gas-purity and moisture checks.
- Send data to an engineer with breaker expertise for analysis according to manufacturer specifications.

Major: The minor recommendations above, plus the following:
- Cycle breaker to verify local/remote close, trip, reclose, trip-free, and anti-pumping (prevents multiple breaker closures) functions.
- Mechanical inspection and lubrication checks (stabs, rollers, bearings). Can impact arc-flash rating.
- Electrical tests: Contact resistance, hi-pot vacuum bottles, megger, coil resistances, and minimum-trip voltage test.
- Send data to engineering for analysis.

2. Visual, minor, and major maintenance activities summarized above were developed from the ANSI/NETA MTS 2015 Guide (pages 66 to 68). These recommendations are strongly encouraged to help protect your plant against "interesting" breaker events

Proper HRSG inspection helps guard against a forced outage

Plant managers diligently pursue O&M strategies that have a high probability of success for keeping their electric generating assets in service throughout the "must-run" season—this to assure a profitable year.

Deciding on what inspections are necessary to access the information needed for reliable decision-making is part of the challenge. Today's meager budgets do not allow for inspecting everything you'd like to check with the latest diagnostic tools available. You have to pick and choose based on a review of operational data, equipment idiosyncrasies, and your instincts honed over the years.

Consider your heat-recovery steam generator. Many combined-cycle plants do not have a boiler expert on staff—one who is relatively knowledgeable about HRSG water treatment and damage mechanisms, welding, and metallurgy. Given the stationary nature of this equipment, damage, such as cracking at tube-to-header welds, may not be identified until it has reached the point when an outage is necessary.

Thus, given access to industry experience with HRSGs of a design the same as, or similar to, yours, perhaps you can develop a meaningful inspection plan that involves frequent visual checks by staff and detailed inspections by third-party experts every couple of years or so.

The experience of others, beyond that provided by colleagues, can be gained through participation in industry meetings—such as the monthly virtual sessions conducted by the HRSG Forum (https://hrsgforum.com)—where you have the opportunity to discuss your concerns with attendees.

Tube-to-header welds. Consider inspections of tube-to-header welds for a moment. You can do a crawl-through and look for signs of cracking when the HRSG has been offline long enough to cool. But you could miss cracks because they tend to "heal" as the unit cools down and it's unlikely you would see cracking on the back side of the tube in any event. But there could be other visual signs of leaks that you would see—possibly steam scoring on a tube's external surface.

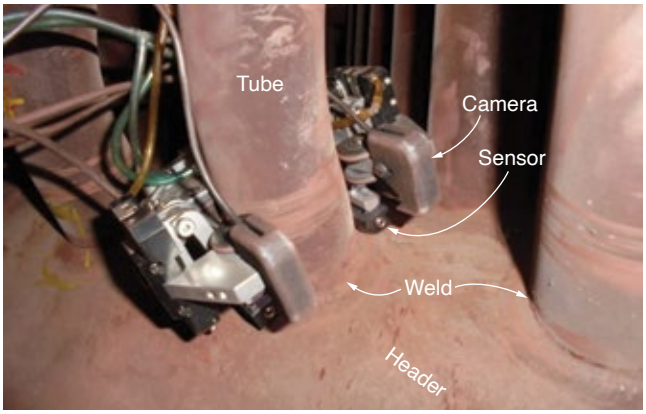
Magnetic particle inspection (MT) is better than a visual-only check, but surface preparation is necessary and you probably won't be able to see more than about 200 deg around the tube surface. Phased-array also is a possibility, but it too requires surface preparation and space restrictions might not allow complete access around the tube.

A better choice might be TesTex Inc's "Claw." It examines tube-to-header welds for cracking at both the toe of the weld and in the weld (Figs 1 and 2). Typically used for inspections in the HP superheater and reheater sections of the HRSG, it relies on the so-called Balanced-Field Electromagnetic Technique (BFET) for reliable identification of indications.

The device is used for header diameters of 4 in. and larger. The claws are able to examine the tube-to-header welds for tube diameters of 1.5 to 3 in.

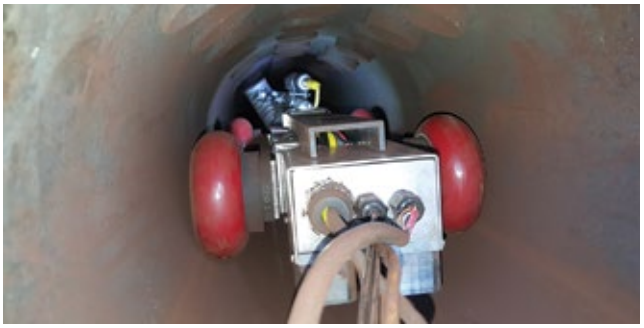
Tube-wall thinning. Using a proprietary Low-Frequency Electromagnetic Technique (LFET), TesTex technicians can examine HRSG finned tubes from the outside to detect and

1. Welds joining tubes to upper headers are inspected for cracking with the Claw. Note the baffle plate in front of the technician. It was removed and scaffolding was installed before the inspection team arrived onsite

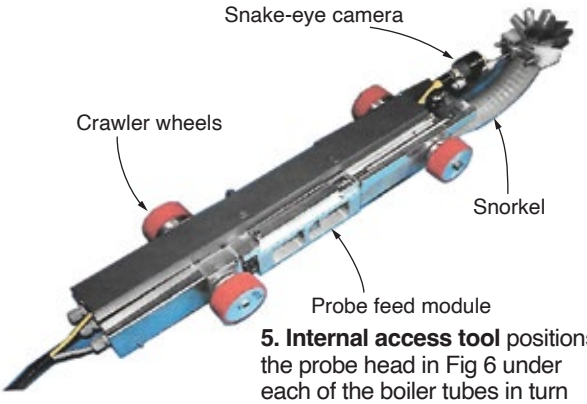


2. Claw, with two electromagnetic sensors (and cameras) located 180 deg apart, traverses 360 deg of the tube-to-header weld. No surface preparation is necessary. A three-person crew is able to inspect about 200 welds per shift

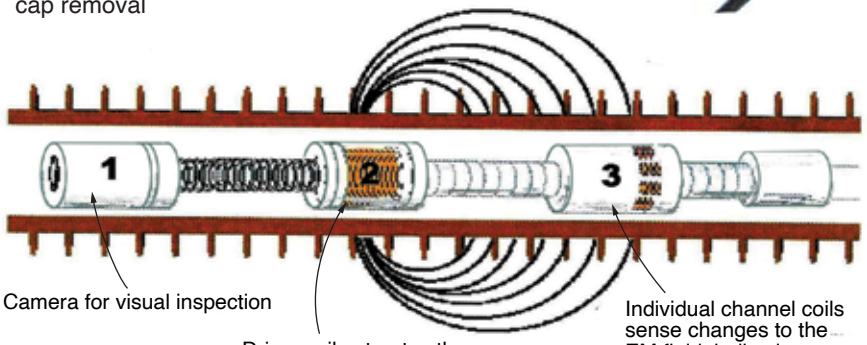
3. Finned tubes are scanned for internal damage. Technicians would expect to find indications of flow-accelerated corrosion, if they exist, within a few feet of the top and/or bottom headers. Under-deposit corrosion and pitting might be found anywhere along the length of the tube



4. Internal access tool is inserted in header following end-cap removal



5. Internal access tool positions the probe head in Fig 6 under each of the boiler tubes in turn



6. Probe head travels up through boiler tube to identify pitting and/or wall loss

7. FAC photographed by probe head is at the entrance to the upper header. Inspection of one header for a typical F-class HRSG takes about four days (30 tubes per shift)

quantify internal pitting, wall thinning attributed to flow-accelerated corrosion, and under-deposit corrosion (Fig 3). Benefit of LFET is that access holes don't have to be cut in the tubes to conduct an inspection.

TesTex's Shawn Gowatski says LFET is very reliable for locating pits of ¼ in. diam and larger, and wall loss in excess of about 20% of the tube wall thickness. This type of damage typically is found in the economizer and back-pass sections of the HRSG, warning of impending issues that can be corrected before a forced outage might be required.

A more exacting inspection of tube internal condition is possible using TesTex's Remote Field Electromagnetic Technique (RFET) using the internal access tool. The crawler (Figs 4 and 5) is inserted in either the upper or lower header after the end cap is removed and the RFET probe, equipped with a camera, is moved through individual tubes to detect wall thinning and make a video recording of the 360-deg internal surface (Fig 6 and 7). Probe travels at 2 to 3 in./sec. Current header-to-header tube-length limit is 70 ft. A benefit of using this tool is its ability to examine the full lengths of all the tubes in a header. CCJ

Secondary ignition in gas-turbine exhaust

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

Turbine Tip No. 15 from the PAL solutions library applies to all models of legacy GE gas turbines.

Secondary ignition (that is, an explosion) in the gas-turbine exhaust section can occur if unburned fuel collects there. On liquid-fuel turbines, false-fire drains are located in the bottom-most combustor and in the bottom of the exhaust plenum. As for operation on natural gas, the problem can become more acute—if the two fuel valves leak. In either case, cranking the unit for at least 10 minutes to purge the internal volume after a "failure to fire" incident is highly recommended.

During startup on natural gas, before firing, should both the stop and control valves leak, fuel will collect inside the unit. When normal firing commences, gas in the exhaust will ignite and explode, possibly causing damage to the stack, turning vanes and silencers (Fig 1).

Hundreds of gas turbines with "black start" capability were sold and installed following the Northeast Blackout (November 1965). Dual-fuel turbines were preferred, to meet the uncertain demands of electric utilities for emergency and peaking situations and fuel availability.

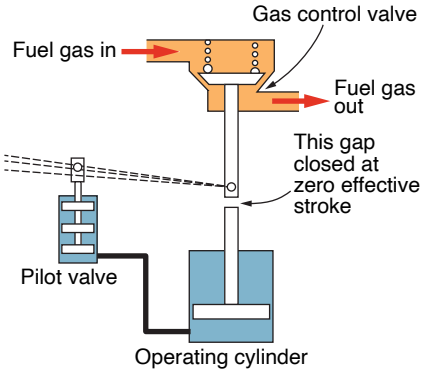
In recent years, operation on natural gas has become the norm because of its favorable cost and availability and the need to move away from distillate oil in power generation. Since natural gas is a compressible fluid, two valves are installed in series for control of both fuel *pressure* and *flow*.

Fig 2 shows a combined gas stop/speed ratio and control valve assembly provided by Young & Franklin for GE gas turbines. As a secondary function, the stop valve is also the pressure controller (abbreviated SRV). Knowing the inter-valve gas pressure (P2), the downstream valve controls fuel flow and is known as the gas control valve (GCV).

The two valves are designed for surface-contact sealing at their seats. Heavy-duty valve springs inside the body casting forcefully push down against the seats, creating positive seals (Fig 3). The clearance above the piston should be approximately 15 mils. This gap is referred to as the Zero Effective Stroke (ZES). The upward movement of the piston closes this gap before the valve begins to move upward, opening to allow gas flow.

1. Gas-turbine exhaust section: Secondary ignition can occur here if unburned fuel is allowed to collect in this part of the engine

2. Positive sealing of the stop and control valves in the combined gas stop/speed ratio and control valve assembly during shutdown is critical to explosion prevention



3. Clearance between the cylinder piston and valve stem should be monitored to insure proper valve operation

Turbine exhaust ignition (explosion) is caused by leaking gas valves. Both the SRV and GCV may not be seating properly. This could be because of poor surface contact, attributed to rust and corrosion. Also, the problem may be insufficient clearance above the piston(s). Both valves might be slightly open at turbine shutdown.

A third possible cause (though less likely) could be improper calibration of the linear variable differential transformers (LVDT) and servo valves. Fig 4 shows the LVDT for the SRV.

In the shutdown mode, the pressure beyond stop valve SRV should be zero, because the speed signal (NHP) is zero. P2 should be zero *upstream* of the GCV. The gas-control valve should be fully closed, as the control signal (VCE) is held to zero volts. Thus, both valves act to block any gas leakage when the turbine is shutdown. For a leakage clue, refer to the P2 pressure gage, which might display above zero psig at shutdown.

Some turbines have an automatic gas purge valve; older turbines should have a manual valve. Whichever is

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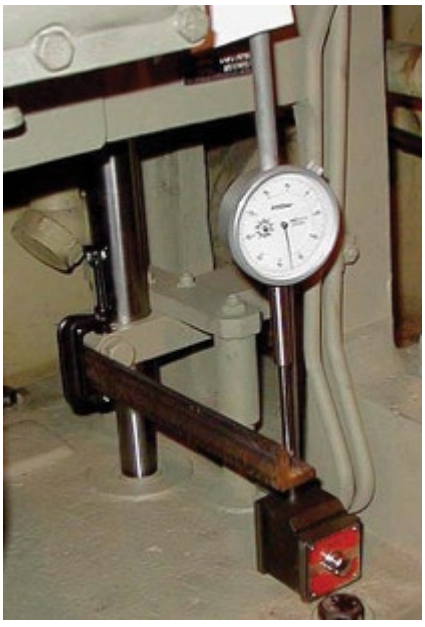
4. Improper calibration of the linear variable differential transformers and servo valves is conducive to gas leakage

installed, observance of the P2 pressure is important when the turbine is in the shutdown mode. It should be zero psig.

Recommended troubleshooting action

1. Determine the clearance above the piston(s) by using a feeler gage (should be 10 to 15 mils). Clean out any debris (rust, foreign materials) so the feeler gage passes freely between the surfaces.
2. Confirm the calibration of the SRV with two simulated signals: Speed (NHP) and fuel pressure (P2) with the hydraulics in operation.



5. Dial indicator is recommended for precisely measuring movement of the gas control valve

The SRV should not begin to move until speed is greater than 650 rpm. At the firing speed of 1000 rpm for GE Frame 5 turbines, the P2 pressure should be approximately 12 to 15 psig. Monitor the stroke and valve position by reading ac voltage of the LVDT. Confirm with a dial indicator as shown in Fig 5.

3. Confirm the calibration of the GCV using the manual VCE pushbutton on the startup card, along with the Man VCE control. See the Speedtronic™ card rack on the control panel.

   The GCV should not begin to open until the control voltage VCE exceeds 4.0 volts. The effective VCE range is 4.0 to 20.0 Vdc (fully closed to fully open). Monitor the stroke reading ac voltage of the LVDT and using a dial indicator.
4. Remove the cover atop the gas valves. If the range for the bolts holding the cover does not allow for removal, the entire valve assembly must be removed from the enclosure. Once the cover is removed, lift out the two springs and respective valve plugs. Inspect the surfaces of the plugs and clean. Look into the cavities to see if corrosion or rust exists on the valve seats. Proceed with lapping compound to clean the surface of the plugs and seats.
5. Reassemble the valve and again verify the clearance above the pistons and the setting of the LVDT position indicators. CCJ

Learn from one utility's arc-flash safety program

GC UG 2021

A quick search through the CCJ's editorial archives at www.ccj-online.com shows how much arc-flash safety is on the minds of owner/operators, especially in the best practices category. Whether you have a formal arc-flash safety program or not at your facility, there's still much to be gained by listening to Aaron Neuvert's presentation on this important topic at the Combined Cycle Users Group's 2021 virtual conference, available at www.powerusers.org.

His company has incorporated the relevant OSHA, National Fire Protection Association (NFPA), IEEE, and state standards to create its own program which "summarizes and simplifies [these standards] for practical application." The presenter's commentary substantially expands on the content of the slides.

Arc flashes are low-frequency, high-impact events but their occurrence is increasing industry-wide. About 2.5% of arc-flash incidents result in the death of a worker; 95% are caused by human error, so training and strictly adhering to, and updating, best practices are critical. Clear and proper labeling is vital, as is the use of the proper personnel protective equipment (PPE), both areas of the standards which have been updated recently.

A few main points:

- An open-air arc in a switchyard or a powerline may be more dramatic, but arc flashes in a contained space (arc in a box) are much more dangerous because the energy has only one path—towards the opening.
- Stay away from ground cables and ask the question, "Can a ground cable withstand the faults the manufacturer claims it can?"
- New best practices are coming into play, based on recalculation of so-called minimum approach distances (MAD).
- When modeling for boundary protection, test for equipment voltage, rather than rely on rated design data from the supplier.
- The arc-flash boundary becomes effective only when hazardous tasks (table) are being performed on or around the equipment.
- Always wear flame-resistant clothing when working around equipment prone to arc flash.

An audience member asked for thoughts on arc flash for dc equipment. The speaker responded that they are only starting to test dc systems; not enough is known about them yet, but he expects updates to industry practices within the next five years.

Long term, Neuvert projected, the solution is to become a "remote-racking" organization and use robotic devices which "take the employee out of the hazardous area." CCJ

Tasks for which the arc-flash boundary becomes engaged

- Any activity that increases the chance of a fault condition.
- Anytime the MAD is breached by a body part or uninsulated tool.
- Working on energized electrical conductors and circuit parts.
- Performing voltage testing.
- Racking potential transformer (PT) trays.
- Installing or removing protective grounds.
- Racking breakers into or out of energized compartments while within the arc-flash boundary.
- Installing or removing temporary barriers that are in direct contact with exposed live parts.
- Installing or removing bolted covers near exposed energized parts.
- Installing or removing buckets from energized motor control centers that are not equipped with integrated arc-flash safety features.
- Manually operating breakers, switches, or disconnects.
- Opening hinged covers on cabinets or panels that contain exposed energized parts.
- Installing or removing fuses.
- Working on control circuits with exposed energized electrical conductors and circuit parts greater than 120 V.
- Opening voltage transformer or control power-transformer compartments.

User Group Conference Schedule, First Quarter 2022

Fifth Annual Meeting and Vendor Fair
February 7 – 11, Orlando, Fla
Contact: ashley@aogusers.com

Annual Meeting and Vendor Fair
February 20 – 24, New Orleans, La
Contact: tammy@somp.co

Annual Meeting and Vendor Fair
February 21 – 25, New Orleans, La
Contact: tammy@somp.co

32nd Conference and Vendor Fair
March 27 – 30, Long Beach, Calif
Contact: wkawamoto@wtui.com

Eight earn Best of the Best honors in CCJ's 2021 Best Practices program

The COMBINED CYCLE Journal and the steering committees of the industry's leading gas-turbine user groups—including 7F, 501F, 7EA, Western Turbine, Frame 6, 501G, 501D5-D5A, AOG, and V—collaborate to expand the sharing of best practices and lessons learned among owner/operators of large frame and aeroderivative gas turbines.

More than 30 plants participated in the 2021 Best Practices Awards program with eight selected by industry experts for Best of the Best honors. Three of the eight are profiled here: Effingham County Power, p 86; Green Country Energy, p 90; CPV Towantic Energy Center, p 94. The others, previewed below, will be profiled in the next issue. Details of the Best Practices submitted by the remaining entrants (see list at the end of this introduction) will be published in future issues.

CCJ launched the industry-wide Best Practices Awards program in late 2004. Its primary objective, says General Manager Scott Schwieger, is recognition of the valuable contributions made by plant and central-office personnel to improve the safety and performance of generating facilities powered by gas turbines.

Industry focus today is on performance improvement and safety—including starting reliability, fast starting, thermal performance, emissions reduction, and forced-outage reduction—is reflected in the lineup of proven solutions submitted for this year's judging.

Milford Power owned by Starwood Energy Group and JERA Co and operated by NAES Corp, provided the details on how it upgraded emissions controls to meet today's more stringent requirements.

CPV Valley Energy Center, owned by CPV/Diamond Generating Corp and operated by DGC Operations, shared its new purge procedure that allows faster start of gas-line maintenance and how it reduced the costs of plant makeup and water discharges. Plus, the benefits of the facility's maintenance review process and its collaborative, comprehensive approach to safety.

River Road Generating Plant, owned by Clark Public Utilities and operated by GE, shared its experiences/solutions in solving problems with steam traps, finding gas leaks with an ultrasound camera, preventing trespassers from entering its transformer yard, and in making maintenance safer.

Kings Mountain Energy Center, owned by Carolina Power Partners and operated by NAES Corp, provided these best practices:

- Chemical-feed and water-treatment changes and improvements.
- Upgrading of automatic generation control benefits dispatch.
- Reducing the number of nuisance alarms with improvements to DCS logic and graphics.
- Safety improvements involving calorimeter vents, strainer removal, and valve relocation.

Woodbridge Energy Center, owned by CPV Shore LLC and operated by CAMS, separated wastewater streams to both reduce the cost of makeup and sewer charges. Also, how a collector-brush-system upgrade reduced maintenance requirements and how a small jib crane greatly improved safety in plate heat-exchanger maintenance.

Other plants submitting best practices that will be shared with users in an upcoming issue are the following:

AES Levant
Amman East Power Plant
Athens Generating Plant
BASF Geismar
Crete Energy Venture
Empire Generating Co
Energía del Valle de México II
Essential Power Newington
Fairview Energy Center
Great River Energy
Hunterstown Generating Station
Klamath Cogeneration
Lawrence County Generating Station
Lincoln Generating Facility
Marcus Hook Energy Center
Middletown Energy Center
New Covert Generating Co
Orange Cogeneration
Rolling Hills Generating
Rumford Power
Shepard Energy Centre
South Point Energy Center
Worthington Generation Station

Effingham

Don't forget transmission-line insulators in your maintenance plan

Background. On three occasions during 2019, Effingham County Power experienced flashover events caused by high-voltage insulator failures. On two of those occasions, the plant was online and experienced full-load trips due to loss of power.

The first event resulted in a loss of cooling water, leading to an overpressure condition in the condenser. The pressure-relief device had to be replaced prior to plant restart. And to restore service, the faulty insulator had to be located and replaced. This required staff to contact the local power company's T&D group for assistance. Utility personnel found the faulty insulator on a highline tower from ground level.

In the second instance, the power company's distribution group inspected all insulators using an unmanned aerial vehicle (UAV). For the third event, the insulator was located from the ground by the T&D group. The faulty insulators were replaced.

The challenge was to determine the insulator failure mechanisms and how they could be avoided in the future. During this process, staff learned there were two types of insulators at the plant: (1) Post insulators manufactured of porcelain and used in the generator step-up transformer yard, and (2) Suspension and string insulators on the transmission line that connects the GSUs to Effingham's substations. These insulators are on a 230-kV line and of polymer construction.

Effingham County Power

Owned by The Carlyle Group

Operated by Cogentrix Energy Power Management

525 MW, gas-fired 2 × 1 7FA-powered combined cycle located in Rincon, Ga

Plant manager: Bob Kulbacki

The post insulators failed because of porcelain glaze erosion from cooling-tower drift reducing their insulating ability (Fig 1). The suspension and string insulators were damaged by corona discharge, which breaks down the polymer and causes their catastrophic failure (Fig 2). All insulators had to be replaced; the utility's T&D group developed the replacement plan.

Solution. During the plant's fall outage, all post insulators were replaced with new ones having an intended service life of 20 to 30 years. Discus-

1. Post insulators failed at Effingham because porcelain glaze erosion from cooling-tower drift reduced their insulating ability

2. Suspension and string polymer insulators without corona rings could be damaged by corona discharge

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- Heat-Recovery Steam Generators
  (moderated by Bob Anderson)
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HRSG FORUM

sion arose with contractors on whether there was a way for the plant to ensure the new insulators would last their expected service lives. Their recommendation: Apply a silicone coating to all porcelain insulators to provide arc resistance and repel water. Note that the coating retains its ability to repel water after contaminants are deposited on the insulators. It also helps mitigate surface damage from electrical activity during extreme weather events.

Bear in mind that the white coating will discolor when it is beginning to fail. Operators visually check insulators on rounds; an electrical contractor inspects for coating integrity and deterioration on five-year intervals. The best method: UAV. These vehicles provide an up-close inspection of the insulators and they also provide photos useful in the development of a re-inspection plan.

The coating supplier recommends a six-year inspection cycle. Coating reapplication typically is required every eight to 10 years.

During the following spring outage, the transmission-line insulators were replaced with new polymer insulators equipped with corona rings. A majority of the original insulators did not have the corona rings and during removal were found to have numerous cracks. They also were severely brittle from corona discharge and in their as-found state were prone to a flashover under certain atmospheric conditions.

Results. The new insulators, designed for service lives of 20 to 30 years, have been in service for nearly two years. The plant developed an inspection program to monitor for damage and schedule maintenance as required. Lessons learned from the 2019 event were incorporated into a training presentation to share with other Cogentrix plants.

The return on investment for replacing all the insulators and coating them will be about a year and a half, based on the cost of the replacement power required by customers during plant trips. While changing out insulators, Effingham was unavailable for dispatch, resulting in lost revenue. Plus, there were costs for replacing the condenser overpressure device and for performing equipment inspections associated with the plant trips.

Project participants:
Sean O'Neill
Bob Kulbacki, general manager

Metal-seated ball valves for HRSG drain service: Reliable, long-lasting

Challenge. Each of Effingham County Power's two heat-recovery steam generators (HRSGs) has seven superheater drain headers: one each for the low- and intermediate-pressure sections, two for the hot-reheat section and three for the HP. The valve configuration for each header is a manual globe valve and a motor-operated valve (MOV, Fig 3). Prior to each start, the three sections of the HRSG (LP, IP, HP) are drained of any residual condensate. Once the gas-turbine purge is complete, the MOVs cycle as part of the GT start sequence.

Superheater drain valves usually are operated 400 to 500 times annually under various steam pressures and temperatures. Typically, the manual isolation valves were closed after startup to minimize heat exposure to the MOV motor. With this mode of operation, the plant eventually would encounter valve failures attributed to steam-cut seats and discs. Result: Steam loss and exposure of the MOV

motor to elevated temperatures, leading to component failure.

The plant replaced the original manual block valves with ones manufactured by different vendors, looking for the design that could survive in this service. One allowed for the plant to re-lap the seat once a steam cut was detected. But such a repair requires a plant shutdown and draining of the HRSG. When the manual isolation valve could not be repaired, it had to be replaced—another repair requiring an extended outage.

Solution. The cost of a new drain valve for this service is about $4000, plus $5000 to cut out the old valve and weld in a new one. Typically, when the manual globe valve required replacement, the MOV was damaged enough to require its replacement at an additional cost of $4000. Staff tracked the lives of these valves and they were in service one to two years, depending on the application, before requiring repair. Lap repairs extended the lives of the valves by a year or two.

Personnel reviewed user-group posts and found that other plants had similar experiences. They reported replacing the manual globe valves with metal-seated ball valves. There were several manufacturers mentioned, each having its advantages and disadvantages. Effingham selected a design and manufacturer based on reviews and the ease of changing out the cartridge assembly once valve leak-by started.

3. Superheater drain headers as-designed had a manual globe valve and motor-operated valve

Now, when either a superheater MOV or manual isolation valve leaks excessively and requires replacement, the isolation valve is upgraded to a metal-seated ball valve. New ball valves come in P91, P22, and SA105 construction so they can be used for all superheater headers in the plant's HRSGs. They also are the same size as the original manual globe valves, eliminating the need for piping modifications.

Results. Since this project started, eight superheater drain valves have been converted to metal-seated ball valves, with these benefits: (1) Ball valves require less time to close than globe valves; thus, operators spend less time performing this evolution, and (2) Although one ball-valve cartridge assembly failed in service, because no welding was required, maintenance was completed during an extended shutdown after draining the HRSG; there was no unit unavailability impact.

Better sealing characteristics also have been observed when using ball valves, contributing to a longer service life for the MOV and its motor. The superheater drains with ball valves installed have not had any MOV failing to open or close because of overheating. Result: Improved heat rate—because of not losing an excessive amount of steam while starting up the unit.

Project participants:
Sean O'Neill
Bob Kulbacki, general manager

Green Country Energy

Owned by J-Power USA

Operated by NAES Corp

801 MW, three gas-fired 1 × 1 7FA-powered combined cycles located in Jenks, Okla

Plant manager: Danny Parish

Improving the HRSG cleaning process and safety

Challenge. Safely conducting pressure-wave cleaning of last-pass tube bundles (stack side) in Green Country Energy's three heat-recovery steam generators.

As is the case at nearly all combined-cycle plants, maintaining optimum HRSG performance is critical to financial success. Rust, ammonia salts, and insulation debris can reduce heat transfer and increase gas-turbine backpressure, thereby increasing plant heat rate. GCE historically had used CO_2 ice blasting to clean tubes; it required approximately 10 shifts to complete and had not proven effective at removing all rust, especially in the tightly bundled LP economizer section. Research indicated that GE Power's Pressure Wave Plus cleaning showed promise for removing rust in these areas.

GCE conducted its first Pressure Wave Plus cleaning in spring 2018. To perform the cleaning, a technician (a/k/a lance operator) had to replace the consumable bag on the lance after each shot sequence. Four lanes had to be cleaned. All lanes selected, except for the final lane, had access doors on the side of the HRSG with platforms that allowed the operator to remain outside the door and use a rope to pull the lance outside the opening to reload with a new bag that is filled with gas and ignited to produce the pressure pulse.

The final lane, on the stack side of the LP economizer, was accessible only by entering the stack through a manway (Fig 1), climbing a 9.5-ft vertical ladder, and entering a second manway opening (Fig 2) in the raised floor of the stack. The second manway opening was offset from the vertical ladder by 16 in., creating an awkward angle for the operator to enter. Each pressure-wave shot required entering and exiting the stack to retrieve the lance flex hose and replace the consumable bag.

1. The stack side of the LP economizer was accessible only by entering the stack through this manway

The awkwardness of the ladder and the offset opening caused an ergonomic issue while accessing the space. After making 28 trips into and out of the stack in approximately two hours, the lance operator experienced a muscle strain in his right hip. A safety stand-down was conduced to assess the situation. Once the issue was brought to the attention of GCE staff, pressure-wave cleaning on the stack side was suspended until an acceptable solution could be identified. The remaining HRSGs were cleaned, except for the stack-side tubes.

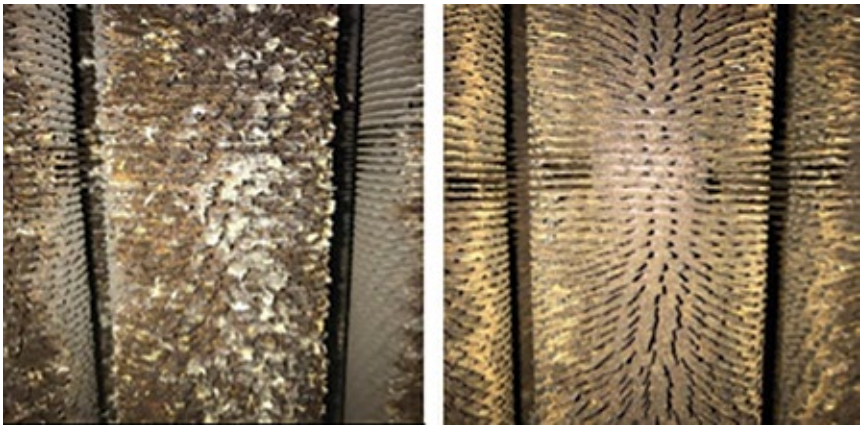
Solution. Constructing a stairway to the opening in the raised floor of the stack was discussed initially. However, the idea was dismissed because the operator still would have to enter the first manway and climb the stairs into the space for each pressure-wave shot.

A better solution would be to create a new entryway into the space, one allowing the technician to remain outside the opening and replace the consumable bags in the same manner as the other lances. GCE personnel identified a location suitable for installing the manway (Fig 3). The new doors then were installed during scheduled outages, thereby allowing cleaning of the stack-side HRSG tubes.

Results. All four lanes of all HRSGs are now accessible for cleaning in the same manner. During fall 2020, Unit

2. Once inside the manway in Fig 1, the lance operator had to climb a 9.5-ft vertical ladder and navigate a second manway (offset from the ladder) to enter the stack (left)

3. Existing HRSG doors are to the left of the new stack door at the far right (below)



4. Fouled stack-side tube is at left, after cleaning at right

2 HRSG was cleaned using Pressure Wave Plus with good results in four 12-hr shifts. Four lines and 11 levels (five shots per level) were completed in each of the four lanes. Thus, 880 bags were used to conduct the cleaning in each HRSG, with the lance operator able to remain outside the doors to reload bags for each level on a line. After each line was completed, the operator would enter the space to assist in moving the rigging to the next line.

With this arrangement, the operator had to enter each space only a few times. The debris accumulation after cleaning ranged from 9 to 14 in. deep at each door; it was removed by a vac truck and held in containers until taken offsite. With the new doors installed in the HRSG stacks, Pressure Wave Plus cleaning was completed successfully (Fig 4) and with no safety incidents.

Project participants:
The GCE maintenance staff led by Chris Shipman

Eliminate compressor fouling caused by inlet-filter seal bypass

Challenge. As is the case with nearly all generating plants powered by gas turbines, maintaining the optimum heat rate on the GT/Gs is critical to financial success. In 2017, GCE experienced significant compressor fouling and heat-rate loss because of unexpected seal bypass on its HEPA filters.

Green Country opted for HEPA filters because of historical issues with the GE 7FA fleet's original R0 blades. From 2007 through 2011, the entire GE fleet was faced with the lack of water-wash options because of R0 blade failures. During this period, GCE began seriously researching options that would improve and/or maintain the compressor cleanliness conducive to low heat rates. The plant's first set of HEPA filters was installed in 2012.

At the time, the expectation was that these filers would last about three years—based on assumptions of about 40% to 50% capacity factor and of maintaining the inlet-filter differential pressure below 2 in. H_2O. The selected filter manufacturer (Gore) had instructed the plant that the factory-installed prefilters should not be removed or replaced during the life of the HEPA filters (Fig 5). GCE's assumptions for run-time hours and differential pressure were reasonably accurate and the filters were replaced in 2016 with no negative effects experienced.

More recently, several HEPA filter manufacturers have adopted periodic pre-filter changeout schedules and today are offering one-piece prefilters. That was not the case in 2012.

In 2015, GCE requested bids for a second set of high-efficiency filters from multiple vendors. With cost-saving the motivation, GEC decided to split the second set of filters between Gore (one unit) and Clarcor (two units). Note that the Clarcor brand is now owned by Parker Hannifin Corp.

During 2016, the run profile at GCE changed significantly. The plant moved from starting 400 to 500 times annually to less than 200, because of round-the-clock dispatch. Plant capacity factor increased significantly. As a result, the filter-life exposure that had previously taken three years was now equal to about two years; however, the plant did not see a substantial increase in the pressure drop across the filters.

During filter-house inspections in spring 2017, plant personnel identified an unusual puddle of dark, molasses-like substance on the clean side of the filters (Fig 6). Lab tests concluded that the substance was consistent with airborne dust and pollen from the area. Initially, staff believed it was caused by leaks or other failures in seals on the inlet housing. A thorough inspection of the filters revealed no significant findings.

Six months later, during the fall outage, this same material was identified in the inlet houses of all three units. A thorough investigation determined that the material on the clean side of the filters was, in fact, dirt bypassing the filter seals.

Explanation: After about 4000 to 5000 operating hours, the filters would load up with a large amount of airborne dirt and tree pollen. The prefilters on the conical/cylindrical filter sets would hold this dirt and debris away from the pleats of the HEPA filters, thereby allowing the HEPA Δp to remain low.

During high-moisture events, such as rain or heavy humidity, the filters became saturated and their weight increased by 5 to 7 lb. The additional weight caused the filters to sag slightly, compromising the seal between the inlet housing and the conical filter and allowing the muddy material to bypass the filter seal. When the moisture event passed the filters would dry out

5. HEPA filters with original prefilters

6. Spring 2017 filter house inspection revealed a puddle of dark, molasses-like substance on the clean side of the filters

and return to their original positions, thus restoring the seal between the inlet housing and the filter.

Solution. The solution required multiple steps. First: Find an immediate solution for the filters that had experienced bypass events. This was accomplished by completing a thorough visual inspection on all 480 filters and replacing those having experienced seal bypass.

Second: Identify an engineering solution to manage the additional weight of the moisture and dirt on the filters. Two solutions identified were (1) Replace the Braden-style tripod supports with upgraded tripods capable of handling a higher load, and (2) Identify a way to manage the dirt load on the filters to reduce the potential for seal bypass to occur. GTC chose not to replace the tripods, because of cost and uncertainty of results. Instead, it installed new one-piece pre-filters over the existing HEPA filter sets (Fig 7).

Final step: Identify the appropriate pre-filter replacement interval to maintain long-term results. Staff decided on a semi-annual pre-filter replacement schedule.

The results thus far have been very encouraging. GCE started the pre-filter replacement program approximately two and a half years ago and staff has seen no evidence of dirt bypassing the filters. During the spring and fall outages in 2019 and 2020, the clean side of the inlet house was pristine.

In addition, GCE has increased the life expectancy of the HEPA filters from approximately 10,000-12,000 to 18,000-20,000 running hours. The annual cost saving is roughly $35,000 per unit based on filter-replacement cost alone. The more significant cost saving is related to maintaining as-designed unit heat rates and avoiding compressor cleaning—including offline water washes and mechanical cleaning during outages.

7. One-piece pre-filters enable replacement schedule conducive to desired long-term results

Important to note is that all plants have unique operating profiles and may have different filter challenges. Lesson learned here is that the plant and the vendor teamed up to find a specific solution to an issue that neither party had experienced previously. That collaborative process led to a reasonably simple and cost-effective solution that can be maintained easily over time.

Project participants:
The entire O&M staff

Managing outages during a pandemic

Challenge. Minimizing Covid-19 exposure risks to operations personnel during plant outages.

Prior to the pandemic (2020), contractors and staff would go to the control room several times a day during outages to sign onto LOTOs and be

issued their safe- and hot-work and confined-space permits. This created a social-distancing challenge for the Covid-19 guidelines in effect. It also put the control-room operator (CRO) at risk for contact exposure given the number of people in/out during the day.

With several major maintenance outages scheduled during spring 2020, GCE personnel recognized that to adhere to the Covid-19 guidelines and keep everyone safe, they would have to make significant changes to how they conducted their outages.

Solution. The first task was moving the exposure factor away from the control room. A 20 × 8 ft temporary office was rented and brought onsite (Fig 8). After 20 years of conducting outages from the control room, there was a lot of equipment to move out and set up in the new "outage headquarters." A new mobile LOTO board was designed, one that allowed lockboxes to be spread apart and easily sanitized (righthand image in Fig 8).

The next task was forming an "outage crew" consisting of three operators who would handle every aspect of the outage—work normally done by the CRO. By forming this new outage crew, contractors no longer had to enter the control room and possible Covid-19 exposure from contractors was limited to those three employees.

A new mandatory mask rule went into effect, along with a 6-ft social-distancing policy when applicable. To minimize traffic inside the portable outage office, only contractor supervisors would sign onto each LOTO, and then take a satellite box for the employees to hang a lock on. Office traffic was limited to no more than four people at a time. Sometimes this would slow down the supervisory effort, but it was necessary to take all precautions possible to prevent the spread of infection. At the end of each shift, the office was sanitized—including all chairs, computers, locks, and tables.

Results. All the new policies and exposure restrictions took getting used to. Near the end of the fall 2020 outage this plan got put to the test when a GCE employee tested positive. Upon receiving this news, management conducted contact tracing for each employee who might have had been exposed.

Nine employees, including the positive case, were quarantined; two were from the dedicated outage crew, the others were maintenance techs. No other operations personnel were affected. Had the new restrictions and processes not been adopted, operations personnel might have been impacted as well—and that could have impacted the ability to meet dispatch. Finally, none of the other eight employees quarantined tested positive for Covid-19,

Project participants:
The entire O&M staff

8. Mobile office for LOTO and permits is at the left, mobile LOTO board at right

Towantic

CPV Towantic Energy Center

Owned by Competitive Power Ventures

Operated by NAES Corp

805 MW, gas-fired 2 × 1 7HA.01-powered combined cycle located in Oxford, Conn

Plant manager: Larry Hawk

Technology-driven safety solutions reduce response time

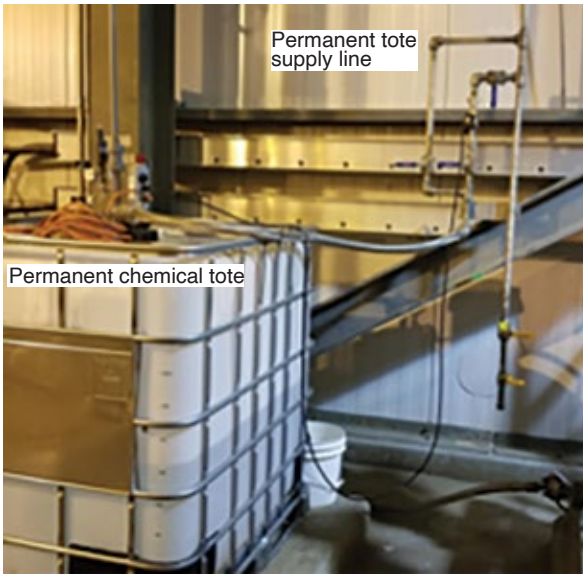
As technology drives reduced staffing, sites are seeing two-person shifts—one to man the control room, the other to perform hands-on equipment interactions in the field. This level of staffing could create risks to ensuring both operators are positioned to be effective in case of an emergency or in responding to alarms and events.

Risks can be mitigated by reducing the effort required to maintain chemical inventory; the staging of "zero-minute" equipment; using technology to enable automatic check-ins; and providing access paths to temporary electrical needs, like heat trace and hand tools, to help maintain safety during challenging times.

Challenge 1. Aqueous ammonia is injected into the steam cycle for chemistry control. The original plant design called for locating portable totes of boiler chemicals at the chemical injection skid. This presented risks—such as chemical spills, fork-lift collisions, and making and breaking hose connections to the injection system.

Solution 1. A hard-piped supply line was installed from the onsite aqueous ammonia storage tank to a permanently mounted tote (Fig 1). This allows for filling the boiler chemical tote with only valve and pump manipulation. There is a built-in, high-level cutoff switch which trips a solenoid valve to prevent overfilling of the tote.

Results 1. The permanent ammonia transfer system allows for on-demand filling of the chemical injection tote, and eliminates the risk of chemical spillage from the moving of totes with a forklift, and when connecting or disconnecting adjoining hoses.



Challenge 2. An extension cord run through a doorway creates a safety hazard with a risk of cutting the cord. Plus, laydown of cords in walkways creates trip hazards.

Solution 2. Through-wall apertures with removable covers allow deployment of extension cords without having to go through doorways (Fig 2).

Results 2. This modification eliminated trip hazards, and electrical-shock hazards caused by cord insulation that has been sliced through. Plus, it allows full door closure.

Challenge 3. A spill of a hazardous liquid could flow into the stormwater drainage system and contaminate drainage ponds, and possibly flow offsite.

Solution 3. Spill kits are staged for deployment at each stormwater catch basin (Fig 3) to contain any hazardous liquids on the surface, thereby preventing spread of the contaminated area.

Results 3. Spill kits enable very fast response to contain spills before they have a chance to flow into the drain system and possibly offsite.

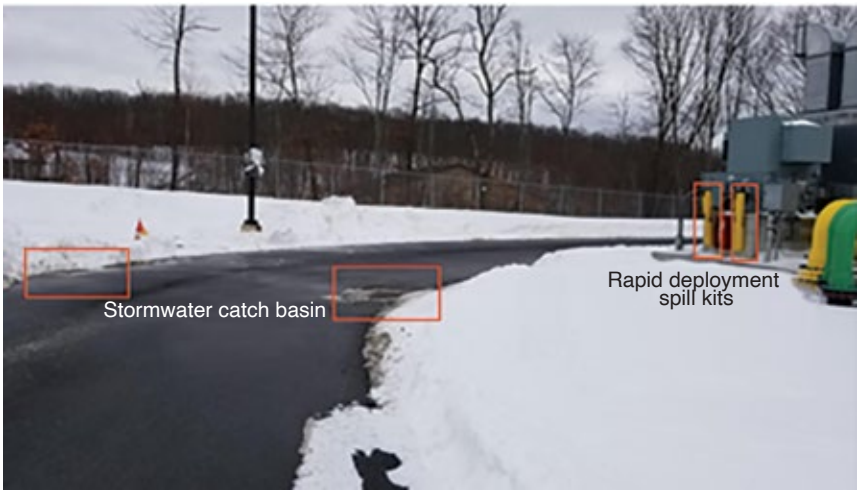
Challenge 4. Operators on night and weekend shifts work alone for extended periods and traverse all areas of the plant. If they fall or are otherwise injured, there may not be anyone around to provide immediate assistance.

Solution 4. Lone-worker monitors track the worker's position in the plant and can recognize a fall (sudden acceleration) or cessation of movement.

Results 4. Monitors are worn by lone workers when they are out in the plant by themselves (Fig 4). If the monitor senses trouble, a remote call center can directly speak to the worker through the monitor device (Fig 4), and an emergency call can be placed to the control room or operations manager if the lone

1. Permanent ammonia transfer system mitigates several safety risks (left)

2. Through-wall apertures eliminate need for electrical cords to go through doorways (right)



3. Spill kits allow fast response to inadvertent release of pollutants into storage ponds (left)

4. Lone-worker device allows CRO to track movement of personnel working outside (right)

worker is injured or unresponsive.

Project participants:

Ryan Earnheart, lead control room operator
Jason Johnson, control room operator
Mike Voytovich, operations manager
Yedes Adou, NAES compliance

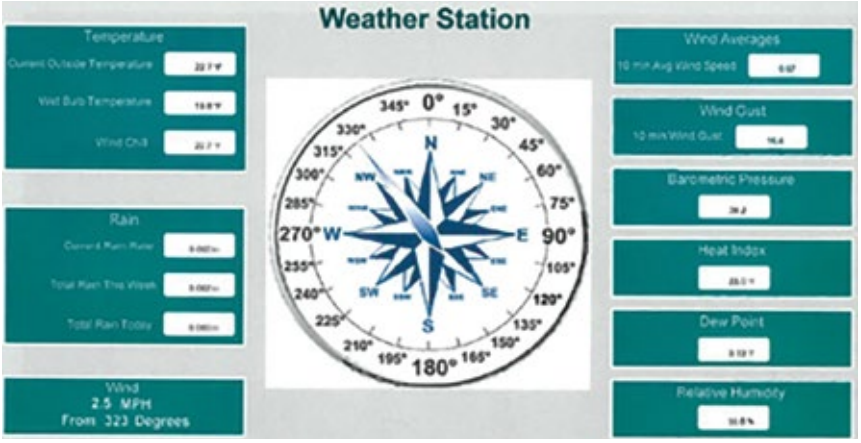
DCS improvements strengthen alerting, analytical capabilities

The site team is continually looking for process improvements throughout the plant. A few examples of last year's improvements: Vent-fan logic modifications to improve plant performance; addition of a weather station to assist plant modeling for dispatch and operations; GT and BOP alarm management to avoid distractions; PI email notifications added to assist with offsite monitoring.

Challenge 1. Gas-turbine package temperature was falling well below freezing during winter cycling. To mitigate the potential for natural-gas buildup in the package, OEM logic was to run enclosure fans anytime the P1 (gas) cavity was pressurized or wheel-space temperatures exceeded the set point. Given Towantic's outside units and northeastern location, this logic was conducive to very low package temperatures. The plant experienced several freezing issues—most often when the engine was on turning gear and wheel-space temperatures were still high.

Solution 1. The OEM approved a logic change allowing compartment fans to be shut down when the P1 cavity is vented and the unit is on turning gear. This has allowed modulation of compartment temperature to prevent freezing.

Results 1. Since this logic change was made, enclosure temperatures have been modulated successfully using compartment heaters and freezing issues have been reduced dramatically.



5. Weather station HMI screen gives operators a good view of real-time conditions

Towantic personnel take a break to celebrate their Best of the Best award

Challenge 2. Accurate local weather data for the plant was not available from a major city or public weather station given Towantic's remote high-elevation location.

Solution 2. Plant installed a local weather station on top of the gas-turbine filter house. Data gathered by this facility are brought into the DCS (Mark VIe) via an Ethernet connection through a Modbus card. An HMI screen was created for an operator interface (Fig 5), and weather points are logged on the site historian.

Results 2. Addition of the weather station has allowed control-room operators a better view of real-time conditions and has significantly increased the accuracy of the dispatch modeling used for bidding into the ISO.

Challenge 3. Most of the OEM-designated alarm classes did not make operational sense for this plant. Also, there were operational parameters specific

to the plant that did not exist in the standard OEM alarm management system provided. Diagnostic alarms—for example, a valve in manual—would create three alarms, creating a significant nuisance issue and clouding operator views of critical alarms.

Solution 3. After a thorough review by the site team, alarms have been "customized" to better reflect plant operations. The OEM provided basic alarms and alarm filters that were decent, but staff discovered they were not always perfect and could be improved. A few examples: Plant output voltage alarms were added to comply with NERC requirements; alarms were added to alert the operator if exciter PSS or AVRs are disabled; and multiple alarms had their levels changed based on site preference.

Results 3. Nuisance alarms that previously flooded the control room's alarm viewer screen (in the thousands) have been reduced dramatically, alarms deemed critical that may not have between identified from the base format have been made more visual, and alarm leveling has been more standardized. These improvements enable operators to focus on the most important alarms and not be distracted by nuisance alarms. Plus, site-specific alarming contributes both to better operation and NERC compliance.

Challenge 4. There was no email notification system in place to inform management of certain operational events—such as line breaker status, PSS/AVR status for NERC compliance, or changes in other important plant parameters.

Solution 4. The OSI PI system onsite was configured to send email notifications of various plant actions. Some examples: GT/ST breaker open/close; unit generator's PSS or AVR not enabled; unit in danger of a CEMS exceedance; unit not following its voltage schedule.

Results 4. These PI notifications have been helpful in enabling plant management to more accurately monitor site activities. This is valuable for nights and weekends, and especially during Covid times when site management may be working remotely.

Overall results. Implementation of improvements by the site team—such as those described above—has enabled staff to more effectively operate, troubleshoot issues as they arise, and ensure regulatory compliance without need of a more significant financial investment.

Project participants:
OEM engineering
NAES operations staff
Jesse Halkett, plant engineer

ACC predictive, preventive maintenance

Challenge. Air-cooled-condenser (ACC) fans—including seals, gearboxes, and motors—are difficult to access and are in very hot areas. These conditions make their maintenance and replacement difficult. Significant safety risks and high costs are a major consideration. The plant's challenge is to prevent component failures to the degree possible.

Solution. Two activities undertaken to reduce the likelihood of component failures are the following:

- During the spring and fall outages, plant personnel use a filter press to remove water, and particulates down to the micron level, from all gearboxes. Typical filter-press run time for each fan is about 90 to 120 minutes. This effort, combined with oil analysis, provides staff a good indication as to where Towantic is regarding oil condition. Use of the filter press also helps keep seals on the gearboxes from failing prematurely and allows personnel to see if anything is breaking down in the gearbox.
- Vibration monitoring. Staff installed three vibration probes on each ACC motor and gearbox, running cables to an accessible switch box below (Fig 6). The 180 probes installed on the 30 ACC fan assemblies allow regular diagnostic vibration readings on operating equipment. Knowing equipment condition, plant personnel can correct any deficiencies—such as misalignment, coupling failure, motor or gearbox bearing failures—in a timely manner to avoid in-service failures.

Results. The proactive approach described mitigates in-service failures with a potential annual saving of $100k in round numbers for repairs to seals, motors, and gearboxes—including the related costs of scaffolding, crane rental, and labor. This estimate is based on a modeled failure-rate analysis.

Project participants:
Thomas Coney and Brian Kennedy, maintenance mechanics
Plant O&M staff

6. Vibration cables are run from motors and gearboxes via cable trays (left) to switch boxes located below each fan (right)

PROFESSIONAL SERVICES

Index to advertisers

7F Users Group....92
7HA Users Group....93
501F Users Group....82
Advanced Turbine Support LLC....17
AGT Services Inc....44, 97
AGTSI....97, 99
Alstom Owners Users Group....33
Arnold Group....10-11, 40, 69, 74, 84
Black Start LLC....47
C C Jensen....53
CCJ Generator Training....69
Chanute Manufacturing....35
Chevron....2
Combined Cycle Users Group....88
Crown Electric....23
Cust-O-Fab Specialty Services LLC....52
Cutsforth Inc....50-51
Donaldson Company Inc....49
Doosan Turbomachinery Services..19
EMW Filtertechnik....75
EthosEnergy....31-33
Filter-Doc Corp....67
Generator Users Group....88
Groome Industrial Services Group....7, 29, 57
HRSG Forum....79, 89
HRST Inc....85, 97
Hydro Inc....4-5
IAPWS....35, 96
IC Spares....97
IPG Srl....77
JASC....15
KinetiClean (Groome)....57
Liburdi Turbine Services....41
MD&A....13
Millennium Power....48
Mitsubishi Power....100
Mobile Excitation Services....85
National Breaker Services....23
National Electric Coil....76
Noxco....29
Pioneer Motor Bearing....43
Power & Industrial Services....27
Power Plant Controls Users Group..88
Power Users, Forums....87
Power Users, Legacy Conference..81
Power Users, Umbrella Organization....25
RMS Energy....46
Schock Manufacturing....60
Steam Turbine Users Group....88
SVI Industrial....68
Taylor's Industrial Coatings....66
TesTex....27
TTS Energy Services....9
Umicore Catalyst USA Inc....21
ValvTechnologies....61
Zokman Products Inc....58

Get more from renewables with seasonal, centralized H_2 assets

In a webinar August 12, experts from Mitsubishi Power Americas (MPA) shared a first-order long-term modeling exercise which showed that a centralized hydrogen storage facility and hydrogen-fueled prime movers can economically avoid having to curtail wind and solar energy in the Western Electricity Coordinating Council (WECC) and improve carbon footprint even further than a baseline case.

The modelers acknowledged this type of modeling is a challenge: "WECC has 6000 generating units," one said. Also, as with all models and forecasts, there are numerous assumptions, including resource costs and electricity demand far into the future, policy frameworks to support decarbonization, and how much renewable energy would actually have to be curtailed.

The so-called "Green H_2 Hub" includes massive underground salt caverns (Fig 1), capable of storing up to 150 GWh of hydrogen, produced by 1000 MW of electrolysis units during the winter/spring shoulder months, and available to burn in gas turbine/generators during summer peaks.

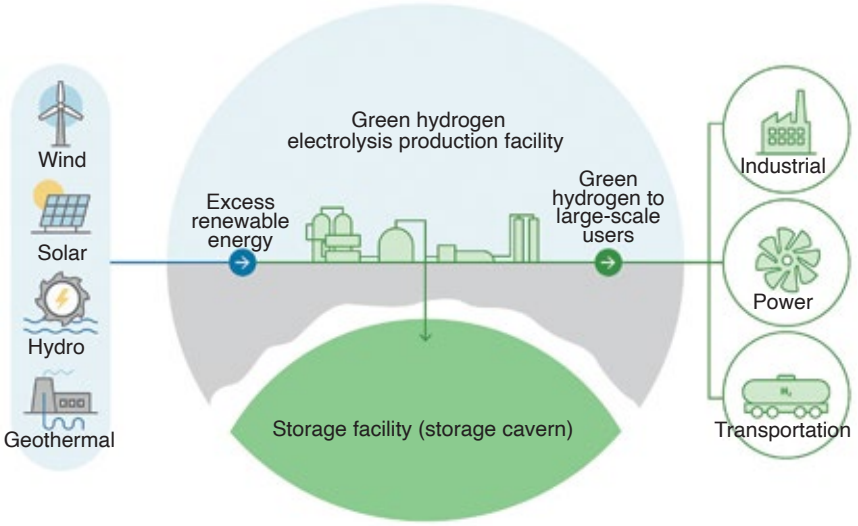
In 2050, the need for firm "green" capacity is evident (Fig 2), said the experts. The basic concept is a double bang for the buck—don't waste carbon-free renewable megawatt-hours because of curtailments, and reduce emissions by burning renewables-derived hydrogen (so-called green hydrogen) instead of natural gas. This long-term storage concept was distinguished from short-term storage using battery-based systems, although MPA also supplies battery systems.

The model also showed that overbuilding wind to solar was optimum.

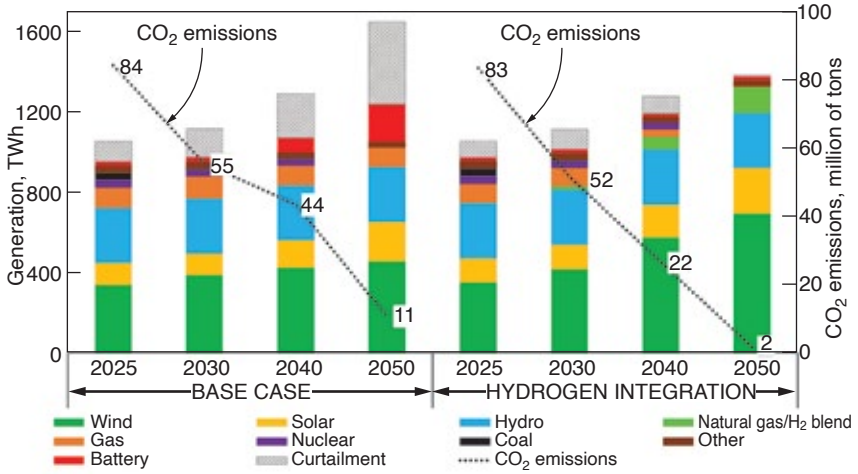
The Q&A session illuminated these points:

- The well-known (among utilities) Plexis cost model was used, not an in-house model.
- In addition to underground caverns, pipeline packing (increasing pipeline pressure) and "bullet" storage (pressurized vessels) can also be considered, but were not here.
- Only powerplants were considered as off-takers, not transportation or industrial facilities as shown in Fig 1.
- Mitsubishi is targeting 2040 when its turbine/generators are capable of 100% hydrogen firing.
- The capacity factors of the turbine units varied between 28% and 45% in WECC but would not necessarily apply to other regions.
- Though there is no agreed-upon definition, long-term storage has typically been considered as 12 hours or more but is evolving to 100 hours or more.

MPA also took the opportunity to highlight recent accomplishments and projects, including the Advanced Clean Energy Project in Utah, in collaboration with Magnum Development, based on the green hydrogen hub concept; adding 200 MW of battery storage to the Texas grid; J-Power's 1200-MW Jackson Generating Station in Illinois, a 2 × 1 J-class combined cycle said to be among the world's most efficient power producers and lowest carbon emitters; and the addition of J-class gas turbines at the coal-fired Intermountain Power Plant in Delta, Utah, which will be an off-taker of hydrogen from the Magnum/Mitsubishi storage facility. CCJ



1. Only powerplants were considered as off-takers for the stored hydrogen to keep the modeling manageable, although a green hub could easily supply industrial and transportation users



2. Renewable energy curtailments in WECC essentially can be eliminated by deploying large-scale seasonal, centralized hydrogen assets as a "green hub" as shown in Fig 1, while reducing carbon emissions substantially compared to the base case

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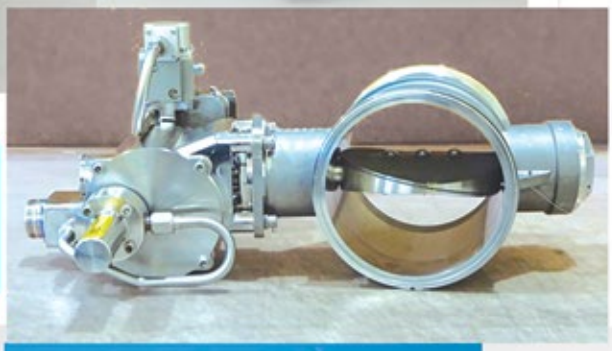

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