$15
Number 65 2021
www.ccj-online.com

CCJ
COMBINED CYCLE Journal

Reports from user-group meetings

Special interest

2020 Best Practices Award
CCJ COMBINED CYCLE Journal

Plants powered by 501F engines

Plants with LM6000s, LM2500s

Features

Register today for these 2021 meetings

From the desk of GTA Managing Director Salvatore A DellaVilla Jr

The Gas Turbine Association (GTA) salutes Congressmen Paul Tonko (D-NY) and David McKinley (R-WV), and Senators Lisa Murkowski (R-AK), Thom Tillis (R-NC), Richard Burr (R-NC), and Joe Manchin (D-WV), for the time and effort they and their respective staffs contributed to advancing the Energy Act of 2020.

GTA Chairman Jonathan Li noted, "GTA appreciates the significant efforts made by these legislators who recognize the importance that gas turbines make and will continue to contribute towards achieving lower emissions and reducing the carbon footprint. We believe gas-turbine technology is integral in realizing decarbonization of our nation's power-generation portfolio, and we look forward to continuing to support these efforts."

The Energy Act of 2020 includes important legislation that would support a multi-year, multiphase program focused on research, development, and technology advances to improve the efficiency of gas turbines in power generation—ensuring that GTs continue to play an important role in the generation mix to support the US with sustainable, clean, efficient, and reliable electricity.

The program's elements include support for engineering and gas-turbine design in the following areas:

- High-temperature materials—superalloys, coatings, and ceramics.
- Improved heat-transfer capability.
- Manufacturing technology required to construct complex parts with improved aerodynamic capability.
- Combustion technology to allow higher firing temperatures while reducing NO_x and CO emissions per unit of output.
- Advanced controls and systems integration.
- Advanced high-performance compressor technology.

Additionally, an area of focus will be to increase fuel flexibility by enabling gas turbines to operate with high proportions of hydrogen or other renewable-gas fuels, something many of GTA's member companies are already working on.

Under this new legislation, GTA will work to pursue the research goal of increasing combined-cycle efficiency to 70% and simple-cycle efficiency to more than 50%. To achieve these objectives, the GTA believes R&D efforts should focus on the following:

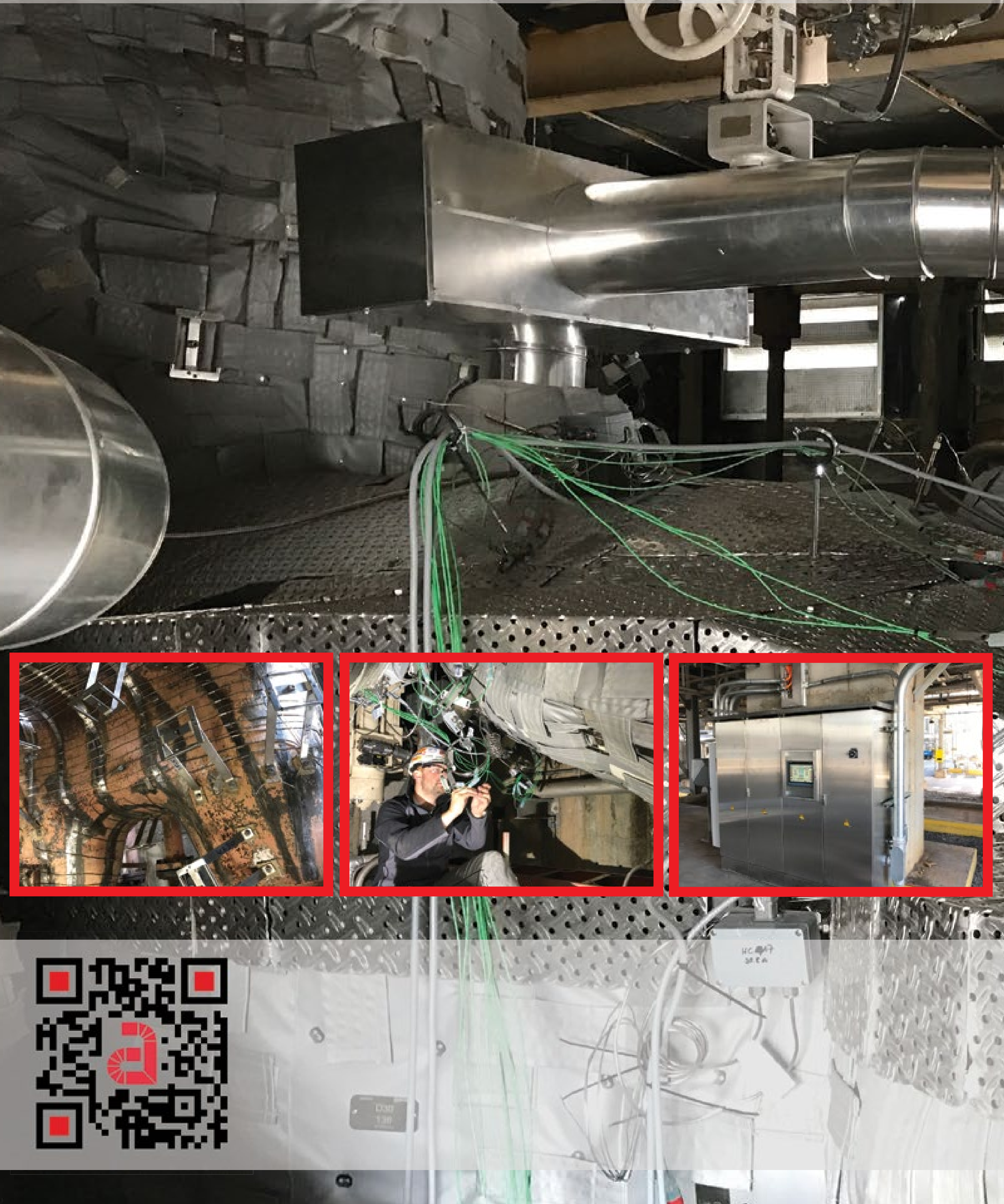
- Combustion technology.
- Additive manufacturing for gas turbines.
- Thermal management and advanced cooling strategies.
- High-fidelity integrated simulations and validation experiments.
- Unconventional thermodynamic cycles.
- Condition-based operations and maintenance.
- Digital twins and their supporting infrastructure.
- Gas turbines in pipeline applications.

About. GTA is a membership organization, established in 1995, that includes gas-turbine manufacturers, owner/operators, consultants, and third-party equipment and services providers. Its mission: Serve as a unified voice for the gas-turbine Industry. Today, GTs produce more than a third of our nation's electricity. They are a cornerstone energy-conversion technology, providing electricity and heat for industries and communities. Gas turbines will play an increasingly important role in the achievement of national objectives related to energy and the environment and will play a key role as part of the energy mix moving forward.

GTA
Gas Turbine Association
https://gasturbine.org

COMBINED CYCLE Journal is published by PSI Media Inc, a Pearl Street company. Editorial offices are at 7628 Belmondo Lane, Las Vegas, Nev 89128. Office manager: Robert G Schwieger Jr.
To cancel or change your subscription, write scott@ccj-online.com

NEXT GENERATION



TURBINE WARMING

Operational Advantages

- Eliminate Cold Starts
- Maintain Hot-Start Conditions
- Faster Starts
- Mitigate Case Distortion
- Advanced, Customizable Control

Maintenance Advantages

- Easy Access to Critical Areas
- Quick & Easy Removal / Reinstall
- Enhanced Operator Safety Features

Economic Advantages

- Gain Competitive Market Advantage
- Seamless Turnkey Solution
- Reduced Fuel Consumption
- Increase Profitability

Contact: Pierre Ansmann
pierre.ansmann@arnoldgroup.com

ARNOLD
GROUP

The 501F Users Group dodged the Covid-19 bullet last year, completing its 2020 conference just days before the pandemic forced the cancellation of in-person industry meetings. This year's conference, which began February 15, was the organization's first virtual event and included content also of interest to owner/operators of 501G and H frames, plus the V engines. Users responsible for all four frames were encouraged to participate.

What follows is a summary of 501F content broadcast during seven days over a two-week period. Sessions began at 10 a.m. Eastern all days and concluded by 4:30. Visit the 501F Users Group's website (https://forum.501fusers.org) to access presentations made available to the organization's membership.

Monday, February 15. Safety roundtable, plus Vendorama presentations by ARNOLD Group, Allied Power Group, Durr Universal, AGT Services, and National Electric Coil covering steam-turbine warming systems, gas-turbine inlet and exhaust systems, generators, and the inspection and refurbishment of generator high-voltage electrical connections.

Tuesday, February 16. Generator roundtable and user presentations, plus Vendorama presentations by Braden Filtration, Donaldson, Frenzelit, Parker Hannifin, and C C Jensen covering self-cleaning air inlet systems, gas-turbine solutions for more power, exhaust expansion joints, oil and water injection systems for dual-fuel engines, and remote monitoring of oil and diesel conditioning.

Wednesday, February 17. Inlet and exhaust roundtable and user presentations began the day's program, which included optional advanced-frame breakouts for owner/operators with engines later than the model FD3. A special training session, Generator Rotor 101, followed. Presentations by PSM concluded the day.

Thursday, February 18. Compressor roundtable and user presentations began the day's program, which included optional advance-frame breakouts for owner/operators with engines later than the model FD3. A special training session, Generator Stator 101, followed. Presentations by Mitsubishi Power concluded the day.

Tuesday, February 23. Rotor roundtable and user presentations, plus Vendorama presentations by Voith Turbo, ORR Protection Systems, SVI Dynamics, Shell, Reliability 360, and NordLock Group covering legacy starting systems, fire suppression, HGP component upgrades, interpreting lab oil-analysis results, monitoring of turbine bearings, and 4-way-joint leak solution.

Wednesday, February 24. Combustion roundtable and user presentations, plus Vendorama presentations by Nord-Lock, EMW filtertechnik, ARNOLD Group, and Doosan covering anti-seize coupling bolts, air inlet filters, and advanced single-layer insulation. GE's presentations to users followed.

Thursday, February 25. Hot-gas and auxiliaries roundtables and user presentations launched the day's program. Six presentations by Siemens Energy concluded the 2021 conference.

Officers and Board of Directors

President/Chairman of the Board
Russ Snyder, *VP generation operations, Cleco Power LLC*

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

Secretary and Board Member
Brian Berkstresser, *plant manager, Liberty Utilities*

Board Members:
Blaine Gartner, *principal engineer, Xcel Energy*
John Burke, *O&M manager, NAES Corp*
Dave Gundry, *senior engineer, Xcel Energy*
Dennis Winn, *managing director, Klamath Energy LLC (Avangrid Renewables)*
Ivan Kush, *principal CT and controls engineer, Cogentrix Energy Power Management*
Jaime Oliveira, *O&M senior manager, EdF*

2020 conference review

The 501F Users Group was the last of the US-based independent gas-turbine organizations serving owner/operators to conduct in-person conferences in 2020. That meeting began Monday, February 10, with the group's annual safety roundtable, followed by live presentations from about 30 third-party suppliers of products and services for the 501F. A vendor fair closed out the first day's program.

Presentations by users; roundtable discussion forums on the rotor, inlet and exhaust sections, compressor, combustor, hot-gas, and auxiliaries; and special closed sessions for the five OEMs serving this user community (Doosan, GE, Mitsubishi Power, PSM, and Siemens Energy) were sprinkled throughout the three remaining days of the conference.

Summaries of the presentations, beginning below, testify to the value of the information disseminated. The complete PowerPoints can be reviewed by registered 501F owner/operators on the user group's website at https://forum.501fusers.org/login. Non-members who meet the

organization's requirements can gain membership status by completing the online registration.

Presentations by owner/ operators

Analysis of K-N steam-turbine vibrations, corrective actions, results

This presentation is recommended reading by all dealing with vibration issues on the No. 1 bearing for a Siemens KN steam turbine—a combination thrust/radial bearing at the front of the HP/IP section. It is based on a thorough analysis by one of the industry's most experienced utility staff engineers and co-authored by the plant manager.

Some background notes: The steamer is an integral part of a 2 × 1 501FD-powered combined cycle, COD 2004, with a history of more than 2000 starts—up to 450 starts some years. Plant was sold by the IPP developer to the current utility owner in 2017. During the major inspection that year, work included the following: an OEM mod—hard-facing of bearing keys to address a fretting issue; high-speed shop balance; and KN coupling alignment. Post outage, the problematic bearing was reworked by the OEM three times in less than three years with changes made to bearing preload, clearances, etc, without resolving the vibration issue to the owner's satisfaction.

Observations related to the vibration problem that helped to guide the ensuing analytical effort and corrective action included these:

- Bearing vibration above 9 mils peak-to-peak at high loads with duct firing and power augmentation (PAG).
- Small thrust movement (1 to 2 mils) might change vibration. Curtailment of PAG reduced vibration.
- Bearing seemed to like the thrust load in a specific direction.
- Unit may run fine in a 1 × 1 configuration (2 to 4 mils), then jump to 4 to 9 mils in 2 × 1.
- Problem seemed isolated to the No. 1 bearing.

More than half the presentation's slides focused on the in-depth vibration analysis, with detailed drawings and charts of value to anyone similarly challenged. Among the findings of the outage taken in 2019 were the following:

- Keys were loose and seat worn, as the analytical work predicted.
- Bearing was aligned to the pedestal not to the journal. Elimination of the tapered gap allowed keys to fit as intended.

Results of the corrective actions taken included these:

- Vibration, which had been 4 to 9 mils at the No. 1 bearing, was reduced to 1.4 to 1.7 mils.
- Now there was nearly no vibration change with load change.
- Axial float near the assembled clearance was less than 12 mils, down from more than 20 mils.

The bottom line: The project was considered a success with the likely outcome that fretting may not increase clearances over time.

Lessons learned were several, with most applicable to many other plant challenges:

- Participate in users groups to gain the experience you might not have. Keep in mind, too, that you only get out what you put into any project. And, if you don't share, don't expect someone else to help you.
- Better to spend time analyzing data, and on understanding what to expect, than to go on a "witch-hunt" disassembly outage.
- Trust, but verify what's being done, even it's the experienced OEM doing the work.
- Never let a "good opinion" stand in the way of data, facts, figures, physics, etc.
- Check things out, document, take photos, understand what's being done while the unit is apart—not after it doesn't run well.
- An OEM data sheet may be signed off and a unit closed up, but if you don't know how and where those data were sourced from, the data sheet is just a piece of paper.
- When your issues have been addressed unsuccessfully more than once, and there are reams of data not understood, don't look for a "knight in white armor" to solve your problems. Own them!

GVPI stator-bar failures, lessons learned

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

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

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

All four stator bars, plus one non-failed bar without ridge as baseline sample, were extracted for root-cause analysis. A full rewind was performed on this stator. The slides did not comment on the difficulties of removing bars from a GVPI winding.

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

Generator inspection findings

The inspection findings on a generator serving one of three gas turbines at this 501FD2-powered, 830-MW combined cycle, COD 2005, are well-illustrated in the presentation and would have value as a training tool.

Minor cracks and greasing are in evidence at non-critical locations in the connection rings, stator endwindings, and leads to high-voltage bushings. Plus, some greasing was found on back-of-core ventilation seals. Note that generator design relied heavily on bonding with epoxy between ties, blocking, and leads.

While the slides do not mention corrective actions taken, if any, they likely would have been minor given the satisfactory condition of the machine, as portrayed in the photos. Replacement of main flex leads during the outage was mentioned; however, this was done based on the OEM's calendar-based recommendation, not because of damage or defect.

Integrating the direct-air-injection system into BOP operations

Uneven cooling of Siemens F-class gas turbines after shutdown sometimes leads to rubbing of turbine and/or compressor blades against the case. The OEM determined that by injecting cool air into the machine during shutdown, a homogeneous mixture of air can keep the top and bottom of the unit at roughly the same temperature and eliminate case bowing.

The standard OEM-supplied direct-air injection system (DAIS) would have used a stand-alone air compressor and injection hardware for each 501FD3 (with partial FD6 upgrade) at this 535-MW 2 × 1 combined cycle. However, plant engineers saw an opportunity to do more with the DAIS compressors.

It installed variable-speed compressors instead of the OEM-supplied conventional air packages and incorporated them into the plant's original air system, plus the piping system that extracts air from the cold-air side of the rotor air coolers (RAC, a/k/a kettle boilers). A slide in the presentation provides a system diagram.

Given the RAC cold-air side temperature is 390F or above, an additional air-to-air exchanger with a variable-speed fan was installed to reduce that temperature to less than 100F. Extraction air, from either the Unit 1 or Unit 2 compressor, is supplied to a common header that can satisfy BOP air requirements as well as the DAIS needs for an offline turbine.

Benefits of this lineup include the following:

- The original BOP service compressors rarely operate.
- GT extraction air typically supplies all of the plant's needs.
- If no gas-turbine compressor air is available, the DAIS units supply plant air.
- Energy is saved—about 680 MWh annually.

Combined-cycle upgrade to T3000 V8.2

Owner/operators planning a control-system upgrade from T3000 to T3000 Version 8.2 would benefit from reviewing the project overview and management and execution slides provided by staff at a plant that recently converted two 2 × 1 power blocks to V8.2. The gas turbines at this facility are 501FD2s, the steam turbines are KNs.

A few of the lessons learned shared at the meeting are these:

- During the initial meeting with the OEM, ask for a full explanation of the major differences between your system and the upgrade—such as PI interface platform, hardware, etc.
- Get your company's PI administrator involved at the beginning of the project.
- Obtain the Modbus list for all third-party interfaces.
- Keep the existing T3000 application server powered up and use it as a reference.
- The more control-room operator eyes the better.

Penflex pipe failure experience

Plant experienced a step change of 4 deg F in the flashback temperature expected on one combustor. Two days later there was an additional step change of 8 deg F. These step changes corresponded to a blade-path temperature shift of about 15 deg F from the expected value.

The combustor section was inspected and a Row 1 vane was found with a heavy breach and an adjacent vane with moderate erosion/possible breach. Siemens opened the unit finding several parts burned up; plus, the Penflex pipe on the right-side top had failed. A full combustion inspection was conducted.

Investigators did not attribute the R1 problem to the Penflex pipe failure. The damaged pipe was replaced. None of the Penflex pipes on the unit showed any damage.

Special closed sessions

Doosan

Doosan Turbomachinery Services' (DTS) presentation to the 501F Users Group, Thursday morning (February 13) from 8 a.m. to 9, featured a company/facility profile followed by details on how it conducts major maintenance on rotors, exhaust sections, and blade rings.

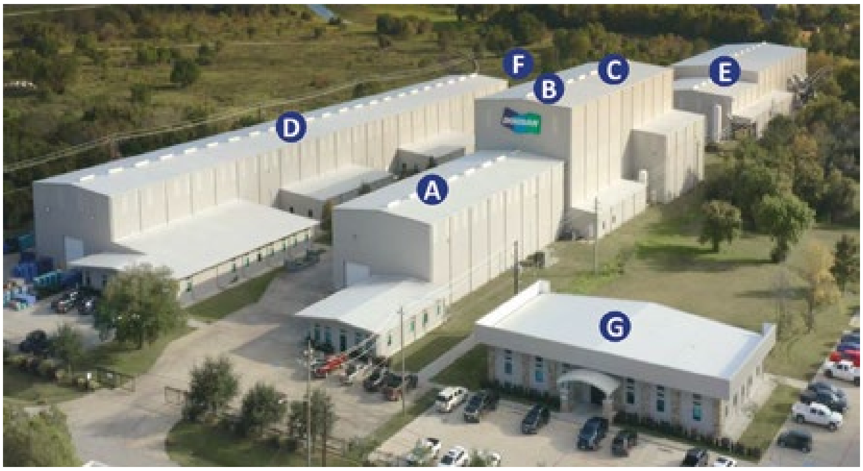
The company's relatively new shop in La Porte (Houston), Tex, has the capability for F-class inspection, overhaul, repairs, and new-parts manufacturing (Fig 1).

Doosan has earned respect among 501F owner/operators for its work in this fleet. To illustrate, the company's repair/upgrade solution developed for the 501F two-piece exhaust system six years ago has been adopted by several plants.

More recently, it completed the in-kind replacement of the torque tube and air separator for a W501FC during a major maintenance interval. Reverse engineering for that project began immediately after de-stack at the La Porte shop. White-light 3D scanning and metallurgical analysis of the existing torque tube and air separator started the process. Note that neither component had failed but the owner decided to replace both given fleet history and unit age.

Doosan Heavy Industries, the parent of DTS, had a turbine forging in Korea that matched the material composition required; the forging properties were confirmed and rough machining commenced shortly after receipt of the rotor. A team of DHI engineers was dispatched to Houston to help complete the reverse engineering and characterization.

In the final stages of the project, DTS sent the 16th-stage compressor disk and curvic adapter to DHI in Korea. The disk was properly matched to the torque-tube pins, the curvic adapter was mated, and components were returned to La Porte for reassembly. The project was completed on schedule. The original torque tube and air separator were refurbished and



1. Doosan Turbomachinery Services has more than 100,000 ft² of shop operations under roof at its La Porte facility, with room for expansion. Rotor bay A in the photo has dual 30-ton cranes, rotor high bays No. 1 (B) and No. 2 (C) each have 100-ton and dual 30-ton hooks, component repair shop (D) has 30-, 10-, and dual 5-ton cranes, thermal spray coating area (E) is equipped with dual 30-ton cranes. Building F is the blast/surface modification facility and G is the admin building

2. Doosan inspectors perform incoming, in-process, and final inspections

3. Blade repair specialists do weld prep at booths in the background; dovetail-root simulators are in the foreground for fitment and rock checks

4. Moment-weigh station ensures all rotating components have optimized sequencing with the highest accuracy and repeatability

5. W501F exhaust-cylinder cases undergo Doosan's "zero-hour" repair process. It includes the shop's baffle-seal mod, upgraded saddle and strut shields, alignment mod and atmospheric vent mod

returned to the customer as emergency spares for its fleet.

Owner/operators might consider reviewing Doosan's presentation posted on the user group's website for the detail it provides. Example: The Class III inspection for rotor lifetime determination begins with an incoming inspection (Fig 2) that includes dimensional checks, runout measurements, balance checks, and a review of customer data and experiences (known issues, for example).

The slide on rotor unstack, the next step, highlights all the various actions involved—including the removal of the air separator and curvic adapter and unstacking of the torque tube and compressor. Unstack checks are next: dimensional checks, mag-particle inspections, fit-up checks, NDE of bolting, etc.

Phase 1 of the life-evaluation process is a thorough inspection after all airfoils and hardware are removed and the rotor is cleaned. Phased-array ultrasonic and eddy-current inspections of critical areas are conducted along with microstructural examinations. Phase 2 of the process focuses on engineering analysis (of flaws found, for example) and recommendations regarding continued service. New components installed may include torque tube, air separator, and upgraded bolting. Pictures of these parts are provided in the presentation.

The restacking procedure focuses on items users should be aware of, such as the following:

- Accurate measurement of compressor torque pins to verify clearances and alignment, assuring proper bolt placement, etc.
- On the turbine end, correct air-separator crush, disc-adapter stretch, proper bolt depth and stretch are important—among other things (Fig 3).
- Balance and reassembly involves runout measurements (verify less than 2 mils at the rotor midpoint, for example), checking locking hardware, moment weigh of compressor and turbine blades for low balance corrections, etc (Fig 4).

The exhaust cylinder was discussed next. This section offers a valuable review of nomenclature before reviewing typical as-found damage—such as strut-cover damage and cracking, and outer diffuser cracking and distortion. Most of the material presented thereafter focused on the company's "zero-hour" program for inspection, baffle seal and strut shield improvements, alignment and atmospheric-vent mods, and manifold repairs (Fig 5).

Think of the content in this portion of the program—24 detailed/heavily illustrated slides—as a checklist of things you should be aware of before digging into an exhaust system project. You'll also learn what work can be done in the field and what requires a shop visit.

Blade-ring disassembly and inspection was the last topic on the Doosan

program. It covered the special fixturing and procedures believed necessary to assure proper repairs and provided a checklist of things to be aware of during shop work—including vane camfit, torque pin slot, seal engagement, joint gaps, etc.

GE

The 2020 conference of the 501F Users Group marked GE's fourth year of participation in this event. Its technical session ran from 10 to 11 a.m. on Thursday (February 13), coordinated by Said El-Nahas, 501F product manager, and Ben Myers, service engineering manager. The program began with an introduction to GE Gas Power, a new organizational structure combining the company's new-unit and services operations under a single business entity focused on advancing sustainable gas-plant technology.

The steering committee requested presentations from the OEM on its exhaust frame and HRSG cleaning solutions, plus an update on hex-chrome findings. The session concluded with a refresher on GE technology adoption for 501F engines—including cooling/seals, coatings, materials technology, (such as dense vertically cracked TBC), and patterned abradable ring segments to extend the repair interval.

GE reported on the success of its performance upgrades at the 2 × 1 Tuxpan and Norte-Durango combined cycles, owned by Naturgy Mexico SA de CV. The former is powered by Mitsubishi 501F3s, the latter by Siemens 501FD3s. Both plants are covered by GE performance LTSAs and include planned and unplanned maintenance for gas and steam turbines and auxiliaries, generators and auxiliaries, main-steam valves and actuators, and control systems.

Here's what the speakers said:

- Maintenance intervals were extended to 32k hours/1250 starts.
- Output was increased by up to 9.2%.
- Heat rate was reduced by as much as 2.9%.

Regarding the exhaust frame, the speakers reported the following findings:

- Severe liner cracking.
- Strut creep affecting rotor position.
- Bearing damage.
- Baffle seal plate cracking.

GE's objective was to mitigate these issues by developing repair solutions that could be implemented during a major inspection without schedule impact. Engineers developed an upgraded two-piece exhaust cylinder, made improvements to the saddle and strut shield, and upgraded baffle seals (new material and replaceable during an outage). Specialized repair processes also were developed for field implementation.

HRSG cleaning technology was covered next—specifically GE's PressureWave Plus system. It was said to be superior to standard dry-ice cleaning, deep-clean dry-ice cleaning, and water washing regarding the following: no scaffolding required, reduced risk of fugitive emissions during startup after cleaning, reduction in cleaning time, depth of cleaning of at least 3 ft, and of no risk to pressure parts.

Hex-chrome concerns, probable causes, and containment/corrective actions were equal or similar to those presented at other user meetings in the last couple of years. Attendees were referred to GE's PSSB 20180709A/B document and any subsequent update.

Mitsubishi Power Americas

Mitsubishi Power spent a productive four hours with users on the third day of the meeting, discussing and answering questions on a wide range of topics. Presentation segments selected by the editors for coverage here, given their high interest to owner/operators, are the following:

- Safety culture and initiatives to help protect plant and contractor personnel.
- Lifecycle experience with critical turbine components.
- Comprehensive rotor inspections and upgrades—for the air separator and torque tube, in particular—to address fleet issues.
- Exhaust-system solutions.

Safety. The Mitsubishi program began with a field-service safety review demonstrating the company's "safety first" attitude and approach to work. Continuous improvement is the goal of its behavioral-based safety programs.

Similar messages open presentations by virtually all OEMs and contractors these days, but many do not dig into the details like Mitsubishi Power did. The company uses OSHA metrics to benchmark its EHS performance against other manufacturers and service providers serving the electric-power and comparable industries. Example: From 2015 to 2019, its field-service effort grew from 1.1- to 1.7-million man-hours—or by about 50% in just five years.

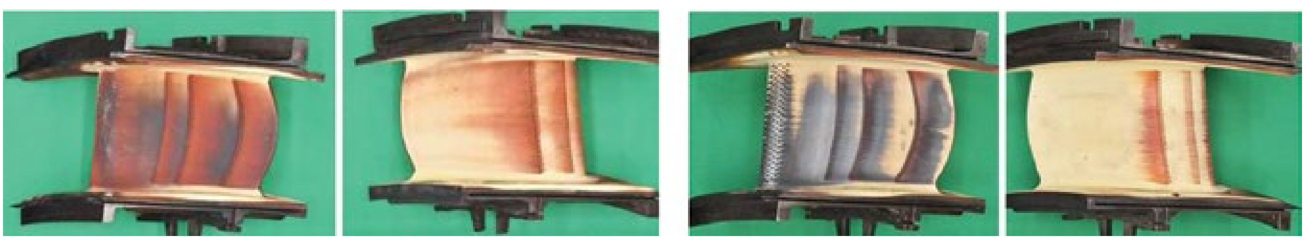
Over the same period, Mitsubishi Power's EMR score was stable at 0.6 in round numbers. Not familiar with the acronym EMR? Experience Modification Rates are provided by insurance companies—in Mitsubishi's case, the National Council on Compensation Insurance (NCCI)—and used by OSHA to evaluate safety standards in the workplace.

The Safety Management Group, which promotes itself as a "nationally recognized" service organization providing workplace safety consulting, training, staffing, and program planning and implementation, says most companies have an EMR of 1.0. Generally speaking, the higher the EMR score, the higher the insurance premium.

Another measure of occupational safety is the Total Recordable Incident Rate (TRIR). It is derived by combining the number of safety incidents and total work hours of all employees in a "standard" employee group—typically 100 employees working 40 hours a week for 50 weeks of the year. Thus, it offers a company the means to benchmark itself against others in its industry, as well as to evaluate its own performance over time.

Mitsubishi Power's average TRIR for the 2015-2019 period studied was 0.84, well below the benchmark figure of 1.1 reported by a reputable source for the electricity, gas, water, and waste services industry. Manufacturing, by contrast, had a 2.8 incident rate per 100 workers; construction, 2.6.

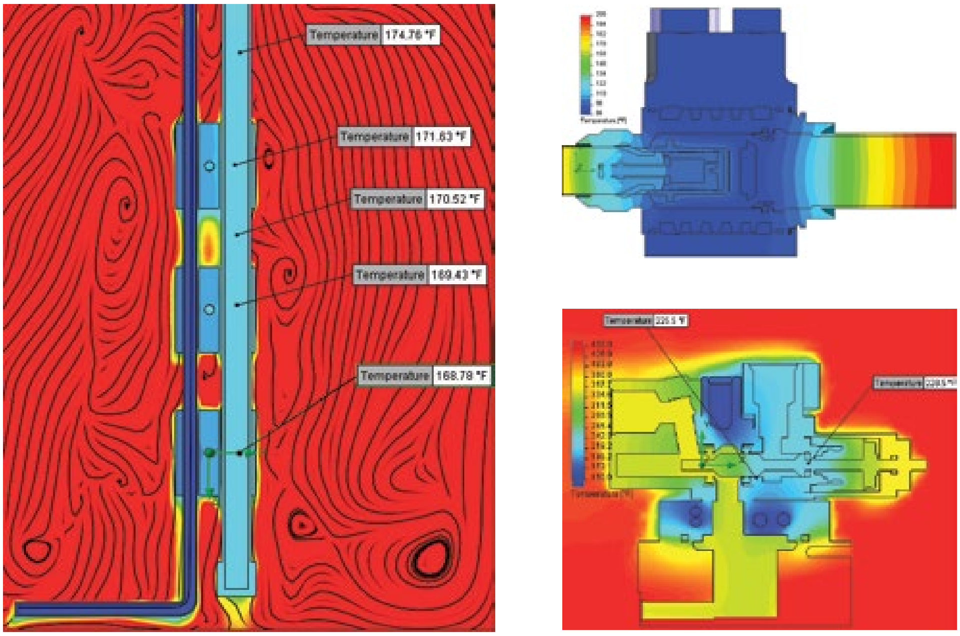
A goal of continuous improvement means there's no time off for a good report. Mitsubishi continues to drive its EHS initiatives forward. In



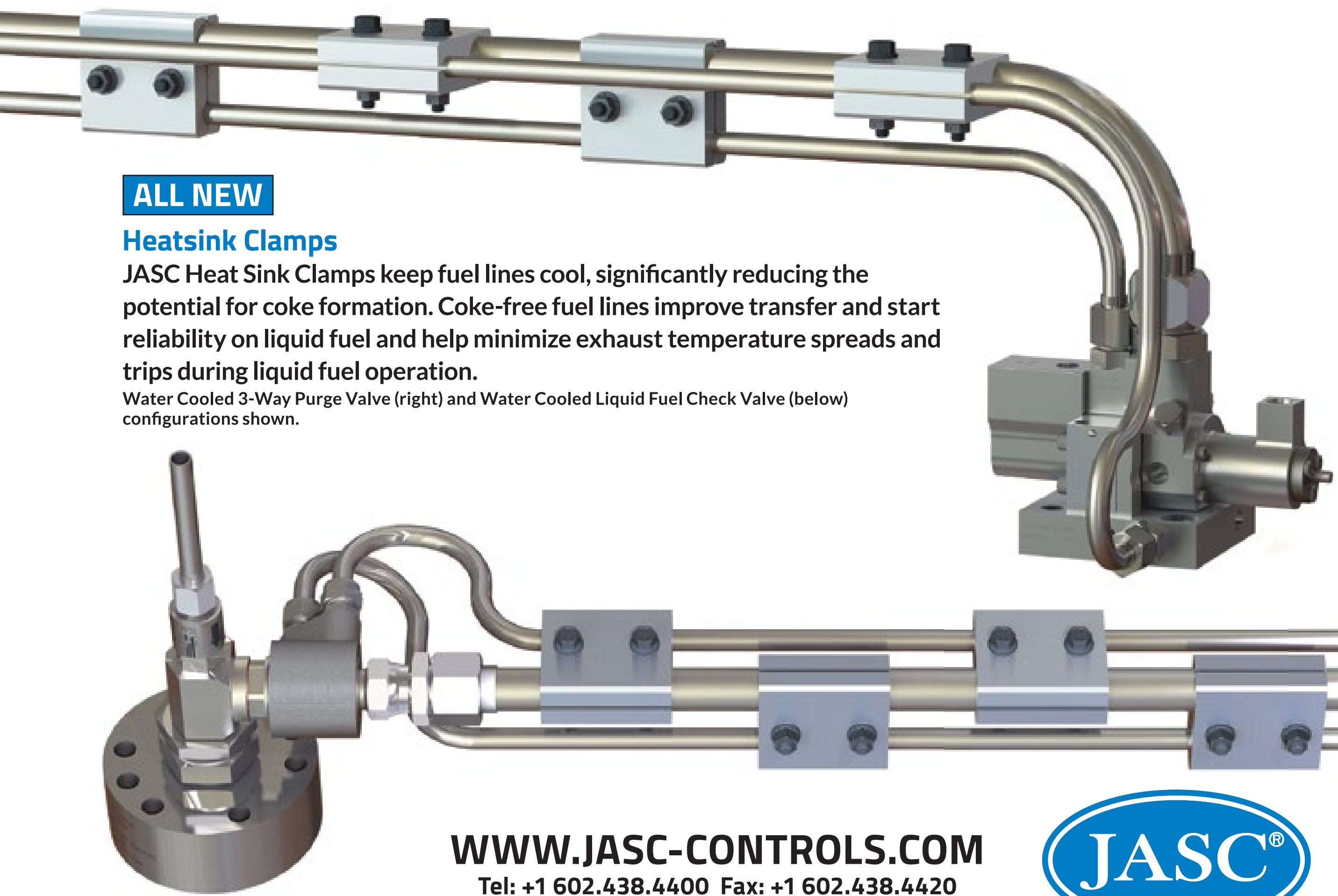
6. Row 1 turbine vanes required only light repairs after 40,000 hours of service (left) and 1000 starts (right)

Maximum Reliability

Water Cooling Technology Provides Increased Operating Intervals Between Liquid Fuel Runs



Thermal analysis shows the affectiveness of active cooling (*left*: fuel lines with heat-sink clamps installed, *top right*: water cooled liquid fuel check valve and *lower right*: water cooled 3-way purge valve).



ALL NEW

Heatsink Clamps

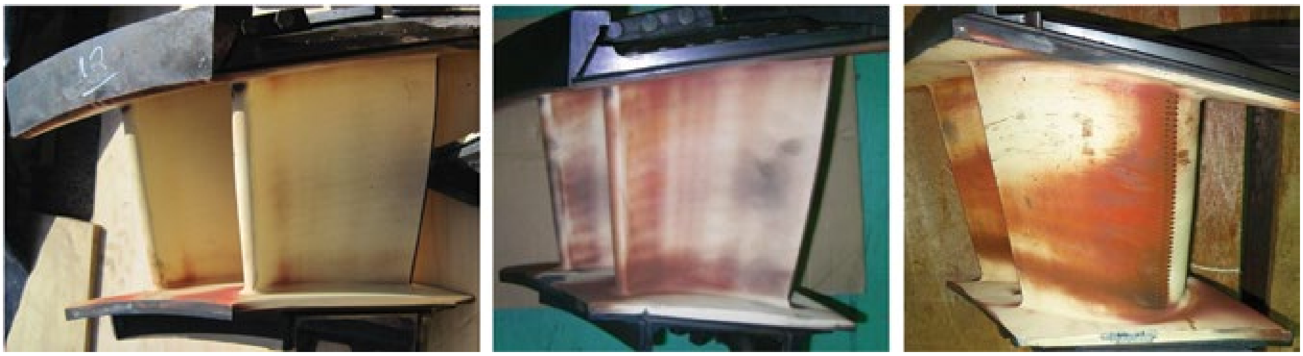
JASC Heat Sink Clamps keep fuel lines cool, significantly reducing the potential for coke formation. Coke-free fuel lines improve transfer and start reliability on liquid fuel and help minimize exhaust temperature spreads and trips during liquid fuel operation.

Water Cooled 3-Way Purge Valve (right) and Water Cooled Liquid Fuel Check Valve (below) configurations shown.

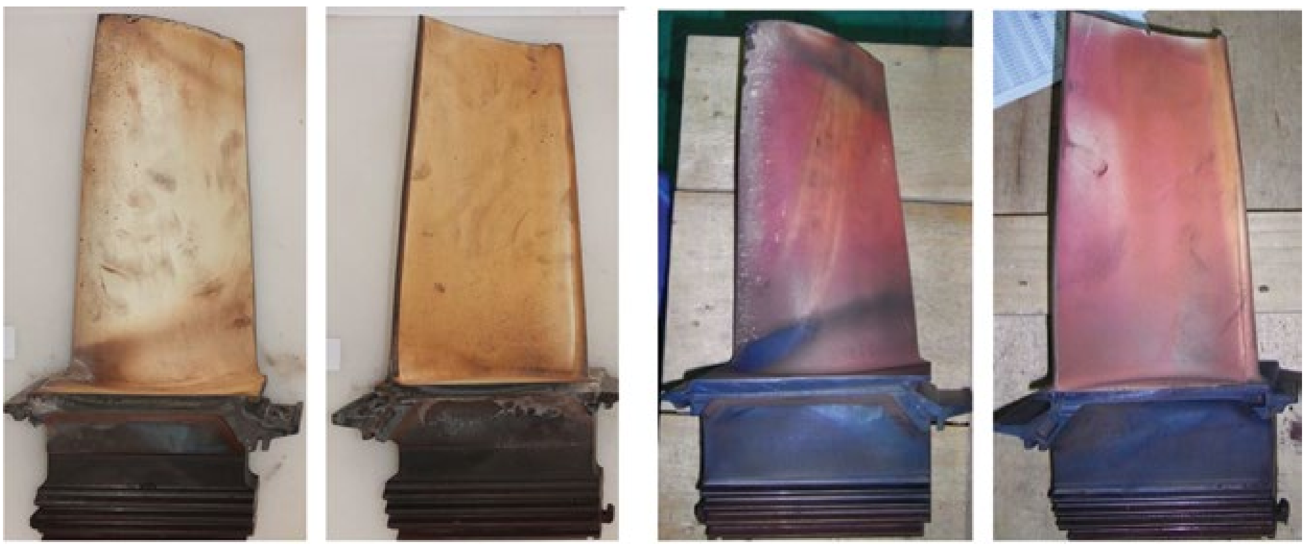
WWW.JASC-CONTROLS.COM
Tel: +1 602.438.4400 Fax: +1 602.438.4420
sales@jasc-controls.com

JASC®

7. Row 1 turbine blades had TBC intact and no detectable cracks after about 35,000 hours of service (left) and 1000 starts (center and right)



8. Row 2 turbine vanes after nearly 35,000 service hours (only 10 starts) required only light repairs; TBC was intact and there was no oxidation-caused wall thinning (left). Same airfoils in a peaking unit with nearly 800 starts (nearly 12,000 hours) were in good condition as well (center and right)



9. Row 2 turbine blades were validated for 32k-hour/1200-start intervals given their excellent condition after running more than 25k hours (left) in baseload service and after starting nearly 800 times in peaking service (right)

2019, for example, the company was approved for ISO 45001 certification. No findings, major or minor, were revealed during a detailed review of its EHS documentation or during a three-day external audit of its field service safety program. Recall that 45001 is the ISO standard for management systems of occupation health and safety. Its goal is the reduction of occupational injuries—including the promotion and protection of physical and mental health.

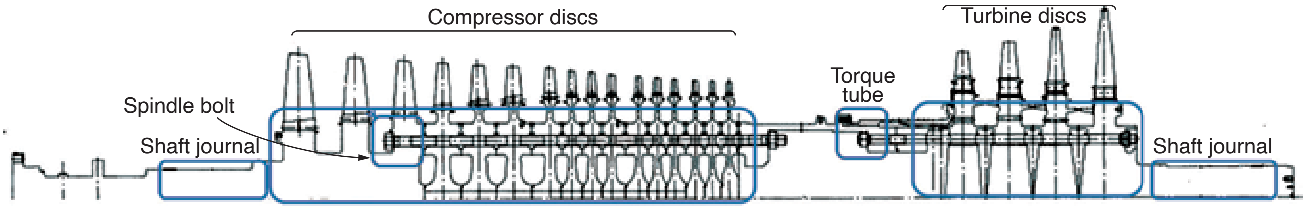
Other 2019 highlights of the Mitsubishi safety program included these:

- OSHA safety training—a 30-hr program for site leadership, 10 hours for non-supervisory employees.
- Confined-space, LOTO, fall-protection, scaffold, and hex-chrome courses for all field-service personnel.
- An increase in full-time safety staffing by 20%.

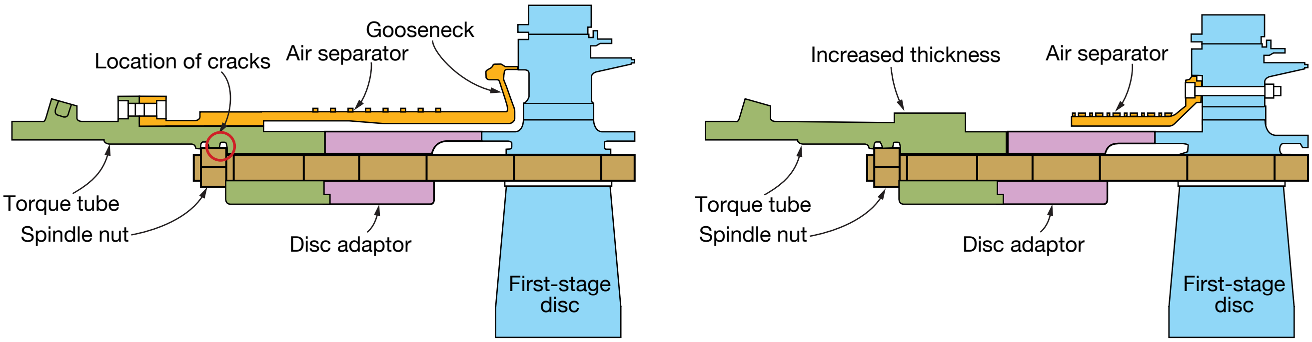
Highlights of 2020 initiatives are the following:

- Review of recent EHS performance and actions taken, including analysis of behavioral trends to identify deficiencies. One example: Inconsistent PSA (Planning and Safety Assistant) quality was identified as an issue. Deficiencies were addressed in a training program.
- Pre-outage safety training, one day. Some of the topics reviewed include site safety plan, proper tool usage, and incident reporting.
- Measurement of training effectiveness and procedure compliance. Service and operations managers perform joint site EHS audits—at least one per outage—and share results with executives and staff.
- Improve vendor management through an EHS review and evaluation of key craft vendors, including a follow-on plan for training, safety, etc, to correct deficiencies.
- Ergonomics. Increase training in the use of support devices for knees, wrists, elbows, and back, and make more devices available in site safety kits.

Critical turbine parts. Scott Cloyd, chief engineer, gas-turbine service



10. Comprehensive rotor inspection involves inspections of critical components such as spindle bolts, torque tube, compressor and turbine discs, etc



11. Bolted-style air separator and thicker torque tube at right are said to eliminate the cracking experienced with the original W501F gooseneck-style air separator and torque tube shown at the left

engineering, and his team reviewed product improvements and upgrades for the compressor, turbine, DLN combustion products, liquid-fuel system, and combustion system. In opening remarks, the MHPS engineering team stressed its focus on best-in-class reliability, availability, and lifecycle maintenance cost, suggesting their products are leading the market in these three performance indicators.

To prove the point, inspection results were presented for Rows 1 and 2 vanes and blades—specifically:

R1 vanes. An R1 vane with a service history of 40,020 hours/290 starts (baseload unit) is shown in the left two frames of Fig 6, R1 vane with 14,499 hours/1010 starts (peaking unit) in the two photos to the right. Condition of all airfoils was excellent with TBC intact, no detectable cracks, and no wall thinning attributed to oxidation. Such positive results contributed to MHPS's decision to validate its R1 vanes for intervals of 32,000 hours/1200 starts.

R1 blades in Fig 7 showed similar results with the blade at the left having a service history of 34,676 hours/10 starts and the one in the two images to the right with 6496 hours/1001 starts. TBC also was intact here. Plus, there was no detectable cracking, or wall thinning attributable to oxidation. Result: R1 blades also were validated for a service life of 32,000 hours/1200 starts.

R2 vanes (Fig 8). Experience similar to that for R1 vanes—TBC intact, visible cooling traces, no oxidation-caused wall thinning, no fillet cracking, and only minor cracking on the platform (within the limits of a light-repair scope). Validated for 32,000 hours/1200 starts.

R2 blades also showed TBC intact, no detectable cracks, and no oxidation-caused wall thinning in both baseload and peaking service (Fig 9). Validated for 32,000 hours/1200 starts.

Rotor inspection, upgrades. Mitsubishi Power recommends what it calls a "comprehensive rotor inspection," or CRI, after 12 years or 100,000 hours of service, whichever comes first. It requires a shop visit and involves complete disassembly of the rotor. All components undergo detailed nondestructive examination; repairs, replacements, and mods/upgrades are performed as necessary to assure performance and reliability goals are achieved (Fig 10).

The Mitsubishi speakers touted the experience of the company's engineers and shop personnel at its Savannah Machinery Works. They also discussed the facility's state-of-the-art equipment and capability to make complex rotor components, plus the depth of SMW's material stocking program. Together, the foregoing attributes enable the OEM to provide the flexible solutions to meet customer needs.

While a full CRI is required to qualify a rotor for an additional 12 years or 100,000 hours, Mitsubishi Power often inspects rotors onsite during the turbine inspection (TI) ahead of the CRI to determine its general condition and to develop a risk assessment to guide planning. MHPS calls this a pre-CRI. It reduces the likelihood of emergent work during the CRI by trending data to anticipate refurbishment scope, thereby allowing the owner/operator to source long-lead-time items in advance.

A pre-CRI conducted as part of a TI (so-called Level 1) has no impact on the scheduled outage and includes a disc creep assessment and turbine-blade groove wear and corrosion evaluation.

If the engine owner finds it necessary to postpone a full CRI, Mitsubishi Power recommends a more detailed review of the machine at the major inspection following the TI, one that includes removal of all compressor blades. This Level 2 pre-CRI adds to the Level 1 menu an evaluation of compressor-blade groove wear and corrosion. It also has no impact on outage schedule.

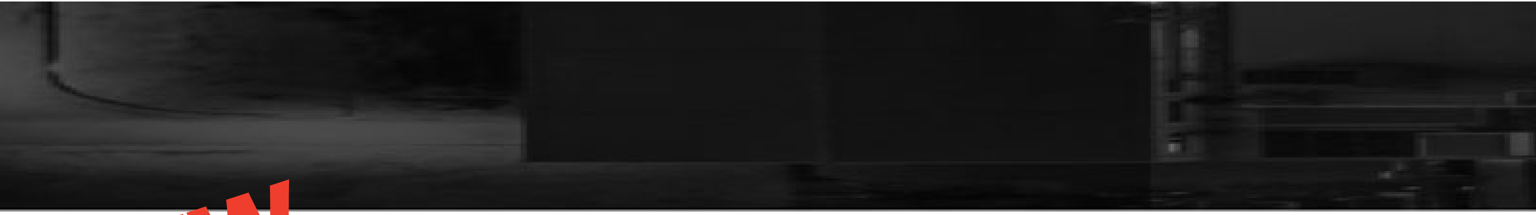
A Level 3 pre-CRI adds cleaning and NDE of all exposed rotor surfaces to the outage scope. Depending on the effort required, this could add to the outage schedule—possibly up to 10 days.

A full CRI in the Mitsubishi Power rotor facility typically takes four weeks, with days added as necessary to accommodate upgrades specified by the owner. A rotor exchange is an option for those requiring a faster turnaround.

Here are some of the important rotor-component inspections conducted during a CRI:

- Spindle bolts, for fatigue or fretting associated with high turning-gear hours and low-speed operation.
- Torque tube, for cracking.
- Turbine-disc cooling-air passages, for clogging attributed to corrosion of the rotor and cooling-air piping and/or foreign material.
- Turbine-disc blade serrations, for wear and fatigue caused by blade rock, pitting corrosion, etc.


umicore
Catalysis



NEW

The Emissions System LTSA

Jeff Bause, President & CEO of NOXCO

Current Situation

The US power industry is undergoing fundamental changes that have created significant operational and dispatch challenges for combined cycle power plant owners and operators. Changes in the generation mix have resulted in reduced on-peak generation, increased plant cycling, load following dispatch and transient state operation, fast start and ramp requirements, pressures to reduce low load turndown—all of which combine to stress the reliability, performance, and availability of aging assets, thus reducing plant profitability. Plants designed for baseload operation are forced to adapt to a very different market environment.

Industry Response

Today there are a number of options to increase the flexibility, response, and performance of the combustion turbine to meet new market operational requirements—such as fast start, fast ramp, increased turndown, and market optimized firing temperature modes. While these upgrades improve turbine operations, many legacy emissions systems remain designed for baseload operation and lack the operational and design flexibility to keep up with the combustion turbines. Therefore, "back end" limits may prevent full value capture from turbine upgrades.

Emissions System Impacts

SCR, CO catalyst, and Ammonia Injection Systems have not, until now, been the focus of combined cycle plant operational and performance enhancements and upgrades. The emissions systems are critical to plant operation and environmental permit compliance. Failures in the performance and reliability of these systems may result in unplanned shutdowns and fines. These SCR, CO catalyst, and Ammonia Injection Systems in existing combined cycle plants were designed, built, and tuned for optimum performance in baseload operation. Typical emissions system maintenance programs are focused on the subset of catalyst life management rather than full system life cycle performance and cost optimization. Emissions systems technology is less familiar to power plant operators than electrical and mechanical rotating equipment systems, resulting in conservative system management decision making to avoid unexpected problems. The result is non-optimum plant performance and higher life cycle costs. These are particularly acute for small power generation systems that do not have access to corporate staff technical expertise knowledgeable in emissions systems technology and optimization.

NOXCO's Unique Solution

NOXCO has recognized this unserved need in the market and is the only company that has developed a unique solution that increases the operational flexibility and performance of the SCR, CO catalyst, and Ammonia Injection System to deliver sustained peak performance at the lowest life cycle cost. NOXCO partners with power plant owners and operators to deliver the first Emissions System LTSA that consists of a full system turnkey wrap—including all system maintenance, inspections, tuning, optimization, catalyst testing, and remaining life projection, catalyst cleaning, catalyst replacement with optimum catalyst selection for the site-specific operational requirements, spent catalyst disposal, ammonia injection system design optimization and tuning, and performance upgrades. The NOXCO LTSA provides a fixed annual price and a full system performance and compliance guarantee backed by a $30 million bonding facility. This transfers emissions system maintenance, performance, and compliance risk from the plant to a group of industry experts with over 100 years of experience in the design, installation, maintenance, operations, and management of gas turbine emissions systems. The owner/operator is left with the peace of mind that the emissions system is in expert hands and will deliver the performance, availability, and reliability required for long-term profitable plant operation at the lowest life cycle cost. The plant staff can focus on core power generation equipment and with the peace of mind that the emissions system is being expertly managed.

From the private equity perspective, the NOXCO LTSA, like the combustion turbine LTSA, further de-risks the power plant by transferring cost and emissions system compliance risk and responsibility to industry experts. Levelized annual cost mitigates Capex spikes associated with catalyst replacements and provides for annual cash flow certainty. Due diligence during plant acquisitions is simplified and ownership transfer facilitated.

If a long-term, fixed price, and guaranteed compliance emissions system LTSA fits with your business model, contact NOXCO for an assessment of your particular circumstances and needs.

www.gonoxco.com

- Curvic clutch, for wear from high hours on turning gear and/or through-bolt relaxation contributing to relative motion between adjacent discs.
- Compressor and turbine discs, for corrosion, cracking, pitting, creep, and/or hardness changes attributed to high operating hours or starts, prolonged exposure to corrosive elements, and abnormal operating conditions.
- Shaft journals, for wear, scoring, and/or cracking attributed to high operating hours, insufficient oil filtration, loss of lube oil, and/or electrolysis.

A focal point of the CRI for most 501Fs is the torque tube, which joins the compressor and turbine sections of the rotor, and its companion air separator. A long-term fleet issue on gas turbines of Westinghouse design (up to and including the Model FD3) has been cracking of torque tubes configured for gooseneck-type air separators, a problem concealed by the air separator (Fig 11).

An indicator of torque-tube cracking is a vibration event, one that can't otherwise be explained. Although visual confirmation of a crack at this location is not possible, it can be confirmed with an ultrasound scan. If a crack is present, it's important to implement a solution quickly. Experts say a crack capable of initiating a vibration event propagates slowly at first but then accelerates through a high-cycle fatigue phase to failure.

Mitsubishi Power solutions for a failed W501F torque tube and air separator are rotor replacement (exchanging with a new or refurbished rotor), in-kind torque-tube replacement, and an upgrade option. The last includes a replacement torque tube of additional thickness where cracks have occurred and a bolted air separator (elimination of the gooseneck design). The upgraded components offered by Mitsubishi are said to have operated failure-free for about 3-million hours and 30,000 starts (round numbers) on its M501F engines.

The first Mitsubishi Power torque tube/bolted air separator was retrofitted on a W501F peaker more than two years ago and reportedly is meeting expectations. Several retrofits have been completed in the interim, with others in the pipeline. Mitsubishi recommends replacement of the torque tubes and air separators on all W501F rotors going through its Savannah shop as a risk-mitigation measure.

Exhaust solutions. Mitsubishi's solutions for the W501F exhaust cylinder and manifold address that model's recurring durability issues—such as cracking of the diffuser and strut shields. They have been adopted from the successful exhaust systems installed on the OEM's G and J units (more than 5.3-million hours and 53k starts) which operate at higher temperatures than F engines.

The Mitsubishi Power two-piece exhaust cylinder is a drop-in replacement for the W501F; no changes to auxiliary piping and foundation are necessary. Additional features: no special tooling is required for installation and the journal bearing can be removed with the upper exhaust cylinder casing in place. To date, five W501F exhaust systems have been retrofitted with Mitsubishi's product.

PSM

Among the gas-turbine OEMs participating in the week-long 501F Users Group conference at the Hilton West Palm Beach Hotel in February 2020, PSM (then part of Italy's Ansaldo Energia Group) provided what at least some users considered the most comprehensive technical program. PSM conducted its portion of the meeting at the company's nearby US headquarters campus. Attendees were bussed to the Jupiter facility on February 11 for lunch, an overview of 2019 milestones, presentations on plant flexibility upgrades, shop tour (see photo display later in this section), and special sessions on rotors and cases and on the exhaust manifold. An evening event closed out the day's activities.

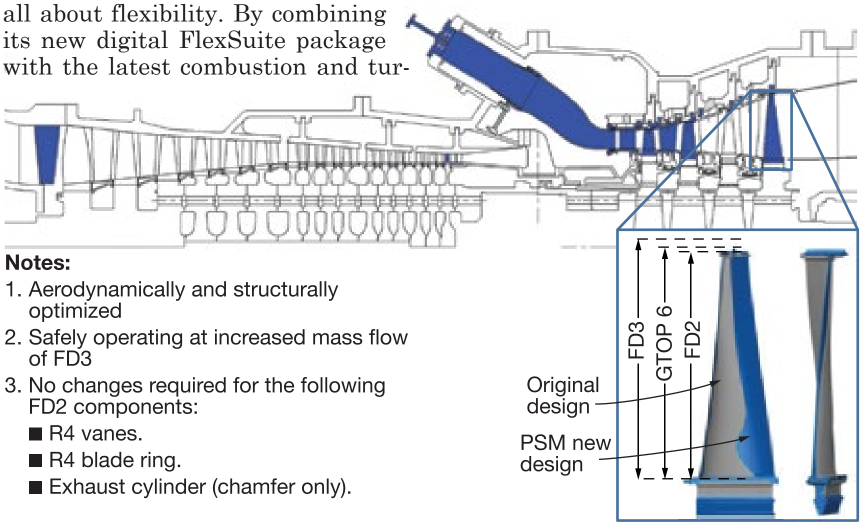
PSM's focus clearly was on engine flexibility, to assure owner/operators the optimal return on their generation investments. In fact, the company's latest product offering for the 501F is all about flexibility. By combining its new digital FlexSuite package with the latest combustion and turbine innovations of the FlameSheet™ and GTOP (Gas Turbine Optimization) programs, 501FD2 users gain significantly improved flexibility over a wide range of operating conditions—from extended turndown to increased output.

The leading presenters on these topics were Katie Koch, product manager; Greg Vogel, manager of technology programs; and Hany Rizkalla, director of combustion engineering.

PSM's effort to provide extended operational flexibility for the 501FD2 began in 2012, early in the development of the frame's GTOP program—specifically GTOP6. The upgrade package is designed to "unleash" the original performance potential of the gas turbine by enabling operation at higher mass flow. This is achieved via a change in the control of the inlet guide vanes (IGVs), combined with upgraded last-stage compressor and turbine components.

The speaker said PSM's upgrade comes at a fraction of the cost of Siemens' 501FD3, which is comparable in performance. The key component in PSM's solution was said to be a redesigned Row 4 (R4) blade (Fig 12) which is compatible with the existing turbine R4 vane, blade ring 4, and diffuser, and provides the following benefits: longer to enable higher mass flow, yet more robust than the original design given its increased flutter margin. A new aerodynamic shape provides an optimized exit flow velocity distribution that improves both pressure recovery in the turbine diffuser and overall unit efficiency.

For a given combustion technology limiting any rise in firing temperature, increased unit output can be achieved by reducing the amount of cooling air used by the first-stage turbine vanes to increase turbine inlet tempera-



12. Redesigned fourth-stage turbine blade enables higher mass flow by increasing the flutter margin relative to the standard 501FD2 blade

ture. However, use of this "knob" is limited by component durability and traditional manufacturing techniques. The latter limits the degree of cooling-circuit intricacy possible to achieve the level of cooling required.

PSM turned to additive manufacturing (AM, Sidebar) to improve on the cooling of first-stage vanes (Fig 13). Recall that AM often is referred to as 3D printing because it involves making components by building them up in layers. The company leverages this technology in the GTOP program to make components of exceptional durability with superior cooling capability.

Improved design of the R1 vane made possible the reduction in cooling air flow. In effect, the new design redistributed cooling air to where it was needed most. A proprietary nickel-based superalloy and improved coating contribute to longer life of the vital airfoil.

By understanding the metallurgical differences between additive-manufactured parts and traditional cast or forged metals, Team PSM realized the vane assembly itself required re-engineering. The company redesigned the vane assembly and also developed its own proprietary powder alloy and unique production process. In 2018, PSM demonstrated and validated its technological advancements in a commercial engine.

The latest GTOP package (GTOP7), includes elements of GTOP6 and the redesigned AM first-stage vane as well as redesigned first- and second-stage blades (Fig 14). The latter have improved aerodynamic and internal cooling arrangements to extract greater benefit. Performance benefits for the different GTOP packages are presented in Table 1. Keep in mind that results may vary from unit to unit depending on plant arrangement. The speaker suggested to attendees that if more accurate numbers are required they should contact their PSM representative.

Additive manufacturing: The future is now

PSM started using additive manufacturing (AM) for F-class combustor repairs in 2014. Four years later it claimed to have become the first company to rainbow test an F-class (501F) hot-gas-path additive-manufactured component. Along the way, PSM had to overcome mechanical and practical hurdles. Among those described in the company's Vendorama presentation available on the 501F Users Group website are the following:

- Challenges of powder processing and qualification.
- Understanding alloys in a powder state versus forged or cast material.
- Handling and benefits of new material properties.
- Design for AM and the cooling advantages.
- Coating adherence.
- Redesign for ideal application and continued utilization.

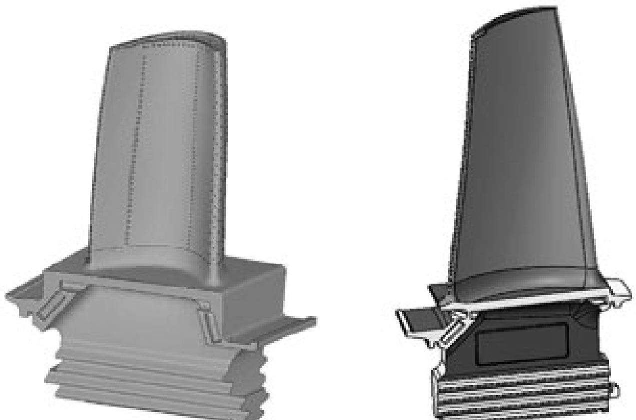
Co-presenters Greg Vogel, manager of technology programs, and Alex Torkaman, manager of airfoils, upgrades, and rotors, reviewed the mechanical testing, redesign for cooling and modular application, engine validation, and the future roadmap applicable to multiple frame engines. Components from different steps in the development process—including production parts installed in spring 2020—were presented.

13. GTOP R1 vane has a removable insert and superior cooling, both made possible by additive manufacturing. The former facilitates repairs and allows for optimal maintenance-interval management because the insert is replaceable with repair of modular side walls

In the last two years, PSM has upgraded more than ten 501F engines with GTOP6 or GTOP7. The speaker said the company also has the ability to tailor the GTOP program for a given site with what it calls "Lite" packages or changes in combustion and/or logic controls depending on specific requirements (Fig 15).

The GTOP elements described above mainly help in extending the upper band of unit operation. But there's also a need to extend turndown capability as well. This is where PSM's FlameSheet™ product comes in, the speakers said. Working together, GTOP and FlameSheet expand the operating profile by increasing both output and turndown.

Turndown has been a primary design initiative for FlameSheet since the first prototype was tested in a 501F engine in 2005. At that time, the goal was to guarantee a low turndown point within emissions compliance where the gas turbine could be "parked."



14. Redesigned first- and second-stage turbine blades for GTOP have met designer's expectations. At left is the R1 blade offering improved aerodynamic design, modified cooling structure, and beneficial platform changes. R2 blade (right) features a cast-in tip design, cooling improvements, and increased trailing-edge durability

Table 1: Performance benefits for GTOP packages

Parameter	GTOP6	GTOP7
Simple-cycle output, MW	+15	+20
Simple-cycle heat rate, %	-3.5	-3.8
Combined-cycle output, MW	+34	+48
Combined-cycle heat rate, %	-1.3	-1.7

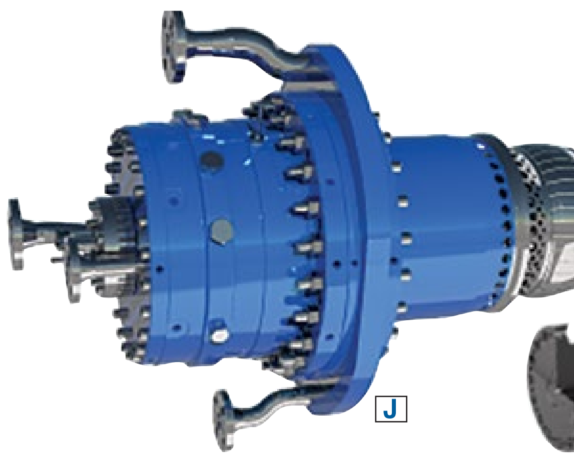
Data are based on the upgrade of a 501FD2 engine (2 × 1 combined cycle)

Table 2: PSM's extended turndown options

Option	Cumulative turndown in load, %
Nominal OEM capability	65 – 70
AutoTune plus part-load performance	55 – 65
Inlet bleed heat	45 – 50
FlameSheet™	35 – 40
Exhaust bleed	Sub 30

Turndown data consider a CO limit of less than 10 ppm

PSM shop tour

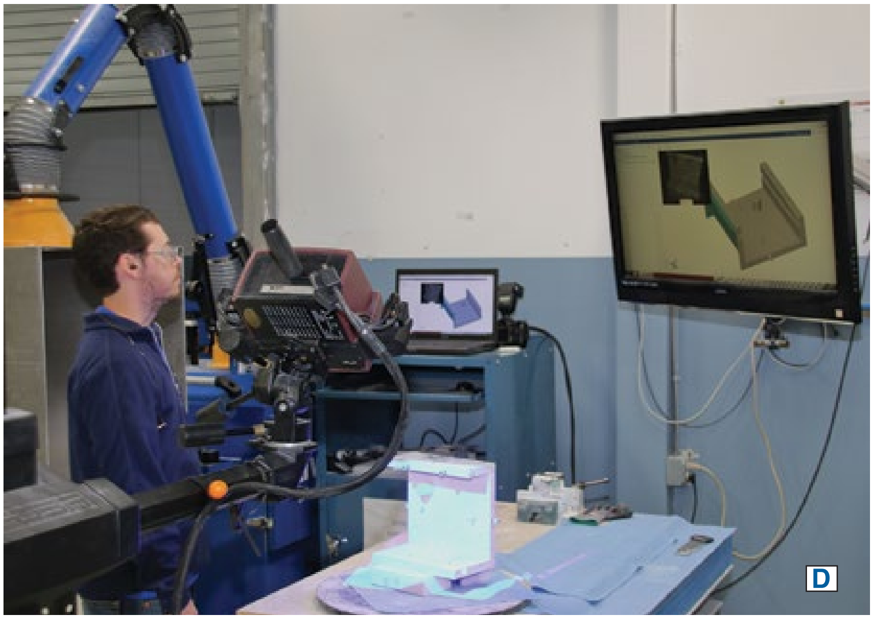


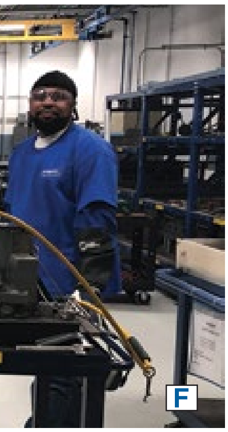
A special feature of the 501F Users Group meeting in 2020 was a shop tour through PSM's 2.5-acre Workshop and Repair Facility in Jupiter, about a half-hour bus ride from the Hilton West Palm Beach conference hotel. Attendees were divided into five groups and rotated through the shop and breakout rooms to learn more about how PSM does the following:

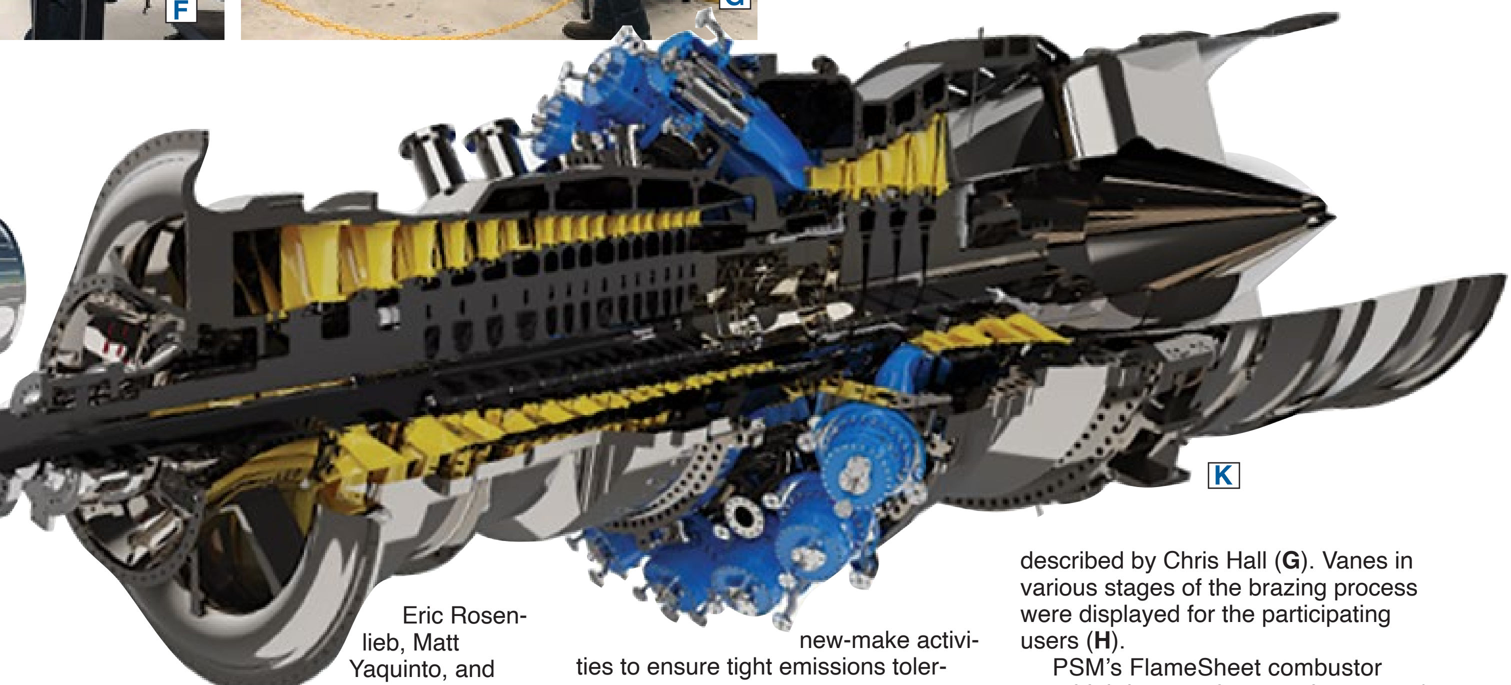
- 501F rotor inspections.
- VGP blade repairs.
- Additive manufacturing to facilitate repairs.
- Monitoring and diagnostics of operating engines.
- Compressor blade manufacturing.
- Brazing of cobalt and nickel alloys.
- Flow testing and combustion wheeling.
- Coating, chemical stripping, welding, machining, and other repair support activities.

Also included: An update on the company's FlameSheet™ combustors.

Highlights of the path taken by CCJ General Manager Scott Schwieger through the PSM shop are shown in the photos. In Fig **A** Andrew Pappadapoulos explains how tip caps are replaced on F-class blades (**B**) using the company's laser-cladding technique.







Eric Rosenlieb, Matt Yaquinto, and Allen Battles of the combustion team demonstrated advanced flow testing and combustion wheeling (**C**). They noted that PSM has multiple flow-test capabilities, allowing for R&D development of new components for repairs and new-make activities to ensure tight emissions tolerances.

Among PSM's many capabilities are in-house CMM and white- and blue-light scanning for repairs and new-part design (**D**). Vane repair and fixture checking are illustrated in **E, F**. Combustion-cell capabilities were described by Chris Hall (**G**). Vanes in various stages of the brazing process were displayed for the participating users (**H**).

PSM's FlameSheet combustor gets high interest from engine owner/operators looking to build greater operating flexibility into their gas turbines. Combustors awaiting shipment are shown in **I**, the one in **J** is ready for placement in the 501F engine shown in **K**.

15. A modified HGP on a 501FD2 included GTOP6 Lite upgraded hardware and installation of proven compressor diaphragms for Rows 1, 2, and 3. Output was increased by 10 MW and turndown improved from 65% to less than 60%. The 16-day outage included IGV calibration, tuning, and testing

16. FlameSheet combustors await shipment to plant for installation

However, as the market penetration of renewables grew, the ability to maintain emissions compliance across the load range became more important. Later design refinements of FlameSheet ensured performance with improved emissions reductions from baseload to low turndown points, providing operators greater benefit from the product.

Key elements for turndown in combustion systems are low emissions and low flammability margin. The FlameSheet combustor is capable of turndown to low loads and to low emissions. High flammability margin is a key enabling factor to achieve low emissions and combustion stability (no flameout) during low-load operation.

How it works. In today's installed fleet, FlameSheet relies on four fuel circuits to enable a "combustor within a combustor" design for advanced flame staging (Fig 16). This simplistic arrangement has two unique aerodynamic stages and relies on a trapped vortex flame to provide wide stability margin. The pilot and main stages are effectively two independent combustors, each with its own robust flame stabilization mechanisms. This allows for either combustor to be operated with the other one off, thereby providing significant operational flexibility.

In 2015, commercial installation of FlameSheet began in a variety of F-class gas turbines. Today, the innovative combustion system is operating in seven 7FAs and one 501F. GTOP7 also was integrated into the latter unit.

As Table 2 shows, when FlameSheet is coupled with PSM's AutoTune, part-load performance option, and inlet bleed heat, turndown can be extended from the 65% to 70% capability of the OEM's standard combustion system to 35% to 40% from baseload. Adding the company's exhaust bleed system extends turndown to as low as 25% to 30%.

For users interested in increasing the operational flexibility of their gas turbines, the PSM speakers said they would evaluate total plant needs and recommend the optimal arrangement of hardware and digital packages to meet the specific requirements. Example: For a combined cycle, the plant startup profile would be reviewed—including HRSG limitations, steam-turbine output, exhaust temperature, etc—with PSM experts advising on startup optimization in consideration of the desired changes. In one case where a 7FA was retrofitted with GTOP and FlameSheet the startup time was cut in half.

In closing, the speakers touted what they believed to be a unique aspect of PSM's digital suite of products: Compatibility with almost any control system, thereby eliminating the need for a controls retrofit. Digital services, such as AutoTune and/or FlexSuite modules, were said to be available with or without the company's hardware upgrade packages. This is of benefit to plants between outages that want to evaluate optimization of their gas-turbine operations.

Siemens Energy

The Siemens session on Wednesday (February 12), from 10 a.m. until lunch, began with a high-level update on the Siemens Energy spinoff. Also highlighted was Siemens Energy's roadmap to "Making Energy Greener." A comprehensive gas-turbine update followed with technical updates on these topics:

- Hexavalent chromium residue.
- Air-separator radial rubs and axial wear.
- Exhaust manifold.
- Advanced two-piece exhaust.
- D5 turbine through-bolt fracture.
- Bearing-bore drop-measurement tool.
- New high-performance Row 4 turbine blade.
- Peak firing and experience with ULN (ultra-low NO_x).
- Parts availability.
- Torque-tube cracks.
- Recent SGT6-5000F5 event.
- Thermal-performance upgrade summary.

Next came a presentation on Brownfield Engine Exchange (BEX) which outlined the benefits and the process for a BEX and provided examples of several projects implemented by Siemens Energy. Following this was a generator update—including a fleet overview, discussion of generator findings observed during outages, and a review of various technologies to help reduce maintenance.

The session closed with a discussion of plant assessments (inclusive of operational assessment, performance/thermodynamic evaluation, availability, reliability, maintenance evaluation, and upgrade capability) and solutions to drive operational flexibility—including emissions reductions, adjusted maintenance intervals and faster cooldowns, enhanced-performance starts and stops, and alignment to grid requirements through load gradients.

Operational enhancements for Siemens and Westinghouse steam-turbines discussed were fast synchronization, fast speed and load ramps, fast close of bypass valves, fast shutdown, variable load-rate capabilities, variable speed rate potential capability, and considerations for speed roll times.

Most of the material presented is available on the Siemens Energy Customer Extranet Portal (https://siemens.force.com/cep). If you are an owner and/or operator of the company's power generation equipment and do not have access to the portal, use the link to request it.

Vendorama

Gas-turbine inlet filters: An ongoing maintenance expense or operational investment? How nanofiber technology impacts the filtration marketplace. *Braden Filtration*

If you've ever ordered gas-turbine inlet filters, you likely know the name Mcleod Stephens. He's been serving users for four decades in management positions at three filter manufacturers. But what you may not know is that a year or so ago Stephens helped to form Braden Filtration LLC, where he is general manager, after purchasing the manufacturing assets from Braden Manufacturing parent Innova Global.

He discusses how the technology of nanofiber manufacturing and application has improved over the years, and how those changes and improvements—targeted at pulse-type air-inlet systems—came about and why. Takeaways for users include the following:

- How filter life can be impacted positively by new, contemporary nanofiber applications.
- How flow resistance is reduced.
- How pulse-cleaning frequency can improve service life.
- How recent design changes to the media substrates contribute to better performance.

Integrated generator monitoring. *Cutsforth*

Chris Delavega demonstrated the value of continuous online monitoring for generators. He noted that numerous fault conditions present themselves through unique, repeatable signature patterns in the shaft voltage and ground current of a properly grounded and monitored turbine generator when viewed as a high-speed time domain waveform. Points made by Delavega, and supported with actual charts and data, include the following:

- Brush health analytics data enable personnel to conduct maintenance based on brush condition rather than a calendar basis. This virtually eliminates the risk of having a ring fire because of short brushes.
- Shaft ground monitoring allows early indication of problems such as shaft rubbing, brush sparking, shorted stator laminations, isophase neutral faults, inter-turn shorts in rotor windings, etc.
- Electromagnetic interference (EMI) monitoring looks for patterns/signatures in the RF spectrum from 30 kHz to 100 MHz to find arcing, corona, partial discharge, noise, sparking, etc.

Gas-turbine power augmentation by wet compression. *Mee Industries Inc*

Thomas Mee may be the industry's foremost expert on fogging/wet compression, having decades of analytical and plant-level experience on the technology. He encouraged attendees to consider this cost-effective method of power augmentation for delivering additional megawatts virtually instantly in times of need.

Fogging/wet compression systems are easy to integrate with gas-turbine controls, he said, adding that his company typically can deliver the necessary equipment in 12 weeks or less and can connect the new system to existing equipment within a favorable outage window—perhaps in only 24 hours.

Erosion risk is reduced with small droplet size—a distinguishing characteristic of Mee systems. Droplet size and its impact on equipment received significant air time (access https://www.ccj-online.com/2q-2010/inlet-cooling/).

Advanced single-layer turbine warming system. *ARNOLD Group*

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

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

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

The ARNOLD system features interlocking high-performance blankets which conform perfectly to the turbine surface. High-quality materials and manufacturing, and long-term high-temperature resistance, allow the company to guarantee reuse of its insulation system for 15 outages without a decrease in efficiency (access https://www.ccj-online.com/7fug-2020-arnold-group/).

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

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

Think beyond the catalyst to improve plant performance. *CECO Peerless*

The company's ammonia injection grid (AIG) is designed and optimized to provide the desired reagent distribution across the duct to assure expected SCR efficiency and performance. The square cross section of CECO Peerless' EDGE™ AIG lances are said to promote better mixing, thereby improving NO_x reduction, reducing ammonia slip, promoting longer catalyst life, and reducing the cost of operation.

A laboratory comparison of EDGE and an AIG with traditional lances revealed better performance from the former in half the distance from the AIG grid to the catalyst. A 30% reduction in ammonia consumption was reported by a plant after conversion of its AIG to EDGE. Brief case studies also are included in the presentation.

Is your SCR/CO system ready for turndown? How increased NO_2/NO_x ratios require additional SCR performance. *Environex Inc*

Andy Toback regularly shares Environex Inc's knowledge of CO and NO_x control technologies with CCJ readers. You can access some of this information with a keyword search of the magazine's archives at www.ccj-online.com. At the 501F Users Group's 2020 Vendorama he began with the following observations:

- NO_x consists of two measured pollutants, NO and NO_2.
- NO_2/NO_x ratios above 50% identify with a significant decrease in SCR performance—that is, NOx conversion.
- High levels of NO_2 are found at turndown conditions.
- CO catalyst can increase the NO_2/NO_x ratio.
- Turndown lowers HRSG temperature which reduces SCR performance.

A case history presented revealed the installed catalyst did not have sufficient activity for the elevated NO_2 condition experienced. Adding additional catalyst would increase the pressure drop by 0.6 in. H_2O. Suggestions to users: Instrument to monitor NO and NO_2 separately; enlist a stack tester to measure low-load NO_2/NO_x ratio.

Turbine retrofit acoustical and struc-

GE 7FH2/324/390H Stator Core Solutions

In addition to generator testing and inspection, AGTServices provides the material and expertise to inspect and mitigate failure due to loose stator core iron.

Background:

AGT*Services* experience in testing, inspecting and repairing large air and Hydrogen cooled generators has shown that as this fleet of machines continue to age, coupled with major increases in cyclic duty demands, is resulting in several instances of very expensive and long scheduled repairs, as well as unplanned additional work during planned outages, all due to loose core laminations, loss of core iron "pieces" and stator/core winding failure. Let **AGT*Services*** assess your GT and/or ST generator stator core and perform tightening sequences, before this issue takes your unit offline…for a while! We can fix those that have already failed, too!

AGT*Services* LOOSE CORE ASSESSMENT:

- Whether it's a field-in "minor" (using AGTServices Robotic Inspection Vehicle) or a field-out "major", we can perform the full range of stator and field testing, inspections and all repairs
- Perform visual inspection of entire stator core iron
- Perform "knife check" for mechanical illustration of core loosening
- Perform keybar nut torque checks – too low a torque value means a loose core!
- Since the majority of all of this fleet of units fail one/all of the above assessments, we arrive prepared to perform a full stator keybar nut retorque – 3000 ft-lbs is the target! Less is insufficient no matter who is telling you!!!
- Core tightening is BEST performed with stator wedges out and belly bands loosened!
- If rewedging, ONLY use Low Shrink Black Canvas, Top Ripple Spring and Tapered Slides!
    - Or you'll be rewedging again in 5-10yrs!
- Oftentimes, we can AVOID a full or partial restack with creative, surgical repairs!
- Larger GT and ST driven 324/390H models are susceptible to Outside Spaceblock Migration, where iron migrates radially inward, penetrating bottom bar insulation! Contact AGTServices for those specialized repairs and mitigations!

AGT*Services* has the Capability, & Knowledge to perform all the recommendations listed above.

AGTSERVICES Inc.

24 SAM STRATTON ROAD AMSTERDAM, NY 12010 | T: (518) 843-1112 | F: (518) 843-8389 | WWW.AGTSERVICES.COM

Nord-Lock solution mitigates 4-way joint leakage from

The editors can't remember a meeting for Siemens 501F users that didn't include at least a mention of leakage at the 4-way joint. A typical fleet-wide remedy was to weld on so-called leak boxes to prevent leakage from offending joints (Fig 1). These, of course, had to be removed during an outage and then reinstalled before resuming operation.

Nord-Lock Group VP Peter Miranda discussed his company's engineered approach to preventing leakage at the 4-way joint in a Vendorama session during the 2020 501F Users Group meeting at the Hilton West Palm Beach, February 10, a month prior to the onset of Covid-19 restrictions. Nord-Lock has continued perfecting its solution since; a progress report on that work follows.

Miranda's presentation can be reviewed by registered 501F owner/operators on the user group's website at https://forum.501fusers.org/t/2020-conference-materials/3974. Nonmembers who meet the organization's requirements can gain membership status by completing the online registration form at https://forum.501fusers.org/login.

Background. New turbine cylinders are perfectly aligned, faces flush, with no leaks at the joints. Over time, extreme thermal variations and start/stop cycles lead to warping and distortion. Cylinder misalignments compound the problem because flange surfaces to not maintain the maximum contact area needed to ensure a proper seal, allowing leaks to occur.

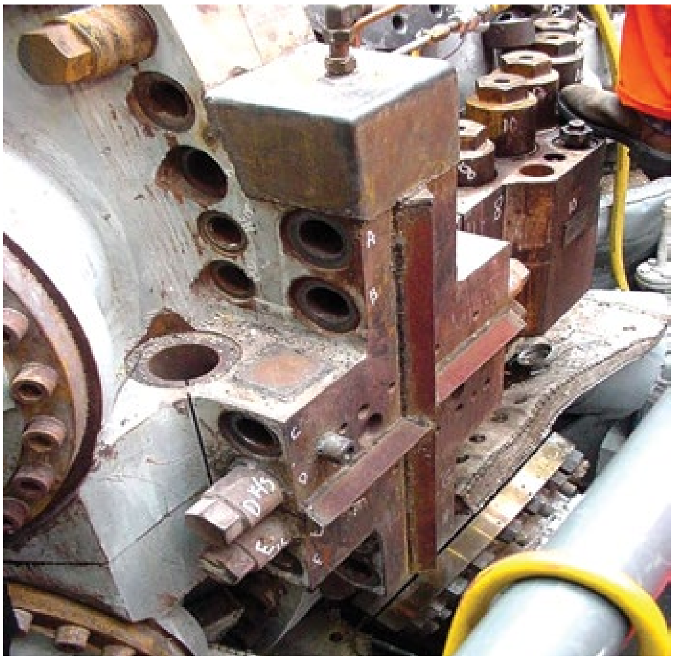
Another contributor to leakage is the lack of an upper-half spigot, which is removed after final assembly in most cylinders. The concept here is simple: Emulate the lower-half spigot (Fig 2) on the upper half since pressure inside the combustion chamber will affect these exposed areas and cause leakage through cylinder joints, bolts, or bolt holes.

The helicoil bolt-hole misalignment shown in Fig 3 is evidence of cylinder displacement of the flange face. To remedy leaks, the misalignment must be addressed. If holes can be forced into alignment and maintain concentricity during loading, the flanges likely will seat flush, preventing the leak. Proper tension of the joint is critical to success.

Leaks can cause significant damage to instrumentation and insulation, and also jeopardize operations and worker safety. Maintenance is required to weld-on leak boxes (refer back to Fig 1) to contain the leak and requires removal and reinstallation during an outage—adding time, resources, and cost to the outage schedule.

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

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



1. Leak boxes at 4-way joint protect against damage to instrumentation and insulation while contributing to personnel safety

2. Location of the lower-half spigot is identified by the red circle

tural design and installation overview. *Durr Universal*

Acoustical and structural engineers walked attendees through a couple of 501F silencer retrofit projects that provided valuable insights for anyone considering same. This presentation required back-to-back sessions, so it was twice the length of others made during Vendorama, totaling more than 60 slides. While it reviews the basic fundamentals of acoustics and aerodynamics required to follow the slides, having background knowledge of these subjects would be very helpful in getting the most from the presentation.

Generator maintenance testing and inspection. *National Electric Coil and Advanced Turbine Support LLC*

NEC's Howard Moudy and Rod

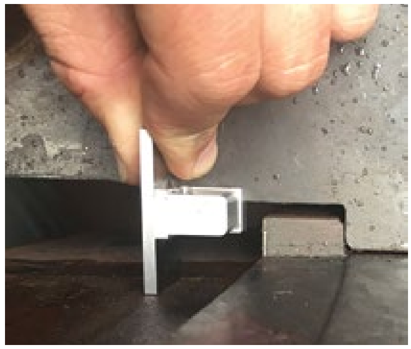
Siemens 501F

and provides the these advantages:

- To quickly assess and manipulate cylinder alignment, the solution includes a Boltight™ hydraulic closure system (HCS, Fig 4). This ensures the 4-way joint is tensioned, temporarily, to conduct a proper alignment check of the cylinder—one similar to a tops-on/tops-off alignment check performed on steam turbines.
- If the bolt hole or flange is misaligned, a proprietary CamAlign tensioner system is used to realign the cylinder. System can close an internal gap of the cylinder by 10 to 15 mils after the cylinder has been "squeezed" by the HCS—to ensure the smallest possible gap is achieved.
- The HCS is pressured up to simultaneously and uniformly squeeze the turbine cylinder around the 4-way joint—thereby isolating the area. Multiple hydraulic tensioners remain pressured up while internal and external gap readings are recorded, and cylinder alignment is checked.
- Once adjustments are complete and the 4-way joint is aligned properly, the joint is squeezed again using the HCS, which allows load transfer to the Superbolt™ mechanical multi-jackbolt tensioners—to permanently tension the joint—without losing tension on the joint.
- Rather than tensioning one bolt at a time, which can continually create movement of the load, the HCS immobilizes the entire joint.
- An internal seal is installed to reduce leakage at the 4-way joint area where the cylinders for the combustion and turbine sections meet (Fig 5). The seal functions to eliminate any leakage paths that cannot be corrected by realigning the cylinders.
- Aggressive operating requirements and maintenance schedules needed to keep pace with operating requirements contribute to misalignments that cannot be corrected completely with CamAlign. The seal provides an added layer of leak protection.

Over the course of several installations, variations were noted in spigot fit and seal shapes. Internal seal retainers were redesigned to allow for thermal growth and variations in the cylinders.

3. Helicoil bolt-hole misalignment points to cylinder displacement of the flange face



5. Internal seal and retainer shown help reduce leakage in the 4-way joint area

6. Combination of new technology solutions from Nord-Lock—multi-jackbolt tensioners, hydraulic closure systems, and alignment tensioners—eliminates forced shutdowns caused by instrumentation and insulation damage, and provides a safer environment inside the turbine enclosure

4. Boltight™ hydraulic closure system contributes to proper alignment of the cylinder

Shidler of Advanced Turbine Support collaborated on this presentation. Motivation for the partnership was to provide increased insight into generator condition in less time and at lower cost than was possible previously. When the partnership's equipment for stator wedge tapping and stator core EL CID testing are coupled with other inspection and testing tools, a solid machine assessment is possible, said Moudy and Shidler.

The presentation has several tables listing inspection and testing activities, their purpose, and frequency—a handy checklist for maintenance personnel. Tables are the following;

- Visual inspection of stator winding, stator core, and rotor.
- Rotor electrical tests, including insulation resistance, winding resis-

tance, flux probe, and pole balance.

- Stator electrical tests, including insulation resistance, winding resistance, hi-pot, and DC ramp.
- Specialty stator tests, including EL CID, core loop, wedge tightness, partial discharge, and bump test.

Ovation machinery health monitoring solutions. *Emerson*

Jason King, machinery health solutions manager, discusses how turbomachinery protection and condition monitoring can be accomplished on the same platform as the turbine controls, providing automated diagnostics to operators without requiring them to learn vibration analysis. For vibration analysts, onsite or at a remote diagnostics center, full-featured analysis capability is possible while still meeting cybersecurity requirements.

Liquid fuel reliability: The good, the bad, and the unexpected. *JASC*

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

Hydraulic filter-element multi-pass tests. *Hy-Pro Filtration*

Richard Trent walked attendees through multi-pass testing of hydraulic filter elements for dirt holding capacity and beta ratio. The test is intended to measure hydraulic (lube) filter performance in a controlled laboratory setting. There are several versions of the test, some closer to the "real world" than others. The details:

- ISO16889 Multi-Pass, steady-state flow.
- ISO/CD23369 Cyclic Flow, cyclic flow.
- SAE ARP4205, cyclic flow.
- Dynamic filter efficiency (DFE), dynamic flow (cyclic).

A point to keep in mind: All filters shed particles during flow transitions. In the real world, flows change, often rapidly. Thus, filters with better cyclic-flow particle retention provide better equipment protection.

Trent reviews the advantages and disadvantages for each of the four tests with helpful illustrations.

501F exhaust cracking RCA and expansion joint upgrades. *Frenzelit*

If your expansion joint is suffering a soft-goods failure and/or exhaust-frame cracking is an issue you're dealing with, this presentation is worth reviewing for its many photos of failures and repairs.

Common root-cause failures of expansion-joint soft goods are the following:

- Missing internal insulation at the round-to-square transition behind the vertical cover plate.
- Evidence of insulation breakdown attributed to water saturation is the discoloration and hardening of the downstream insulation.

Common root causes of frame cracking are these:

- Sagging of external insulation, thereby exposing the bottom area of the joints and frame components to heat capable of causing expansion-joint failure as well as radial and lateral frame cracking.
- Sagging external insulation and missing internal insulation are conducive to superheating of the bottom of the frame, causing non-uniform heating of structural components with frame cracking the result.

Selecting the correct lubricant. *American Chemical Technologies* (Recall that ACT was purchased by Shell in late 2019, shortly after this presentation was developed for the 2020 meeting of the 501F Users Group.)

Chelsea Butkowski (née Kovanda) presented a primer on lubricant selection of practical value to O&M personnel new to the industry as well as to experienced staff requiring a refresher. Lubricant selection is one of those subjects you might not think about for years but when necessary it's good to have a backgrounder like this at your fingertips. Topics covered were the following:

- Functions of a lubricant.
- Overview of base stocks (Groups I through V).
- The three types of finished lubricants (rust and oxidation inhibited, anti-wear, and extreme pressure or EP formulations).
- Selecting the optimal lubricant for the two most common powerplant applications: electrohydraulic control (EHC) systems and turbine lube oil.

This is a presentation that could provide the basis for a lunch-and-learn session in the plant break room. It covers the compatibility of new and existing lubricants, additives, viscometrics (measures of viscosity, viscosity index, and pour point), safety (flash point and toxicity), oxidation and hydrolytic stability, fire resistance, and environmental impact.

Butkowski spent most of her time at the front of the room addressing the value of polyalkylene glycol (PAG) as the fluid of choice for EHC and lube-oil systems. Recall that PAG is a Group V base stock—man-made. Powerplant experience is highlighted as well as PAG's value as a treatment for varnished systems (access https://www.ccj-online.com/how-does-pag-stack-up-against-mineral-oils-after-a-decade-of-experience/).

De-mystifying varnish analysis: remedies and benefits. *C C Jensen*

Technical Manager Axel Wegner presented on the following three methods to remove varnish:

- Physical filtration, including absorption and adsorption. In use are depth or surface filters with and without preconditioning: electrostatic and balanced-charge agglomeration.
- Chemical filtration. In use are cartridges with chemical bead compositions of varying mixtures that can be adjusted to accommodate different brands of lube oil and machine types.
- Depth-filter absorption/adsorption with advanced agglomeration, called VRU in C C Jensen speak. These systems precondition the oil in a way that all soft contaminants fall out of solution, agglomerate, and are removed by depth-filter inserts with high dirt-holding capacity.

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

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

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

Lessons from the Australian coast: Applying the three-pillars-of-filtration performance. *Donaldson Gas Turbine Systems*

Mike Roesner presented a case history illustrating the value of his company's Three Pillars methodology for selecting the optimal filtration solution at a given site—in Australia in this case (access https://www.ccj-online.com/three-pillars-methodology-helps-users-select-the-optimal-filter-for-plant-conditions/). The advantages cited were longer filter life, more stable output, additional equipment protection, and lower cost of ownership. Side-by-side testing of sister units (one with the new filters, the other with the originals) was conducted to verify results.

Improving SCR performance on gas-fired units. *SVI Dynamics*

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

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

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

Inlet and exhaust life extension. *Schock Manufacturing*

Schock Manufacturing, which specializes in retrofit solutions for auxiliaries at the gas-turbine inlet and exhaust, identified typical inlet systemic problems, issues in the 501F exhaust section, and the simplicity of proper routine repairs. The presentation contained about four-dozen photos to assist users in identifying problems they should be aware of. Attendees then were invited to book a free inspection on the company's website.

Unconventional design/construction leads to complex stator rewinds. *AGT Services Inc*

Jamie Clark's well received 60-plus slide presentation with photos of high value for helping O&M personnel come up to speed regarding the key steps in a stator rewind was the subject of an article in CCJ No. 63, p 48.

NAES and Duke case study TrimKit. *Millennium Power Services*

Valve issues have become a headline item at user-group meetings in the last couple of years given the wear and tear being experienced by severe-service valves serving steam turbines and HRSGs in cyclic operation. This presentation is recommended reading (by the editors) for owner/operators having to buy parts—such as stems, plugs, cages, seat rings, soft goods, etc—and restore flow-control devices to perform their intended functions. It provides case histories that compare the cost of parts, lead times, and refurbishing options from the original manufacturer with those for third-party suppliers.

The speaker points to these pre-outage savings:

- Reduction in inventory management cost.
- Elimination of pre-outage ordering by the user, the burden being moved to the supplier.
- Many part numbers replaced by one "kit" number.

The outage savings including the following:

- A 50% reduction in labor verses open and inspect.
- Outage easier for the owner/operator to plan and bid.
- No surprises with missing parts or searching the warehouse for individual parts.

The saving possible from using pre-owned parts instead of new parts was also reviewed.

Mission-critical fire protection. *ORR Protection Systems*

Fire protection is a topic in safety discussions at virtually every user group meeting, one that seems to be generating more interest as plants age. For example, systems installed 20 or more years ago have been cited for unwanted release of the extinguishing agent because of unreliable sensors. In some cases, the extinguishing agent is no longer in favor and should be replaced.

It's important to keep safety systems current and well maintained. With the many retirements and staff changes of late, perhaps the person with most knowledge of your plant's fire protection system is gone. That knowledge gap must be filled. This presentation is a good first step in the learning process. It offers a reference list of fire-protection codes and standards with which you should be familiar.

Orr promotes itself as a one-stop shop for things having to do with fire protection—including alarm, detection, notification, and suppression. It provides testing, inspection, and maintenance services for all types of fire protection systems offered by the major manufacturers of that equipment. This presentation focuses on CO_2 and water-mist systems.

The 10 most frequently asked questions about gas-turbine compressor cleaning. *Rochem Technical Services*

This presentation seems well-suited for guiding a discussion session on compressor cleaning in the break room over a pizza at lunchtime. The questions asked and answered are the following:

- What are the options when cleaning a gas turbine?
- Why clean the compressor?
- What are the benefits of cleaning?
- Water versus chemical cleaners—what's more effective?
- Where should you place the compressor cleaning nozzles?
- What if the foulant redeposits in later stages?
- What about erosion as a result of compressor washing?
- What are the effects of surface wetting?
- Is there a need to heat the wash fluid?
- If HEPA filters are installed is a compressor cleaning system still necessary?

Fluid-film bearing visualization. *Pioneer Motor Bearing Co*

Pioneer Motor Bearing's presentation focuses on damage mechanisms found in fluid-film bearings for motors, turbines, and generators. Topics including theory of operation, bearing design features and materials of construction, and lubrication basics are reviewed in brief at the beginning of the presentation. This information serves as a backgrounder for the ensuing discussion of some typical damage mechanisms observed in today's bearings—with an eye toward prevention of recurrence and recovery from the problem.

Goal is to give attendees the ability to examine post-service bearings with a better perception as to how markings and damage to the bearing surface would affect continued operation and long-term reliability. Owner/operators will come away with an ability to relate those damage markings to some specific degraded conditions in the machine—such as shaft currents and misalignment.

Pioneer Motor Bearing specializes in the repair and service of large oil-lubricated bearings, with a focus on engineering problem-solving. The company, a licensee of Siemens Energy, GE, and the UK's Mitchell Bearings, may be best known to users for its Babbitt-bearing repairs, new manufacture, reverse engineering, upgrades and custom designs, and technical support. CCJ

Dogwood

Sticking to a site map

Dogwood Energy Facility

Owned by Dogwood Energy, City of Independence, Missouri Joint Municipal Electric Utility Commission, Kansas City Board of Public Utilities, and the Kansas Power Pool

Operated by NAES Corp

650-MW, gas-fired, 2 × 1 combined cycle located in Pleasant Hill, Mo

Plant manager: Steven Hilger

Challenge. In the 17 years prior to implementation of its Confined Space Map, Dogwood had several occasions where a lock-out/tag-out (LOTO) involving a confined space was cleared, but remained open. After an HRSG door was left open following an outage, the plant started looking into ways to eliminate the potential for a recurrence, having to track over 150 confined spaces at the plant.

Solution. CRO Michael Davis, a member of the Safety Committee, had advocated for a visual way to account for confined-space status in the control room. After reviewing different ways to track confined spaces, he noticed that most of the solutions relied on technology that increased both cost as well as the CRO's workload. He focused on finding a low-risk, low-cost, low-technology, high-results outcome.

His idea was to create a site map showing the major equipment and some of the underground systems on a white magnetic board that included all the plant's confined spaces. This map would be installed in the control room above the LOTO cabinet.

Davis worked with NAES drafting to develop a simplified site plan for the plant. In addition to the major equipment and underground information, the 45 × 45-in. map also includes the following:

- Safety showers in green.
- Tornado shelters.
- Water storage tanks and capacities.
- Manholes with system identification and numbers.
- Electrical manways.
- Hazardous chemical locations.

For work requiring a confined space, the CRO moves the magnet label for the associated confined space from the label storage board, at the right in Fig 1, to the site map's left-hand side and then places a red magnetic dot at the location of the confined space on the site map (Fig 2). This provides personnel at Dogwood with a visual of the approximate location of open confined spaces at any given time. After a confined space has been closed and returned to its normal state, the label and dot are removed and returned to the storage board. Keeping the process simple helps its success.

The map also provides a visual representation of the plant to facilitate discussions among plant personnel and contractors, and to show evacuation routes and muster points, and all door swings.

Results. The Confined Space Map has been in use for more than a year. Dogwood personnel believe it has resolved the issue of leaving confined spaces open when they should be closed. In addition, the site map has provided the plant a good visual for discussions with contractors by identifying the locations of equipment and various underground manhole connections and safety showers. This is a safety and awareness win for the employees and contractors.

Project participants: Michael Davis, Eric Smith, Monty Ross, Jim Feitz, Mary Baptista, Steven Hilger.

1. Confined Space Map is mounted above the LOTO cabinet and alongside the label storage board (left)

2. Mike Davis places a magnetic red dot at the location of the confined space requiring entry (right)

Working safely on the package roof

3. Handrail system (before at left, after installation at right) allows personnel to work on package roof without fall protection all the time

4. Roof access was achieved by addition of a small platform and short ladder with a safety gate between the platform and the mechanical package (before at left, after at right)

Challenge. O&M personnel have a routine need to perform maintenance and inspections on BOP equipment located above the gas-turbine mechanical package. Access to this equipment required personnel to either climb an extension ladder or climb over railing from the GT access platform. Once on the roof, fall protection was required for the duration of work, restricting mobility. When multiple individuals were working on the roof at the same time, fall protection was more complex.

Solution. Dogwood worked with local firms to design and install an access point and handrail system to allow personnel to work on top of the mechanical package without the need for fall protection all the time (Fig 3).

The easiest part of the project was to give personnel access to the mechanical package roof by adding a small platform and short ladder with a safety gate between the GT access platform and the mechanical package and by adding railing to three sides of the area (Fig 4).

The most difficult part of the project was determining the best way to allow forklift access to the roof to transfer equipment while still providing a system to minimize the need of fall protection when working on the mechanical-package roof. While Dogwood would have preferred a prefabricated swing gate for forklift access, a custom design was required to accommodate the plant's configuration.

When removal of large equipment is required, personnel don their fall protection PPE and tie off before removing sections of the front handrail to allow access. Sleeves were installed on the mechanical package roof to allow for storage of the removed handrail sections during these evolutions. Safety signs were added to each handrail system reminding personnel that fall protection PPE is required when the handrail system is removed.

Results. Dogwood completed installation of the hardware on both GT mechanical packages in December 2019. Personnel performing work on top of the packages now have safe access to the roof and a handrail system to eliminate the need for fall protection during most work.

By eliminating the need for fall protection during most work, personnel have better mobility and more unrestricted access to the equipment located on top of the mechanical package and do not need to worry about tripping over fall protection lanyards.

Planning, collaboration key to outage management process

Challenge. IPPs with minimal staffing must be flexible and tactical when planning all outages. Utilizing a standardized (but adaptable) process for planning and execution helps keep employees and contractors safe and surprises to a minimum.

Solution. The plant's O&M team works closely with asset-management staff, third-party support, and equipment OEMs to plan and execute outages.

CPV Valley Energy Center

Owned by Competitive Power Ventures and Diamond Generating Corp

Operated by DGC Operations LLC

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

Plant manager: Ben Stanley

Key elements to the program are:

- An outage planning procedure that outlines the process for the team. This procedure is reviewed by the team before any upcoming outages.
- An outage summary document that states the purpose of the outage, the intended worklist, EHS planning, third-party participation, logistics, training, cranes and rigging, etc. It provides a narrative or "story" of the outage and evolves over time as the team refines the plan and gathers more detailed specifics around the work needed.
- A checklist that details the main components of the outage. Starting with the type of outage (routine, minor, CI, HGP, major) and expected duration, the planning checklist includes the following:
  - Internal meeting schedules—including those for LTP/LTSA service planning, EHS planning, budget reviews, and meetings with third-party vendors.
  - Outage-date requests and approvals to energy managers and ISO organizations.
  - Outage project list, which comes from the work-management process in the CMMS. Work orders and PMs are appropriately identified, prioritized, and classified for each type of outage. This list is reviewed continuously during the routine work-management process (backlog and work planning meetings).
  - A preliminary outage schedule is developed and shared with stakeholders early in the process. Critical-path items are identified and highlighted.
  - Work schedules. Operator/maintenance crew shift schedules are reviewed and updated. Shifts are added where needed to support plant evolutions, EHS activities, operator training, etc.
  - Special compliance inspections needed (pressure vessels, insurance/risk inspections, compliance metering).
  - Rigging and lifting. A review of the need for lift plans and special rigging certifications is performed. In some cases, rigging/crane certifications require long lead times with third parties.
  - Safety planning and third-party support (confined-space rescue, audit support, and site security).
  - An EHS plan for the outage details items such as hazardous waste generated, inspection and audit planning, potentials for high-risk environmental issues, etc.
  - Logistics. Parking, laydown, deliveries, additional office space, etc, are reviewed and an updated site map is generated.
  - Budget and procurement. The business-administration and asset-management teams are fully integrated into the process with a detailed list of parts/inventory needed, executed contracts, purchase orders, and appropriate delegation of financial authorities. The team also maintains awareness of the potential for additional discovery work and prepares to communicate variances as they occur during the outage.
  - In-house parts inventory is reviewed. Long-lead-time items identified should be ordered well in advance.
  - Severe-weather contingency planning includes a review of forecasts, historical weather patterns, and lessons learned. Focus is increased on personnel safety during severe weather. Consideration is also given for activities such as water washes during freezing ambient temperatures, delays in deliveries during extreme weather events or snow-

storms, emergency lodging/hotels, etc.
- Plans are developed for pre-, in-, and post-outage testing. Bear in mind that several tests are best performed during shutdown to minimize reliability risks (turbine auxiliaries, overspeed testing, fuel swapping, etc). There are other tests that should be performed only when the plant is offline. Finally, certain validation testing is performed during the restart process.
- NERC task review of the required compliance testing items is performed for NERC applicability.
- An integrated checklist is developed for critical site and contractor contacts. Since this changes for each outage, it's important for staff to update the list specifically for each outage.
- External notifications. Regulators, emergency management organizations, and in some cases local government agencies, require notifications. Best practices have been adopted to make courtesy notifications to town supervisors, boards, mayors, etc. This prepares them for increased traffic in the area, additional vehicles parked onsite and potential inquiries from the public/media.
- Scope freeze. The O&M and asset managers determine the appropriate date for scope freeze so that no additional work items are planned for unless they fall under a higher amount of scrutiny by plant management. This helps to minimize schedule impacts.
- A lessons-learned meeting is conducted shortly after outage completion. Focus is on both when and where improvement is needed. As many stakeholders as possible are invited to the session. The list generated helps to create corrective actions and items to consider for the next outage. Continuous improvement is the goal.

■ Final outage report includes the outage summary, detailed schedule, facility outage map, detailed costs and variance report, and final results of the work list.

Results. The collaborative efforts of the team leads to safe, well-planned, cost-effective, and well-documented outages. Utilizing the procedures and tools developed by the team helps to ensure that the outages are completed on schedule and on budget with minimal surprises.

Project participants: The entire O&M staff, including Donald Atwood, Ben Stanley, Ed Peters, Dave Engelman, Tanya Rovner, Josh Zimmer

Duplex lube-oil filter installed on BFP skid fluid drive

Lea Power Partners LLC

Western Generation Partners

Operated by Consolidated Asset Management Services

604-MW, gas-fired, 2 × 1 combined cycle located in Hobbs, NM

Plant manager: Roger Schnabel

Challenge. Under the original design, debris from any failed bearing in the system would be collected in the fluid-drive sump and then circulated through the system. This would cause damage to other bearings. Of particular concern was the debris that would accumulate inside the dead zones of the shell-and-tube lube-oil coolers. The design of those heat exchangers made them difficult to clean after a bearing failure. Debris hidden in the coolers would circulate onto the new bearings and cause premature failures.

Solution. Adding a set of duplex filters after the pumps and before the lube-oil coolers eliminated recirculation of bearing debris through the system (Fig 1).

Results. After an upcoming overhaul, the heat exchangers will be cleaned thoroughly. They will remain clean because lube oil now is filtered. Even if a bearing failure were to occur, debris from that failure would be removed by the filters and not get into the lube-oil coolers. This will increase fluid-drive reliability and increase bearing life.

1. Filters eliminate recirculation of bearing debris though the lube-oil system

Duct-burner fuel-skid shut-off valve leakage test retrofit

2. Addition of block and bleed valves allow leakage test not possible previously

Challenge. The duct-burner control system wasn't designed to allow operators to leak-test valves in the fuel-gas system. The leak test is an insurance-company requirement.

Solution was to add a block valve between the last block valve and the duct-burner distribution manifolds, plus a bleed valve, vented to a safe location between the two block valves (Fig 2).

Results. The system now can be isolated from the duct-burner manifolds and tested for leaks. A leak test was performed during a recent outage and satisfied insurance-company requirements.

Redundant filter system for ammonia injection skid

Challenge. The original design had a filter before the single valve controlling ammonia flow to the HRSG. Debris from the ammonia tank would collect in the tubing and plug the filter. An outage was required to correct this problem each time the filters clogged up.

3. Addition of a redundant filter system allows removal of plugged filters without taking an HRSG out of service

Solution was to add a second filter in parallel to the original one with all the required block valves, drain valves, and pressure differential gages, thereby enabling one line to be taken out of service without stopping ammonia flow to the HRSG (Fig 3).

Results. After this modification was completed, the second filter was placed in service and blocked off. Once the filter in service shows sufficient pressure differential, the standby filter is lined up. Thus, a filter can be changed-out without taking an HRSG out of service.

Redesign HRH bypass-steam diffuser in the ACC duct

Challenge. The hot-reheat bypass diffusers in the air-cooled-condenser duct were failing regularly. The diffusers were fabricated of ½-in. plate in two sections with ½-in. holes totaling 50-in.^{2} of flow area. The holes were very close together (Fig 4) and a combination of flow and vibration would break the metal between the holes. In the first 10 years of plant operation these diffusers had failed twice.

Solution. The solution was to redesign the diffuser area, using the same ½-in. plate but drilling 1-in. holes on 2-in. centers for the same total flow area. This increased the distance between holes and therefore making the entire diffuser much stronger to withstand the flow and vibration.

Results. Following the installation of the newly designed diffusers, the ACC duct was inspected after about four months of operation. The diffusers showed no damage or cracks. Plant personnel plan to monitor diffuser condition whenever the opportunity exists.

Flowmeter installation on the air-ejector steam line

Challenge. As designed, the plant didn't have a flowmeter to measure the amount of steam used by the ACC air ejectors. This made it difficult to evaluate ejector performance.

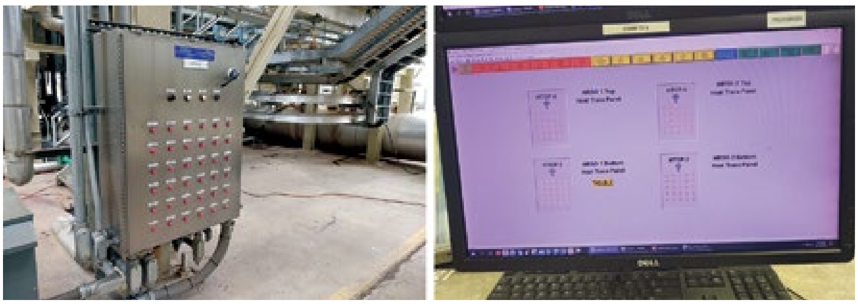
4. HRH bypass-steam diffuser was redesigned to withstand damage from flow and vibration

Solution was to install an annubar in the steam line common to all the ejectors (Fig 5).

Results. After flowmeter installation, the plant was able to trend steam use by the ejectors during startups and normal operation. Flow measurement has helped in the troubleshooting of ejector issues that could not have been diagnosed previously.

5. Flowmeter enables operators to trend steam use by ejectors

Upgrade heat-trace control panels to alert CRO with DCS alarm



6. Heat-trace control panel with breaker lights at left; graphics screen at right

Challenge. Heat-trace control panels (HTCP) supplied with the plant included individual breaker-condition indicator lights on the front of the panel for local indication of a problem. During cold-weather operation, plant operators were making frequent rounds to verify there were no tripped breakers on the HTCPs that could lead to plant reliability issues caused by frozen instrument sensing lines.

Solution. Install new cable runs from HTCPs to the control room DCS. Wire the relay board to create an alarm series circuit such that if any breaker trips an alarm is generated on the DCS. In addition, create new alarm points and graphics screen on the DCS (Fig 6).

Results. After the HTCP remote alarms were implemented, the incident rate of frozen transmitter sensing lines was reduced by early detection which allowed faster corrective action. The HTCP DCS alarm functionality has improved overall facility cold-weather reliability.

Project participants: Roger Schnabel, Carlos Sanchez, Richard Shaw, Kelvin Mendenhall, and Tyler McCoy

Turbine-enclosure ventilation-system upgrade

Monroe Power Co

Owned by Southeast PowerGen LLC

Operated by Cogentrix

380-MW, gas-fired, two-unit, simple-cycle plant located in Monroe, Ga

Plant manager: Mike Spranger

Challenge. During a test run following a planned maintenance outage, one unit experienced a fire-system high-temperature trip in the turbine enclosure which caused a turbine trip. One of the contributing factors to the fire-system trip was that the turbine enclosure ventilation system did not respond to the rising temperature fast enough.

Solution. Staff designed and installed upgraded ventilation system controls.

The thermostats by the door were replaced by RTDs mounted on the ceiling so that the ventilation system is operating based on the hottest areas in the turbine enclosure. Louvers operate independently from the fans at a lower-temperature setpoint, allowing heat to escape naturally and reduce the stress on fans and motors. A ventilation graphics screen was added to the DCS so a control room operator can monitor and operate the system remotely.

Results. The ventilation upgrade, completed for less than $500 per unit, improves the operation and reliability of the gas turbines.

Project participants: James Goins, Chris Harris, Scott Hobbs, Charles Gibson, Nick Sanz, Bly Crane.

CCC Tuxpan II & V

Owned by Electricidad Águila de Tuxpan and Electricidad Sol de Tuxpan

Operated by NAES Corp

Tuxpan II: 500-MW, dual-fuel, 2 × 1 combined cycle located in Tuxpan, Veracruz, Mex

Tuxpan V: 500-MW, gas-fired, 2 × 1 combined cycle located in Tuxpan, Veracruz, Mex

Plant manager:
Jorge Gamel Esparza Cárdenas

Avoid thermal shock from control valve bypass

Challenge. During unit shutdowns, there's always the possibility of thermal shock—particularly in the low-temperature reheat line, because of flow bypass in the HRSG HP bypass spray control valve.

Solution. During unit shutdowns of Tuxpan II and V, the practice is to close the isolation valves for the tempering control valves to avoid possible thermal shock from spray-water bypass. The isolation valves are opened when the spray attemperation is required again.

Results. Since 2007 there have been no thermal shocks to the HRSG or to the main-steam pipelines. This has kept the HRSG in good condition, as confirmed by the nondestructive tests performed.

Project participants:
Leonel Rosas Maitret, Everardo Guadalupe, and Jorge Gamel Esparza Cárdenas

LIVE CONFERENCE

☆ NEW DATES ☆

30 ANNIVERSARY

7F Users Group®

1991-2021

7F Users Group

30th Anniversary Annual Conference

☆ August 23-27, 2021 ☆

Marriott St. Louis Grand

www.PowerUsers.org

Age is only a number

The adage "age is only a number" pertains to equipment as well as to people, homes, and many other things. This article illustrates how gas turbines well cared for can provide good value far beyond their design lifetimes with modest investment.

Perhaps the best place to start this case history is with the Great Northeast Blackout of 1965. As the event title indicates, the Northeast went dark late in the afternoon of November 9 when a transmission line near Ontario, Canada, tripped, causing several other heavily loaded lines to fail—a domino effect.

Restoring power was a chore. As some involved in the process recall, the key to getting the New York metropolitan area up and running was a black-start Frame 5 on Long Island. Bootstrapping a grid start was the day's challenge. The success of gas turbines in this endeavor made these machines the backstop of choice for grid support going forward.

Sales of simple-cycle gas turbines boomed in the late 1960s and early 1970s, with GE's Frame 5 and Pratt & Whitney's (P&W) FT4 leading the charge. Westinghouse Electric Corp (now Siemens Energy) had its W171, W191, and a few years later the W301, but those machines weren't as popular in utility board rooms at that time.

The early gas turbines were conservatively designed and had "good bones," assuring long life if properly operated and maintained (Fig 1). However, most have disappeared because larger and more-efficient machines make best sense in the majority of applications today. But some of these legacy units, uniquely positioned in the market, not only remain productive, but are worth investing in to extend their lifetimes beyond the half-century or so they have already served.

Kimura Power LLC, with generating plants in Ohio and Indiana, upgraded the control systems of its four- and five-decades-old gas turbines in 2016 primarily to improve their reliability in starting and in dual-fuel operation—an investment that continues to pay dividends. A bit of history: The Kimura Peaker Portfolio was a unit of AES Ohio Generation LLC, a wholly owned subsidiary of DPL Inc (Dayton Power & Light Co), until it was acquired by Rockland Capital LLC in spring 2018.

1. **Hutchings W301** gas turbine reflects the care it has received during a half-century of service

The upgrade projects described below involve Kimura's Yankee FT4s and Frame 5s, and Hutchings W301—assets identified in the accompanying table. These peaking units serve the PJM capacity and black-start markets. They average about 70 starts annually, virtually all during June, July, August, and September. Typical summer-peak run time is 16 hours—early morning to about 9 p.m.

Kurt Lammrish and Mark Meade were among the decision-makers on the DPL team responsible for upgrading Kimura's legacy peakers with 21st century controls.

Design, installation, and commissioning of the new hardware and software, and training, were done by Orlando-based Turbine Technology Services Corp (TTS). Today, Lammrish is plant manager and Meade, who retired from DPL as peaker supervisor about when the Kimura assets were sold, serves the plants in a consulting capacity.

They told the editors the relay logic on the Frame 5s and the 301 had not been changed since those units were commissioned and that the Fives were equipped with Young & Franklin (Y&F) fuel regulators for engine control.

Rockland Capital's Kimura portfolio

Plant	No. units	Type	Model	Capacity, MW*	Fuel
Monument	5	Recip	GM MU-20E	12	Oil
Hutchings	1	SCGT	W301G	25	Gas/oil
Sidney	5	Recip	GM MU-20E	12	Oil
Tait	7	SCGT	GE 7EA	586	Gas/oil
Tait	4	Recip	GM MU-20E	10	Oil
Yankee	1	PV		1	Sun
Yankee	3	SCGT	P&W FT4A-9	51	Gas/oil
Yankee	4	SCGT	GE MS5001LA	52	Gas/oil

*Nominal summer rating

2. **What a difference** 50 years makes! New turbine and generator controls for Kimura's Frame 5 assets are at left, original generator panel is at right

Molecule to Megawatt

Our legacy is founded on a global footprint and technical solutions for operational excellence

We specialize in innovative and high value-engineered solutions that help our clients maintain, upgrade, and enhance their power generation and gas compression assets. Our longevity, experience, and global agility distinguish us, our integrity and intellectual candor align us with our client's interests and success.

Improved Plant Efficiency

Through Upgrades and Modifications

- Turbine Control System Upgrades
- Generator Control and Protection Upgrades
- PLC Migrations
- TMOS/HMI Upgrades
- BOP/DCS Upgrades
- Instrumentation Upgrades
- Fuel Flexibility Upgrades
- Fast Start Upgrades
- Vintage Unit Reliability Programs
- Spare Parts
- Mechanical System Upgrades
- Operational Flexibility For F-Class Gas Turbine (DYNAFLEX)

35 YEARS | **102 COUNTRIES** | **454 CLIENTS** | **27MM kW** | **21 INNOVATIONS**

12661 Challenger Parkway,
Suite 250
Orlando, FL 32826
Phone: +1 (407) 677-0813

www.TTSEnergyServices.com/power

Recall that the fuel regulator *predated* GE's Speedtronic™ I, the OEM's first electronic control and protection system for gas turbines. Think about the challenge associated with finding spare parts for those machines and then locating a technician to do the controls work needed.

The Kimura upgrade

The original control systems for the legacy peakers, tough to troubleshoot, were replaced with TTS's TMS-1000S turbine management system, built on Allen Bradley's widely used ControlLogix® distributed-control platform (Fig 2).

Not having to rely on the OEM for service cuts both outage time and cost when repairs, logic changes, etc, are needed.

The TMS-1000S uses the Ethernet-based Device Level Ring (DLR) architecture for processor I/O connections, thereby meeting NERC cybersecurity requirements.

The provided switch assures a secure access point to the NERC recommended security perimeter by networked devices—such as remote HMI or engineering laptop.

TMS-1000S also relies on dedicated DeviceNet Networks for communications with such upgrades as the vibration monitor, electronic overspeed detection system hardware, and the electronic valve-position controller for GT gas-fuel control. DeviceNet uses the Common Industrial Protocol (CIP) to provide the control, configure, and data-collection capabilities for industrial devices.

Modbus TCP/IP delivers additional information from the TMS-1000G (generator) system, which includes generator protection relays, auto sync, power and energy meters, etc. Finally, the Distributed Network Protocol (DNP3), together with the power-quality and revenue meter, allows for remote viewing of output parameters such as megawatts, megavars, and generator breaker status.

Here's an overview of key actions undertaken by TTS to bring the Kimura assets up to current requirements:

- **Unit rewire.** First, removed all existing wiring and terminals, cleaned all conduit, tray, and junction boxes, and replaced broken and damaged conduit fittings and terminal blocks. Next, installed new high-temperature cabling designed specifically for gas-turbine applications (Fig 3).

- **Fuel systems.** Control valves are core to the fuel system, which has experienced significant technological advancement in the last two decades. Removed pneumatic and electrohydraulic systems and replaced them with modern Woodward and Y&F electronic fuel valves, both highly reliable based on industry experience (Fig 4).

- **On-base devices.** Replaced transmitters and pressure switches and upgraded all instruments, thereby increasing reliability and making more information available to the control system and the operator (Fig 5). These upgrades allow the control system to generate more meaningful diagnostic alarms, thereby facilitating troubleshooting of problems.

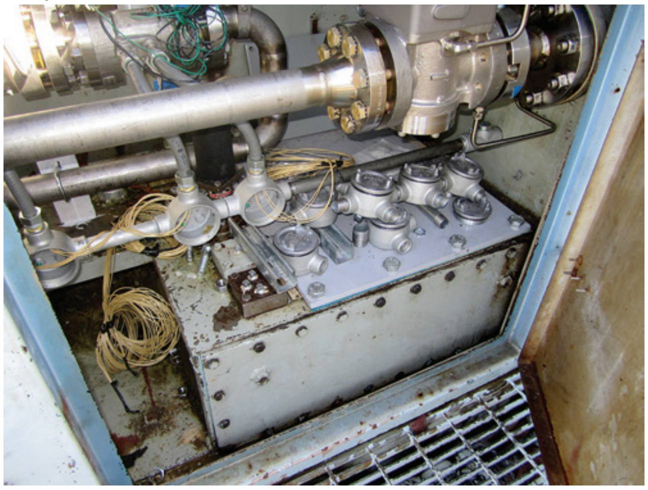
- **Liquid fuel system.** Modified fuel pumps, replaced flow dividers, and upgraded other components to up reliability during starting, load changes, and fuel transfers.

- **Multiple-unit HMI front end.** TTS engineers believe upgrades to the human machine interface (HMI) offer huge benefits to users. Examples: Eliminates the need for an operator to enter pressures and temperatures in a log book, provides an indication as to why a unit tripped, etc.

The modern HMI with the proper mix of useful/usable/readable graphics, alarm messaging, and real-time and historical trending provides operators the tools to properly manage the machine, monitor the unit and react as necessary to changing conditions, respond appropriately to alarms, and provide actionable information to others. An example

3. Rewiring of the Frame 5 involved removing all existing wiring, cleaning of junction boxes, replacement of damaged terminal blocks, and install of new high-temperature cabling

4. Gas-valve retrofits on the Frame 5 (below) and W301 (right) brought the fuel systems on both engines up to today's standards



5. Replacing instrumentation, transmitters, and pressure switches increased engine reliability, made more actionable information available to operators

6. Excitation-system retrofit helps bring a Frame 5 into the digital world

of the last: Give maintenance teams the tools needed to identify and resolve problems quickly, minimizing downtime.

- **Generator controls.** The excitation-system upgrade involved removing the existing relay, potentiometer, static-based system and replacing it with a modern digital excitation control system (Fig 6). The protection-relay upgrade focused on the original electromagnetic relays. While reliable, they do not provide the historical information so valuable in troubleshooting. Modern digital protection relays provide the needed protection as well as actionable information.

The excitation and protection systems are connected to the turbine control system, allowing key information to be displayed, trended, and logged by the HMI.

When all upgrades were completed—on time and within budget—the units were tested to base and peak loads on both fuels, and to maximum and minimum VArs. Plus, fuel transfers were executed successfully on load. Note that the controls for the Yankee and Hutchings peakers are local (at the individual units) with all remote-start capable and AGC (automatic generation control) operable. Control central is at the Tait facility, which has seven 7EAs and is manned 24 × 7.

The results

As to the all-important question, "How have the upgrades and the units performed over time," Lammrish and Meade shared their experience thusly: Excellent! As of this writing, no outage or reliability issues have been attributed the TTS control system. In fact, Kimura will be ordering control-system spares for the first time in 2021—nearly five years after commissioning. There is no retirement plan for these units.

In closing, Lammrish and Meade shared their thoughts on TTS: A highly reliable, very capable partner always willing to go the extra mile to do the job correctly. A case in point was recreating controls drawings for the units, which involved an unexpected engineering effort. CCJ

WTUI

2021 Virtual Conference
June 8 – 24

When the Western Turbine Users concluded its 2019 conference, in Las Vegas, Wednesday, March 20, all of the group's business indicators were pointing upward. Another annual meeting—the organization's 29th—with more than a thousand attendees, more than 150 exhibitors, few if any hiccups, plenty of wholesome food, good evening events, and endless coffee.

Plus, Wayne Kawamoto, the conference executive director and an active member of WTUI since before its incorporation in 1990, had signed contracts with venues and hotels for meetings through 2022, and negotiations underway for years beyond that. Plus, plus, there was money in the bank.

Then the roof fell in. Covid-19 reared its ugly head late February/early March 2020 and the governor of California's attendance restrictions for meetings wiped out the conference scheduled for Long Beach beginning March 29. Western Turbine was the first meeting focused on gas-turbine owner/operators to be canceled. The 501F Users Group was the last organization to hold an in-person conference, in early February (page 6). A brief virtual meeting was held in 2020 to bring Western Turbine members up to date on what the OEM and its licensed authorized service providers (ASPs) were doing.

With Covid-19 and its many variants still raging, WTUI will conduct its first virtual meeting modeled after the in-person conferences of yesteryear beginning June 8. A preliminary program follows with all times East Coast. Keep current on updates regarding content and times at www.wtui.com. User registration will be there, too. Vendor participation is being coordinated by Sheila Vashi; contact her at sheila.vashi@sv-events.net.

Steering committee

Officers

President, John Hutson
Vice presidents: Jim Bloomquist, David Merritt, Ed Jackson, Bill Lewis
Treasurer, Wayne Feragen
Secretary, Jermaine Woodall
Historian, Mike Raaker

Board of Directors

Todd Kutz, Cogentrix Energy Power Management LLC
Dennis Johnson, Sentinel Energy Center
Paul Park, Chugach Electric Assn
Robert Nave, Procter & Gamble
Garry Grimwade, City of Riverside
Andrew Robertson, Wellhead Services Inc
Steve Willard, Enmax Energy Corp

Conference chairpersons

LM2500, Garry Grimwade
LM5000, Perry Leslie
LM6000, Dave Fink
LMS100, Steve Worthington
New users, Andrew Gundershaug

Support staff

Wayne Kawamoto, conference executive director
Wayne Feragen, webmaster
Charlene Raaker, conference coordinator

Week One, users only

Tues, June 8, LM6000

0900, Top 10 contributors to forced-outage incidents, Strategic Power Systems (SPS)
0930, ASP 1, MTU
1015, ASP 2, IHI
1100, ASP 3, TCT
1200-1300, ASP breakout rooms

Wed, June 9, LMS100

0900, SPS Top 10
0930, GE presentations to users
1130-1230, GE breakout rooms for controls, simple-cycle operation, repairs and field services

Thurs, June 10, LM2500

0900, SPS Top 10
0930, ASP 1, MTU
1015, ASP 2, ANZGT
1100, ASP 3, TCT
1200-1300, ASP breakout rooms

Week Two, users and GE only

Tues, June 15, LM6000

0900, GE presentations to users
1100-1200, GE breakout rooms for controls, combined-cycle operation, simple-cycle operation, repairs and field services

Wed, June 16, LMS100

This is a users-only session
0900-1100, User presentations and roundtable discussion

Thurs, June 17, LM2500

0900, GE presentations to users
1100-1200, GE breakout rooms for controls, combined-cycle operation, simple-cycle operation, repairs and field services

Week Three, special presentations

Tues, June 22, State of the Engines

This session open to all conference participants
0900, John Hutson's welcome
0930, Gas-turbine business update by Consultants Mark Axford (Axford Turbine Consultants) and Tony Brough (Dora Partners)
1030, CAISO presentation
1100-1500, Vendor fair with up to 20 company sponsors (TBA)

Wed, June 23, Special technical presentations to users

0900, Vendor presentations, total of six, 30 minutes each (TBA)
1200-1300, Breakout rooms for the day's presenters

Thurs, June 24, Special technical presentations to users

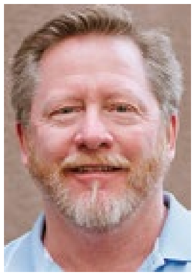
0900, Vendor presentations, total of six, 30 minutes each (TBA)
1200-1300, Breakout rooms for the day's presenters

WESTERN TURBINE USERS

Best practices shared by aero users can benefit all

The Western Turbine Users and CCJ work together to expand the sharing of best practices and lessons learned among owner/operators of GE aero engines. WTUI VP Ed Jackson, plant manager of Missouri River Energy Services' Exira Generating Station in Brayton, Iowa, says the organization's mission is to help members better operate and maintain their plants, and a proactive best practices program supports this objective.

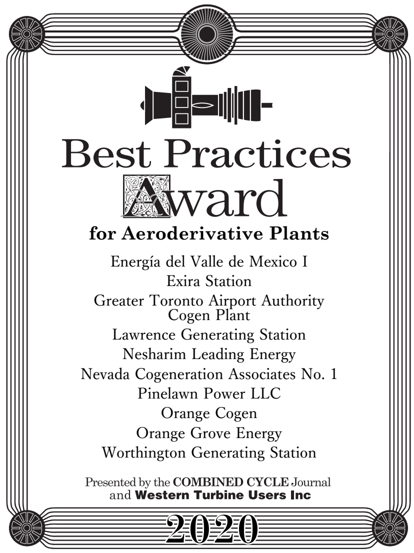
Jackson stressed the value of the joint program during the user organization's last in-person meeting in Las Vegas in March 2019. He encouraged attendees to support the initiative and explained how they would benefit from the experience. The latest fruits of that effort are the best practices profiled here, submitted by the 10 plants identified in the figure.



Jackson

Recall that 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 owner/operator personnel to improve the safety and performance of generating facilities powered by gas turbines.

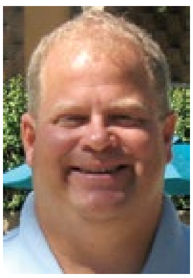
Industry focus today on safety and performance improvement is reflected in the lineup of proven solutions profiled on pages 54-65.



INDUSTRY PEOPLE

Say it ain't so, Jeff

William J (Jeff) Gillis has cleaned out is multiple industry lockers—at ExxonMobil, the 7F Users Group, and Frame 6 Users Group—and retired after more than four decades of service to the electric-power and energy industries. The editors wish Gillis, always available to help a colleague solve a knotty problem, fair winds and following seas.



Gillis

The man was never without a smile and kind word, and could challenge the top experts in the industry on Frame 6 Jeopardy—if there was such a game show. He was the premier discussion leader at the 6B meetings in recent years, the group he co-chaired with Sam Moots until the latter's company sold its last Six B and he tendered his resignation in accordance with the organization's bylaws. Gillis was Frame 6 co-chair, and a member of the 7F Users Group's steering committee, for more than a decade.

He was an expert on how to operate and maintain plants safely and he shared his extensive knowledge with insightful presentations at both the 6B and 7F meetings. Gillis had a global perspective on the subject, being ExxonMobil's senior engineering advisor for machinery the last several years. He traveled the world and brought back to the US good ideas on plant design, safety standards and equipment, and O&M techniques.

When a person retires, you often hear the hackneyed phrase, "He (she) will be missed." The absence of Gillis' contributions to the industry most certainly will create a void—hopefully only a temporary one, until someone steps up and fills his big shoes.

TICA elects officers, directors for 2021-2022

Don Punwani, executive director, Turbine Inlet Cooling Assn (www.turbineinletcooling.org), called to say the organization had elected officers and directors for 2021-2022. Recall that TIC is a resilient, sustainable, fast-response, and carbon-reduction option for gas-turbine owner/operators.

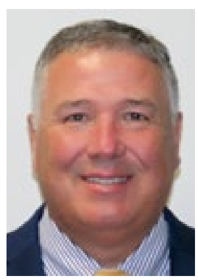
Learn what inlet cooling can do for your plant/company by visiting the resource-rich TICA website when time allows. It offers a TIC performance calculator, experience database of over 400 installations, webinars, technical papers, etc.

The non-profit trade association, established 20 years ago, develops and disseminates worldwide information on all TIC technology options—wetted media, fogging, wet compression, mechanical chiller system, absorption cooling systems, and LNG vaporization systems, and various combinations of these alternatives.

Don Shepherd of Caldwell Energy was elected chairman for the new term; he had been vice chair. Andrew Sickler of Baltimore Aircoil moved up to vice chair following a term as president. The new president is Rob Pugh of Danfoss, VP previously. Justin Rose of Munters was elected VP and Keith Flitner of Victory Turbine Secretary. Consultant Patricia Graef continues as treasurer. Richard Buckley of Johnson Controls (Asia) is the new director.

Remembering Dave Theis

David Wayne Theis died suddenly Nov 27, 2020 in a home accident. At the time he was president/CEO of Houston-based APG (Allied Power Group), and a member of the Board of Directors.



Theis

Theis was well known to owner/operators of power-generation assets, having spent three decades in leadership positions at several aftermarket-services companies—including GE/Preco, Dresser-Rand, and PAS Technologies, plus APG. He founded Leading Edge Turbine Technologies and served as its president/CEO until its sale to Dresser-Rand in 2010.


IHI
Realize your dreams
IHI Cheyenne Service Center (CSC)
Fulfilling your LM6000 Maintenance Needs
Are you satisfied with the services available to you for your LM6000 engines? At IHI, we are all ears, listening to respond to your specific requirements flexibly and quickly with its long-time experience and proven technology developed through many years in the jet engine maintenance business. Authorized by GE since 1995 as a Level 4 Depot for LM6000, we are ready to serve your engines with the professionalism and sincerity expected of a 'takumi' and 'omotenashi.'
Takumi: a person who has vast experience and knowledge in a specific field.
Omotenashi: customer-specific hospitality catering to each customer's unique needs.
IHI doubled maintenance shop area
M40
KAIZEN
IHI Corporation
http://www.ihiincus.com/index.html
Cheyenne Service Center
3909 West 5th Street, Cheyenne WY 82007 TEL 307-638-8983 Email: atsunori_ikejiri@ihi.co.jp

Turbine-oil sampling improvements

Challenge. The best place to get a representative sample for oil analysis is from the engine bearings before fluid filtration, which removes particles that you need to know are in the oil. The path of oil from the bearings of an LM6000 is through the scavenge pump, scavenge filter, cooler, and back to the oil tank. If you grab the sample from the cooler discharge, or the tank, then3 it is downstream of the scavenge filter and the oil you sample will be filtered.

Unfiltered scavenge oil from the bearings before the cooler is above 200F. Sampling this oil is not only dangerous because of possible burns, but it softens the plastic sample containers. One way around this is to collect the sample in a glass container and allow it to cool before transfer to the sample lab's plastic containers. However, the more times the sample is handled, the greater the opportunity to introduce contaminants, while perhaps not lessening the chance of burns from hot oil.

Solution. Install a sample cooler. This eliminates the chance for burns, making sample collection safer, and reducing the chance of introducing contaminants into the sample; plus, it allows you to grab an unfiltered sample. A small stream of cooling water can be directed from any water source, even city water, to flow though the sample cooler while taking the sample. Water discharged can be directed to a drain, or sewer, or recirculated back to the cooling system. For about the same amount of water as it would take to flush a toilet, you can cool the sample oil temperature from more than 200F to cool-to-the-touch.

Plant personnel obtained a stainless-steel sample cooler for less than \$500 and clamped it to a piece of Unistrut they added to existing tube steel on the auxiliary skid (photo). For the oil lines to/from the cooler they used ¼-in. tubing and for the water lines to/from the cooler, ⅜-in. tubing. There is an existing connection on the inlet to the scavenge cooler that is piped to the high side of the differential-pressure gage. A Swagelok ¼-in. tee was installed in this line to supply the cooler with the oil to be sampled in an afternoon.

Results. Plant personnel now obtain oil samples directly from the turbine scavenge prior to filtering, reducing the potential for an inaccurate sample caused by entry of contaminants (table). Plus, there's a safety benefit: Reduced potential for burns from hot oil.

Project participants: Chad Case, Brendon Clancy, and Allen Scarf

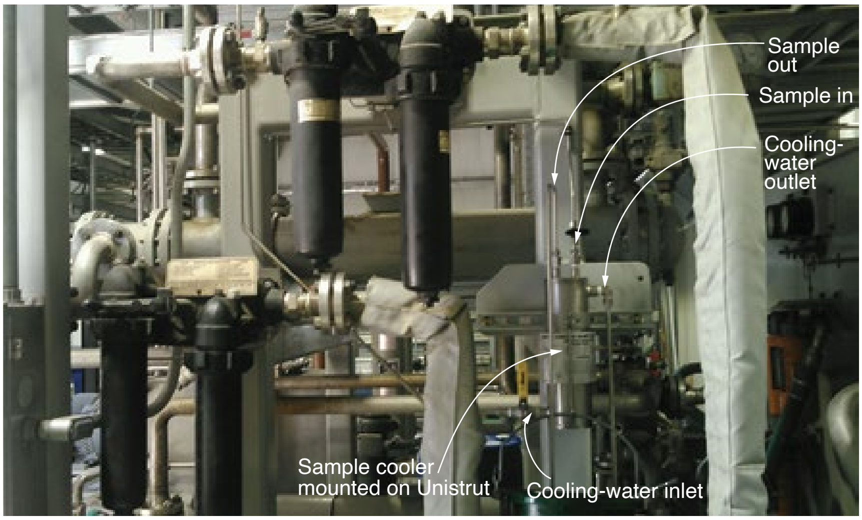
Exira Station

Owned by Western Minnesota Municipal Power Agency

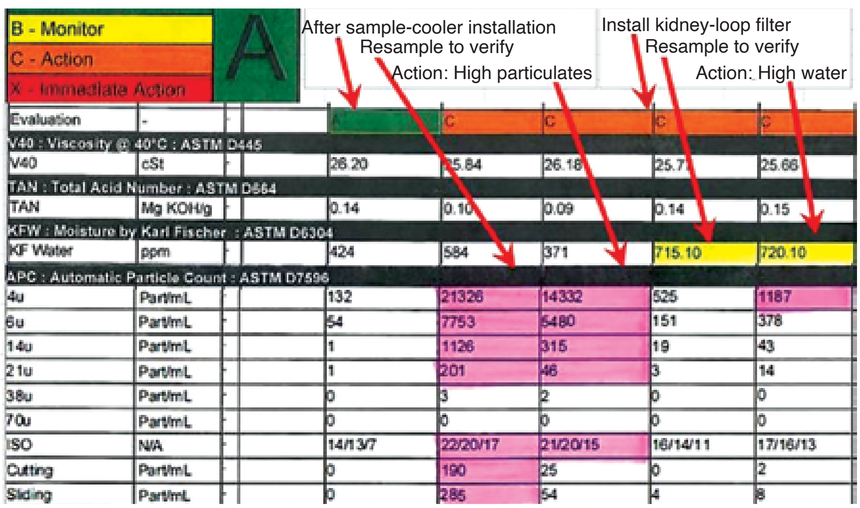
Operated by Missouri River Energy Services

140-MW, dual-fuel, three-unit, peaking facility located in Brayton, Iowa

Plant manager: Ed Jackson



Retrofit sample cooler helps assure more accurate oil analysis



Evaluation	-			A	C	C	C	C
V40 : Viscosity @ 40°C : ASTM D445								
V40	cSt	-		26.20	25.84	26.16	25.71	25.66
TAN : Total Acid Number : ASTM D664								
TAN	Mg KOH/g	-		0.14	0.10	0.09	0.14	0.15
KFW : Moisture by Karl Fischer : ASTM D6304								
KF Water	ppm	-		424	584	371	715.10	720.10
APC : Automatic Particle Count : ASTM D7596								
4u	Part/mL	-		132	21326	14332	525	1187
6u	Part/mL	-		54	7753	5480	151	378
14u	Part/mL	-		1	1126	315	19	43
21u	Part/mL	-		1	201	46	3	14
38u	Part/mL	-		0	3	2	0	0
70u	Part/mL	-		0	0	0	0	0
ISO	N/A	-		14/13/7	22/20/17	21/20/15	16/14/11	17/16/13
Cutting	Part/mL	-		0	190	25	0	2
Sliding	Part/mL	-		0	285	54	4	8

Lube-oil analysis shows particulate concentrations can vary widely. Even after cleaning bottles and resampling, particulates still were introduced to the sample. Reducing sample handling minimizes the chance that particulates will be introduced in the sample and the sampling process is simpler and safer

Engineering improvement facilitates steam-turbine access

Challenge. The plant's Siemens steam turbine has an inline condenser with a nominal 20-in.-diam bolted manhole on top for inspection purposes. The approach to this manhole is restricted by condensate and process-steam pipes. The manhole cover, at a height of about 13 ft and weighing about 30 lb, must be open when inspecting the condenser. This normally is done twice annually during the planned shutdowns, if not for emergency work on control valves in that area, which need occasional maintenance.

Plant staff used to approach this area with the help of ladders and fall-arrest and secure the fall-arrest at non-designated securing points. It was a challenge to work in the area with restricted body movement and most of the times posed a safety concern, especially while handling tools.

Solution. Install a permanent access ladder to this area (Fig 1). The intricate access dictated that the ladder be designed and fabricated in sections. Dimensional drawings were made by plant staff and provided to a contractor for certification and manufacture. Installation was completed with the contractor's help. It was not an easy fit because of the various obstructions at the location of interest.

Results. The modification enables safe access to the area to open the manhole cover (Fig 2) for periodic condenser inspections and to inspect control valves when the plant is running. The platform, and railings around the manhole cover, provide safe working conditions both on top of the condenser and to anchor the fall arrests of personnel going down into the condenser for inspection.

Project participants:
Socrates Furtado, plant manager
John Power, operator

1. Permanent ladder provides safe access to manhole cover

2. Manhole cover is removed to perform condenser inspections

GTAA Cogen Plant

Owned by Greater Toronto Airport Authority

Operated by SNC Lavalin O&M

117-MW, gas-fired, combined-cycle cogeneration facility located in Mississauga, Ont, Canada

Plant manager: Socrates Furtado

Eliminating hazards in lubrication activities for turbine, generator fans

Challenge. EVM I was initially planned as a peaker plant but growing electric consumption forced operation 24/7 during months of high demand. This required that lubrication of rotating equipment be conducted more frequently. To illustrate: The axial turbine and generator enclosure fans, which are mounted vertically and operate continuously, now must be lubricated weekly.

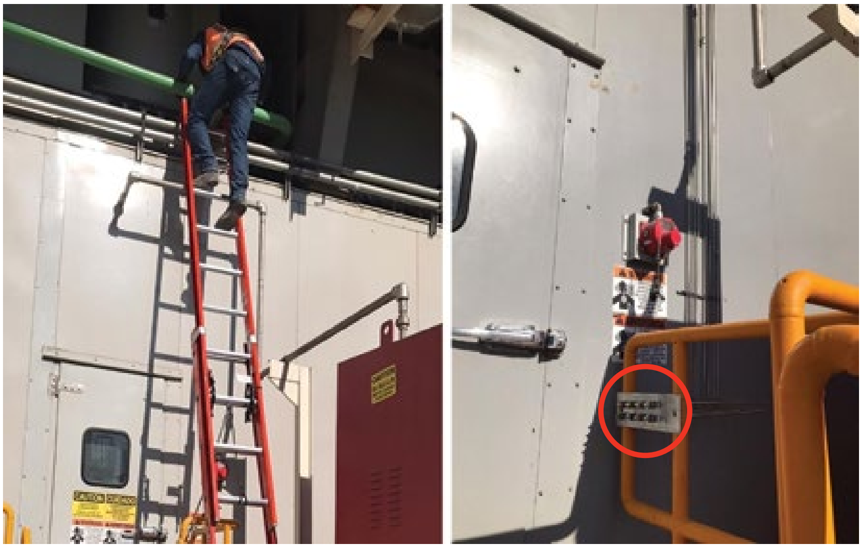
Energía del Valle de Mexico I

Owned by EVM Energia SAPI de CV

Operated by NAES Corp

100-MW, gas-fired, three simple-cycle LM6000PF gas turbines located near Mexico City

Plant manager: Javier Badillo



Lubrication of fan bearings, originally requiring a ladder and safety gear (left), was simplified by installing grease fittings at ground level (right)

Access to this equipment for lubrication was complicated and dangerous. In addition, it required two technicians to do the work and took approximately two hours to lubricate all the fans serving the three gas turbines onsite. Technicians had to use a ladder, harness, and lifeline to access the fans, making the risk of this activity "high" as determined by a critical-tasks analysis (photo, left).

Solution. Goal was to create a way to lubricate the fans that was more accessible to technicians and to reduce the man-hours required for this activity. Staff determined the optimal approach was to place the grease fittings at ground level and guide the grease through tubing to the fan and motor bearings.

To do this it was necessary to design the lubrication system with input from operations personnel to assure installation of the rack of grease fittings (photo, right) was located appropriately. Staff decided to make the connections from the bearings to the rack of grease fittings using economical tubing installed by plant personnel, to minimize cost. The project took about two weeks to complete.

Results. This solution eliminates the need for ladder, harness, and lifeline to lubricate fan bearings, thereby eliminating the risks of falls and crushing. In addition, the activity now is performed by only one technician and the lubrication time has been reduced to 1.32 hours per month, down from 16 hours.

Project participants:
Alonso Saldivar, maintenance manager
Andres Hernandez, shift supervisor

Fuel-compartment wind block eliminates unit trips

Lawrence Generating Station

Owned by Hoosier Energy (four units) and Wabash Valley Power Assn (two units)

Operated by NAES Corp

258 MW, six simple-cycle LM6000 natural-gas-fired peaking units, located in Lawrence County, Ind., and connected to Hoosier's 161-kV transmission line

Plant manager: Robert VanDenburgh

Challenge. Lawrence County experienced several fuel/water compartment pressure problems during inclement weather, especially during windy conditions. Increased wind velocity entering the fuel compartment inlet duct caused erratic compartment pressures.

During normal operations, the fuel/water compartment pressure is 0.15 – 0.20 in. H_2O. However, high winds directly entering the fuel-compartment inlet duct caused a drop in Δp to as low as 0.05 in. H_2O. Such a low signal from the transmitter activates the low-Δp alarm, which must be cleared within 60 consecutive minutes, to prevent the Woodward control system from activating the LM6000 SML trip. Note that immediate action is required to restore proper fuel-compartment pressure.

Solution. Plant O&M technicians

Fuel-compartment inlet duct as originally installed is at left, with wind block at right

collaborated with local sheet-metal workers to create a stationary wind block, located 6 in. in front of the fuel-compartment inlet duct and securely fixed to the concrete below. It allows more than enough air to enter the inlet duct to maintain proper compartment pressure while preventing wind from directly entering the duct.

Results. Following installation of the wind blocks on all six units, no impedance to air flow was observed; compartment pressures were normal regardless of weather conditions. SML shutdowns caused by high winds entering the fuel compartment have been eliminated.

Project participants:
Matthew O'Hara, lead OMT
Jared Thomas, O&M/IC&E technician
Kevin Wildner, OMT

Orange Grove

From toxic to excellent, focus on culture drives substantive change

Orange Grove Energy
Owned by J-Power USA
Operated by NAES Corp
96-MW, gas-fired, two-unit, peaking facility located in Pala, Calif
Plant manager: John Hutson

Challenge. Orange Grove Energy faced many obstacles in its first several years of operation. Examples: OGE had four plant managers within two years of commissioning, the entire hourly staff turned over in the first few years, and there were four asset managers during Year Three. Plus, the plant received multiple environmental NOVs (notices of violation) annually, and its safety culture would have been classified as poor.

Solution. By 2014 the site was on the verge of hiring its fifth plant manager, morale was low, and there seemed to be no solution to preventing air-permit NOVs on a semi-annual basis. In late 2014, the site embarked on a positive trajectory that would later pay dividends beyond what would have been imagined earlier.

Staff ratified a set of "Shared Values and Guiding Principles," agreeing that to become what we wanted to be as a team, we had to be held accountable to those values. Job candidates were introduced to the "Shared Values and Guiding Principles" and had to support and embrace them before an employment offer was made.

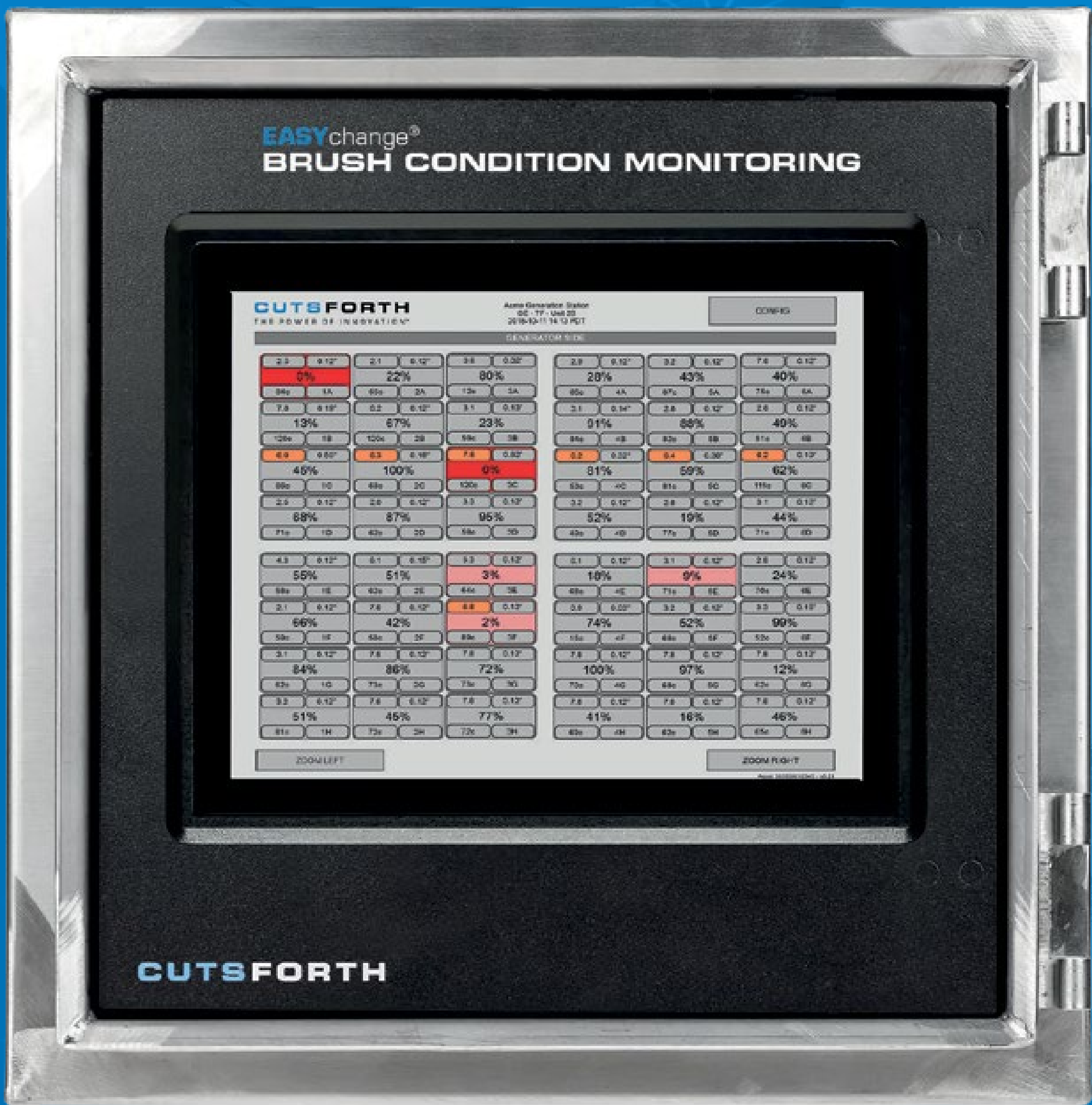
In addition to these values, the team agreed that they should be able to enjoy their work. A workplace free of harassment, of course, but the team also encouraged fun and celebration, which became the new expectation at OGE.

"Shared Values and Guiding Principles" gave the team a firm foundation of knowing who we were and what was expected of those who worked at OGE. The site began to consciously embrace employee empowerment. Each team member was given various projects and the freedom and responsibility to own those projects, and expected to lead them to completion.

Ideas were not only desired but expected: People began exchanging solutions and ideas in daily and monthly meetings with the intention of prioritizing issues and finding the best solutions possible to improve the site.

By the end of 2015, the site had transitioned into the NAES O&M company, still owned by J-Power USA, and had made two key personnel changes.

WIRELESS BRUSH HEALTH DATA TO YOUR DCS



Holder with
alth Sensor

Touch-screen data displays installed near brush excitation rigging

REDUCES YOUR RISK OF RING FIRES!

ORE @
.com/BCM

ANAB ACCREDITED
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

OGE personnel celebrate receiving the NAES President's Award in 2018

Those hired in 2015 were largely evaluated on their ability to fit into the new OGE culture and how they would be able/willing to drive cultural-change improvements at OGE.

NAES brought with it additional operational and safety programs. The key was that the OGE team embraced those corporate policies and worked hard to make them their own. Embracing the structure NAES brought gave the site additional clarity and continuity which helped ensure the employees felt supported from a corporate level.

In 2016, OGE was beginning to improve, as it was the first year since commissioning that the site did not receive an environmental NOV. Additionally, the plant implemented a site cost-saving initiative with a goal of reducing costs by more than $100,000 annually. The team at OGE was happier and becoming more productive.

Late in 2016, OGE conducted a comprehensive anonymous "Cultural Survey and Disc Assessment" with the staff. The Cultural Survey was intended to identify two things: (1) Overall status of the employee's perception of OGE culture, and (2) Specific areas still requiring focus. The overall measured results were surprisingly higher than expected, but it did reveal areas in need of improvement. There was still plenty of work and opportunity to improve in order to get where we wanted to be as a team.

The Disc Assessment focused on teaching personnel about their own personalities and the personalities of others. The employees would use this information to communicate better with each other. The two surveys were endorsed by ITOCHU, NAES's parent company. A professional facilitator helped lead the team in maximizing the learning gained from the exercise.

In 2018, OGE convinced the plant owner to reorganize the facility to better meet its current needs. One action was to eliminate the plant administrator position and replace that role with a day-shift lead OMT, who would fill in for vacations, sick call outs, and training coverage. The plant-admin duties would be shared by the team—largely distributed between the plant manager and lead OMT. Staff efficiency increased significantly.

Results. A collective focus on improving site culture has produced operational excellence at OGE. It is a rewarding workplace for all employees. Countless programs and projects have been developed and implemented by the site team, programs and projects they own as leaders. One important result: No safety or environmental violations for four years running.

Another: The plant received the 2018 NAES President's Award, given to only one facility in a fleet of more than 170 plants nationwide. Among other accomplishments:

- OGE was certified as a Cal-OSHA VPP Star facility within one year of its initial application.
- Operationally, OGE recorded its best-ever contractual availability of 99.7% in 2019.
- It is approaching Year Two without any staff turnover, another site record.

Aside from OGE's awards and recognition, there are material financial impacts that have been realized by the culture change that's taken place at OGE over the past several years. The turnover costs associated with replacing technicians is valued at $35,000 per year.

Improved capacity revenues resulting from increased plant availability is valued at $120,000. Initiatives driven by better project leadership and cost sourcing has consistently produced over $110,000 annually in bottom-line cost savings.

Best-practice capex efforts and work processes have significantly reduced costs over $100,000 per year. Efficiency gains in work performance and shift coverage driven from reorganization has reduced labor costs by $30,000 annually. Eliminating permit violations has saved another $10,000. In sum, the improvements made at OGE have produced an annual benefit of more than $400,000.

Project participants:
Anthony Moretto, lead OMT
Al DeLuna, Erik Cherry, Gregg Stephens, and Paul Braemer, OMTs
Ramiro Garcia, compliance manager
John Hutson, plant manager

Infrared camera finds steam leak

Pinelawn Power LLC
Owned by J-Power USA
Operated by NAES Corp
80-MW, dual-fuel, 1 × 1 combined cycle located in West Babylon, NY
Plant manager: Kenneth Ford

Challenge was to find the location of a steam leak on insulated and covered high-pressure steam piping. The leak was a minor one and initially identified by condensed moisture dripping from a seam on the insulation covering. The site hoped to locate the leak without jeopardizing the safety of plant personnel and having to remove a large amount of insulation and associated covering.

Solution. The site deployed its infrared camera (initially purchased to aid in identification of electrical hotspots) to pinpoint the leak location. From a safe distance, the infrared camera was used to scan the surface temperature of the insulation

Pinelawn

(Fig 1) and quickly find the leak. Once the piping was cool, staff removed the insulation in the affected area to reveal the small weld defect responsible.

Results. Use of an infrared camera to locate the leak reduced the hazards to involved personnel and also helped reduce restoration costs by minimizing the amount of insulation requiring removal.

Project participants:
Mark Whitney, O&M manager

Utility cart ladder/ accessory rack fabrication, installation

Challenge. The site utility cart manufacturer did not offer an option for a ladder/accessory rack. Staff wanted to increase the utility of the cart by including provision for safe transport of ladders and other tools/equipment. Personnel had to ensure that any addition to the utility cart would not interfere with its tilting-bed feature or exceed the carrying capacity.

Solution. Site OMTs designed, fabricated, and installed a custom ladder rack out of aluminum square tubing. Aluminum was chosen for its superior corrosion resistance, low weight characteristic, and ease of construction.

Results. Addition of the ladder/accessory rack (Fig 2) has significantly improved the usefulness of the cart and simultaneously created a safer work environment for site personnel by decreasing the need for manual carrying of ladders, tools, and other equipment to work locations throughout the plant.

Project participants: Frank Pagano and John Stral, OMTs

Add storage rack to forklift

Challenge. Site personnel identified an unsafe work practice whereby the floor of the site forklift could potentially be used to transport tools, rigging, or other equipment, thereby obstructing free and clear access to forklift foot pedals and impeding operator entry/egress.

Solution. Plant technicians designed, fabricated, and installed a removable storage rack made of aluminum square tubing. The rack was designed to accommodate two portable tool totes. Aluminum was chosen for its superior corrosion resistance, low weight characteristic, and ease of construction.

Results. Addition of the storage rack to the forklift has improved its usefulness by converting previous "dead" space into new storage space and simultaneously creating a safer work environment for site personnel by decreasing the chances that staff would be tempted to use the floor of the forklift for transport of tools or equipment.

Project participants: Frank Pagano and John Stral, OMTs

1. Infrared camera finds steam leak at a distance, keeping personnel safe

2. Cart mod allows safe transport of ladders and other tools/equipment

3. Forklift mod makes "dead" space useful for transport of tools/equipment

Worthington

The benefits of upgrading package lighting to LED

Challenge. The S&S packages for Worthington's gas turbines have two lights that when working properly will illuminate the entire engine space. However, these incandescent lamps constantly fail and are extremely unreliable. Inevitably, technicians have to replace the compartment lights prior to completing their assignments.

This can be dangerous and extremely time-consuming, requiring fall protection given the locations of the bulbs and a LOTO to eliminate the shock hazard. The challenge presented to the safety committee was how to improve the longevity, dependability, and reliability of package lighting. Better lighting would greatly reduce the amount of time technicians spend donning fall protection and working under the lighting LOTO clearance.

Solution. The safety committee discussed several compartment lighting options and made the decision to install industrial LED bulbs. Staff purchased the bulbs and hired an electrician to inspect the wiring and selector switches. Plant technicians removed the old light bulbs from each of the compartment light fixtures and replaced them with the new LED bulbs.

Results. The LED lights are extremely reliable. Turbine compartment visibility has improved dramatically (photos). The selector switch on each side of the package is reliable. LED lamp longevity will both reduce the number of LOTOs needed to replace lamps and time spent in fall protection. Upgrading package lighting significantly decreased the amount of time needed to complete PM work in the package.

Project participants:
Matthew O'Hara, OMT
Jason Robertson, O&M/ICE tech
William Hooker, OMT

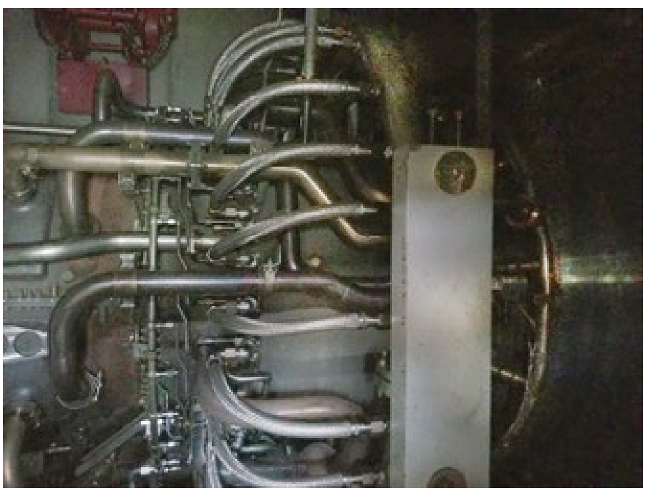
Worthington Generating Station

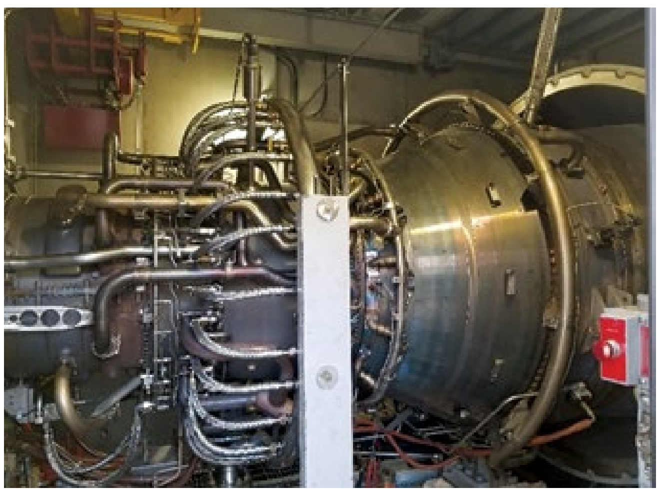
Owned by Hoosier Energy Rural Electric Co-op Inc

Operated by NAES Corp

174 MW, four simple-cycle LM6000 natural-gas-fired peaking units, located in Greene County, Ind, and connected to Hoosier's 138-kV transmission line

Plant manager: Robert VanDenburgh





Engine visibility improved dramatically going from incandescent (left) lamps to LED bulbs (right)

Nesharim

Nesharim Leading Energy
Owned by Clal Industries
Operated by Mashav Initiating and Development
120-MW, gas-fired, 2 × 1 combined cycle located in Ramla, Israel
Plant manager: Kobi Ivenshitz

Insulating filter house roof conserves energy

Challenge. Nesharim's filter house is installed over its gas turbines and doubles as a roof for the units. The upper portion of the sheet-metal structure is exposed to the sun's radiation. An electric chiller is used to cool turbine inlet air to 46F the entire year. In summer, solar radiation heats up the filter house to more than 130F, resulting in a loss of cooling energy and a loss of power produced by the turbines.

Solution. A nano-ceramic insulation—in effect, a 0.2-in.-thick coating of "paint"—was applied as a fine layer on top of the cooling area, on the entire upper surface and side walls. By insulating surfaces exposed to the sun's radiation, less energy is required for cooling inlet air, and air that has been cooled is not reheated by the sun. This fix has increased power generation and reduced parasitic power consumption. Thus turbine efficiency has increased.

Results:
- When comparing the chillers under identical ambient temperature/humidity conditions before and after the insulation was applied, there is a saving of about 60 kW per hour in chiller energy consumption, and a decrease in the inlet air temperature at the turbine entrance of about 3.6 deg F.
- The chiller's ability to reduce air inlet temperature is improved and its response time to changes in ambient humidity and temperature is faster.
- The insulation provides an additional layer of protection from corrosion and water penetration into the filter housing.

Project participant: Kobi Ivenshitz, plant manager

Reducing offline water-wash time for gas turbines

Challenge. Compressors are water-washed monthly as part of the plant's gas-turbine maintenance program and to maintain maximum output. During the offline wash there is a loss in production time of about eight hours, reducing turbine availability by about 1%. The water-wash process involves eight washes of water together with detergent. During the first two wash cycles, the fluid is heated to about 165F. The plant was commissioned with only one wash-water tank, so it took time to warm the water for the second hot wash.

Solution. Plant duplicated the original wash-water tank and added the second tank in series with the first (photo). With this improvement, heating is carried out in the two tanks simultaneously, thereby saving a few hours. In addition, the OEM's software was modified to shorten ineffective processes, which saved more time.

Results. This improvement has reduced the offline water-wash time by about half, allowing a faster return to production. The second tank heats the water for the second cycle before and during the first cycle, enabling the second rinse cycle to begin just a few minutes after the first rinse ends. Previously there was a waiting period of two and a half hours. The benefits:
- Rinse time reduced from eight hours to four (breaker to breaker).
- Turbine availability increased by 36 hours annually.

Project participant: Kobi Ivenshitz, plant manager

The wash-water heating tank added increases turbine availability by 36 hours annually

Nevada Cogeneration Associates No. 1

Owned by Northern Star Generation Services

Operated by CAMS

90-MW, gas-fired, 3 × 1 LM2500-powered combined-cycle cogeneration facility located in Las Vegas, Nev

Plant manager: Howard Forepaugh

Turbine-inlet evaporative cooler control

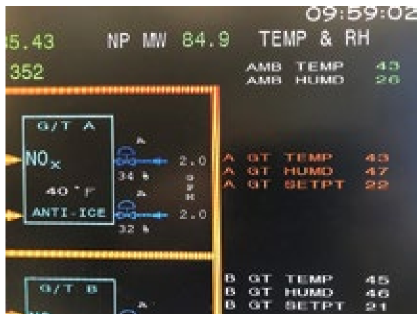
Challenge. Nevada Cogen's gas-turbine packages use an evaporative system to cool engine inlet air. There are two levels of inlet air flow. The original configuration used 1-in. manual gate valves and a roto flowmeter, one for the lower level and one for the upper level of each turbine.

When the inlet temperature required adjustment, the control room operator would direct his outside operator to do that. If that person was tied up with a delivery or another task, then the adjustment would wait until the operator was finished. Thus, the turbines could not run at maximum efficiency all the time.

Solution. Install Mag flowmeters and characterized ball valves (photo left) with electropneumatic positioners. Wire the flowmeters and valve controls into the DCS, giving the CRO the ability to monitor flow (photo, right) and make adjustments remotely.

Results. The new system has worked extremely well, and the outside operator is free to concentrate on other responsibilities.

Project participants:
Shawn Malcolm, O&M manager
Justin Robbins, I&E technician



Upgraded fluid-system components wired into the DCS give CRO the ability to make flow adjustments remotely

Lightning warning system helps protect personnel

Challenge.. Florida receives approximately 1.2 million lightning strikes annually and leads the nation in lightning-related deaths. Outside work can be extremely hazardous, and potentially deadly, during a thunderstorm. For this reason, no outside

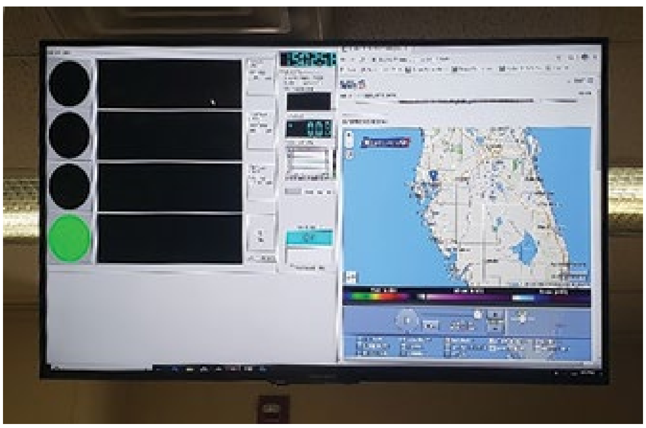
Orange Cogeneration

Owned by Northern Star Generation

Operated by Consolidated Asset Management Services LLC

104 MW, gas-fired 2 × 1 combined-cycle cogeneration plant powered by DLN-equipped LM6000 engines, located in Bartow, Fla. Condensing, extraction steam turbine is rated 25 MW. Steam is sold to producers of orange juice and ethanol

Plant manager: Allen Czerkiewicz



Lightning detector (left) triggers warning light (right) when danger is imminent

work is permitted at Orange Cogen when lightning is detected within 10 miles of the facility.

The existing lightning detection system at the plant feeds a display in the control room that flashes red and notifies the operator when lightning is detected within 10 miles of the facility. System includes a 30-min countdown timer that resets each time more lightning is detected. When lightning is detected, the control room operator announces same to all plant personnel via the intercom and plant PA system. The operator informs personnel of the danger and reminds personnel to seek shelter and stop outside work until the all-clear is given.

Personnel (contractors, vendors, delivery personnel) who entered the facility after the warning announcements were made had no way of knowing that the plant was under a lightning warning and would expose themselves to great risk.

Solution. A large flashing blue strobe light was purchased and installed at a very conspicuous location that anyone entering the facility would not be able to miss. A connection on the lightning detector module (photo, left) is used to transmit a signal to the blue light, causing it to activate (photo, right).

Results. Since installation in September 2019, the system has performed flawlessly. Any individual entering the facility now has an obvious warning to alert them of any potential lightning dangers, making the plant safer for everyone onsite.

Project participants:

Ken Judd, materials coordinator
Charles Chancey, I&E technician
Kristen Albritton, EHS manager

Webinars, virtual conferences help users identify, implement plant-betterment solutions

If the coronavirus pandemic has taught us one thing, having the ability to access the expert information needed to perform O&M tasks at the highest level without leaving the plant (or home) is vital. With good internet connections generally available at most powerplants, the challenge might be finding the information required. You likely have several preferred websites to search, ones that may have helped you in the past.

If CCJ is not one of them consider adding it to your "preferred websites" list. Our online library, keyword searchable on the homepage at www.ccj-online.com, can direct you to perhaps unimagined resources on the operation and maintenance of gas turbines and combined cycles. Included among these resources is our webinar library.

At home you might access a service such as Netflix for leisure viewing; at work search CCJ's webinar library for guidance on how to identify and implement critical O&M solutions capable of helping you and your colleagues improve plant safety, availability, and performance.

To learn more about the library and its value for your facility, please skim the content summaries below of webinars conducted in the last few months and watch one or two. (Access at https://ccj-online.com/onscreen.) No charge! Note that several more online conferences and webinars are scheduled before year-end—including the 2020 meetings of the 7EA, Steam Turbine, Generator, Combined Cycle, and Power Plant Control Users Groups.

CONCO. Practical application of tracer-gas leak detection and cleaning methods for air-cooled condensers, *Gary Fischer, national sales manager, Conco Services Corp.*

Every owner/operator of a plant with an air-cooled condenser (ACC) might benefit from listening to Gary Fischer on the value of an ongoing condition-assessment program and how the experts find performance-robbing leaks quickly. His presentation is fast-moving, easy for both new and experienced employees to understand, and answers the question, "Why do we *not* want to try doing this with plant personnel?"

Fischer begins with several slides on the importance of cleanliness, the sources of fouling, and how to remove external deposits (Fig 1). The free flow of air across all heat-transfer surfaces is critical, the chairman of the ASME Heat Transfer Committee reminds. A 20% reduction in air flow because of fouling and debris nestled in an ACC's finned tubes will increase turbine backpressure by 33%, decreasing electrical output and reducing revenue.

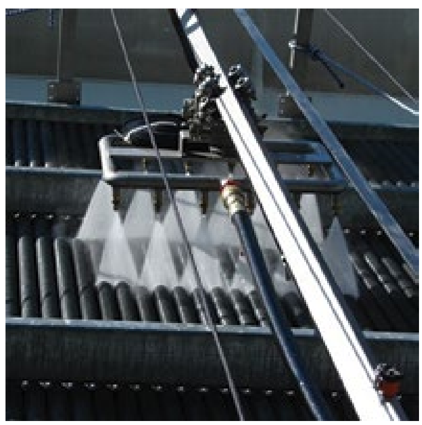
Pushing fans to their maximum to reduce the impact of fouling is not a solution. It only exacerbates the negative impact on financials because auxiliary load increases and you wind up consuming more power at a time when you're making less money.

Fischer dismisses the use of fire hoses (too much water, minimal cleaning effect) and high-pressure hand lances (damage to fins and galvanized surfaces) in short order and touts the value of automated cleaning (tight process control, uniform cleaning, no need for scaffolding).

Automated online cleaning systems, such as that shown in Fig 2, have the advantage of delivering a high volume of water at a pressure that will not damage fin and tube surfaces; plus no scaffolding is required. A focused array of water jets mounted on a trolley distributes water deep into the bundle with the opportunity to adjust the jets to optimize the washing effect. The typical carriage holds a nominal one-dozen jets and travels at constant speed across the tubes, assuring effective cleaning in one or two passes.

Testing for and minimizing air in-leakage was the focus of the second part of Fischer's presentation. For identifying the source of air in-leakage, he says non-hazardous helium wins hands-down. Detection is quick and reliable for most leaks at 1 part in 10 million above background (5 ppm). Perspective: Sometimes you're looking for a leak less than the size of a dime in a surface area equivalent to three or four football fields. Helium can help you find that.

1. Extreme fouling at left can be created by pollen, dust, leaves, insects, plastic bags, bird carcasses, etc, picked up by fans, entrained in the air stream and forced through the tightly spaced finned-tube bundles. Progress in removing deposits is shown in the center, wash cycle is complete at right



2. Automated online cleaning system with a typical 12-jet carriage at constant speed

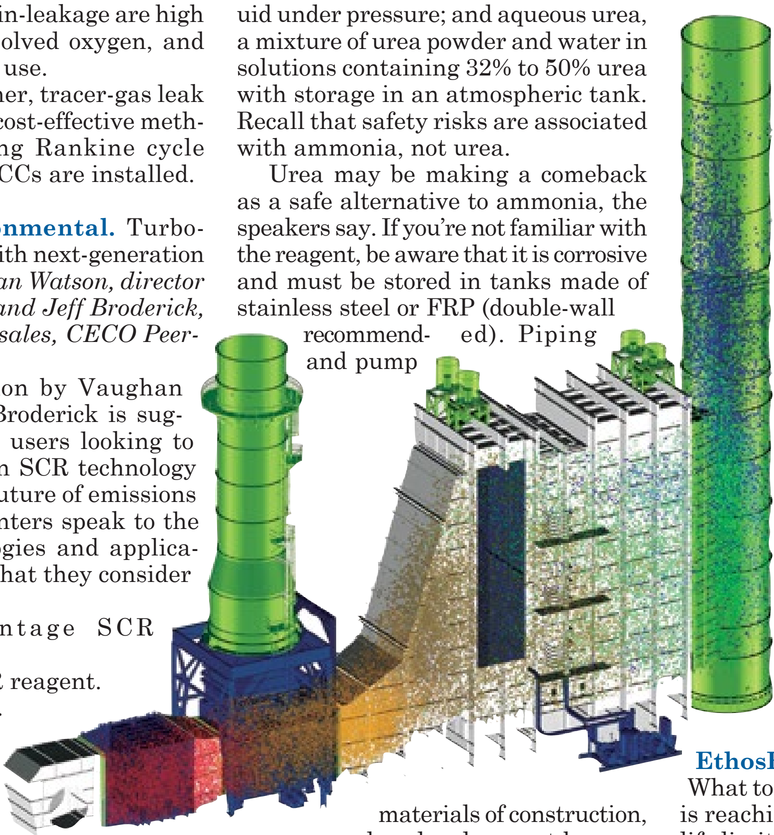
Oftentimes leaks are not where an inexperienced person might believe they are. A leak can be outside the ACC proper and in the hogger or hogger exhaust, the gland-seal drain/trap, the crossover bellows, or at welds in retrofit projects, etc. Don't be surprised to find an air leak in a new unit, Fischer adds. Indicators of in-leakage are high backpressure, dissolved oxygen, and continuous hogger use.

Concludes Fischer, tracer-gas leak detection is a very cost-effective method for maintaining Rankine cycle efficiency where ACCs are installed.

CECO Environmental. Turbocharge your SCR with next-generation technology, *Vaughan Watson, director of power retrofits, and Jeff Broderick, director of retrofit sales, CECO Peerless.*

The presentation by Vaughan Watson and Jeff Broderick is suggested viewing by users looking to come up to date on SCR technology and peer into the future of emissions control. The presenters speak to the following technologies and applications from CECO that they consider "next generation":

- Rapid Advantage SCR (RASCR™).
- Urea as an SCR reagent.
- Direct injection.
- EDGE® ammonia injection grid (AIG).



RASCR, Watson and Broderick say, can be adapted easily to an existing plant to maximize SCR performance. It uses fuel as the heat source for reagent vaporization, rather than an electric heater, thereby promoting rapid compliance with permitted NO_x emissions during unit starts and transients. Emissions compliance reportedly is achieved within 30 minutes of a gas-turbine start, typically in less than 15 minutes. Natural gas or oil can be used as the heat source for all reagent solutions, including urea.

Retrofits can be installed during a short outage. RASCR integrates with the existing ammonia vapor discharge line and the fuel supply system. Today's low natural-gas prices typically offer an ROI in six months or less based on the reduction in parasitic power consumption.

Webinar attendees provided these facts related to NO_x control at their facilities:

- Seventy percent of the participants said their plants have duct burners upstream of the SCR.
- The heat source for ammonia vaporization was electric 59% of the time, gas 28%.
- Fourteen of the plants polled were using RASCR technology, including five on HRSGs.

Reagent options for SCR systems are anhydrous ammonia, 99.95% pure NH_3 stored as a liquid under pressure; aqueous ammonia, typically 19% to 29% NH_3 by weight and stored as a liquid under pressure; and aqueous urea, a mixture of urea powder and water in solutions containing 32% to 50% urea with storage in an atmospheric tank. Recall that safety risks are associated with ammonia, not urea.

Urea may be making a comeback as a safe alternative to ammonia, the speakers say. If you're not familiar with the reagent, be aware that it is corrosive and must be stored in tanks made of stainless steel or FRP (double-wall recommended). Piping and pump materials of construction, and seals, also must be compatible with the fluid.

Plants using anhydrous or aqueous ammonia as the reagent for their SCRs can be made more safe by converting to urea. In the case of anhydrous ammonia, the conversion to aqueous ammonia or urea requires addition of a fluid handling skid and vaporizer system. A new storage tank also may be required depending on its condition, capacity, etc. Going from aqueous ammonia to urea will require a stainless steel or FRP tank and possibly changes to the fluid handling system regarding materials compatibility. Plus, vaporizer capacity probably will have to be increased as urea decomposition requires more energy than ammonia vaporization.

Direct injection is a method for supplying ammonia vapor to the SCR system gas path without need for a vaporization system or AIG. Its advantages include lower capital and operating costs, primarily because there's less equipment. Photos, case history, and data tables presented by the speakers make listening to the presentation beneficial.

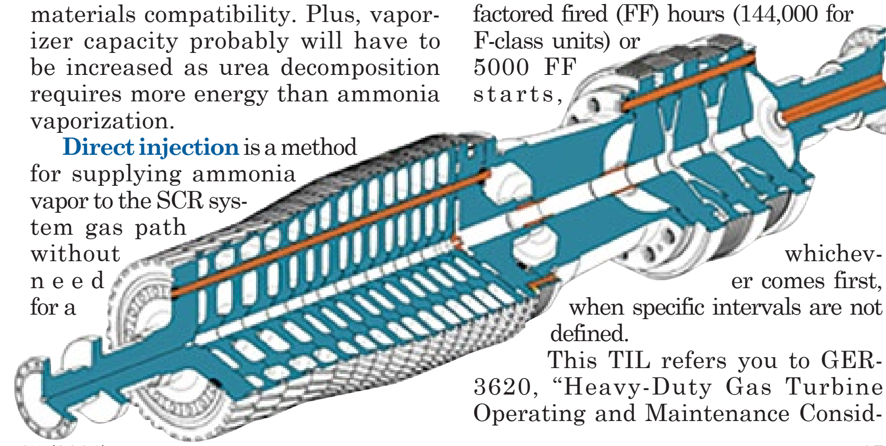
EDGE. Participants learned that CECO's new AIG lance with a square (instead of circular) profile is designed and optimized to provide the desired reagent distribution across the duct to assure expected SCR efficiency and performance. The square cross section promotes better mixing, thereby improving NO_x reduction, reducing ammonia slip, promoting longer catalyst life, and reducing the cost of operation. The likelihood of AIG fouling and plugging also is reduced because EDGE provides a place for deposits to accumulate without plugging the nozzles.

Explanatory drawings, lab flow-test results illustrating the degree of mixing achieved, and a case history provided in the presentation attest to the product's success in the field.

EthosEnergy. You can run longer: What to do when your GE gas turbine is reaching the designed rotor end-of-life limit, *Kale Dreymala, gas-turbine rotor project manager, EthosEnergy Group.*

If your plant is equipped with a GE industrial gas turbine—Frame 3, 5, 6, 7 (A, B, C, E, EA, and/or F)—and mention of the OEM's Technical Information Letter 1576, "Gas Turbine Rotor Inspections," does not strike a responsive chord, obtain a copy today from your plant's GE representative.

TIL-1576, released in 2007 and updated in 2011 (1576-R1), identifies the equipment and personnel risks associated with operating gas-turbine rotors beyond 200,000 factored fired (FF) hours (144,000 for F-class units) or 5000 FF starts, whichever comes first, when specific intervals are not defined.



This TIL refers you to GER-3620, "Heavy-Duty Gas Turbine Operating and Maintenance Considerations," for overall guidance on centerline maintenance recommended by the OEM. The latest version of 3620 is Rev N, issued in November 2017. You can obtain a copy with a simple Google search. Rev N is important because it considers the impact of forced cooling on rotor inspection calculations (pages 30 to 35 and Fig 45), replacing the "trip from load factor" in earlier versions of the document.

Kale Dreymala walked webinar participants through the inspection scope recommended by EthosEnergy Group (EEG) for turbine wheels, distance piece/spacers/stub shaft, and compressor wheels. Here's the lineup of inspections typically recommended:

Compressor and turbine wheels

- Visual inspection of all surfaces.
- Semi-automated phased-array ultrasonic (UT) inspection of the bore, web, and rim areas.
- Semi-automated eddy current (ET) inspection of the through-bolt holes.
- 100% ET inspection of the dovetail serrations in the compressor wheels and the fir-tree serrations in the turbine wheels.

Distance piece, spacers, stub shaft

- Visual inspection of all surfaces.
- Semi-automated ET inspection of the through-bolt holes.
- Semi-automated phased-array UT of the bore.

Other inspections

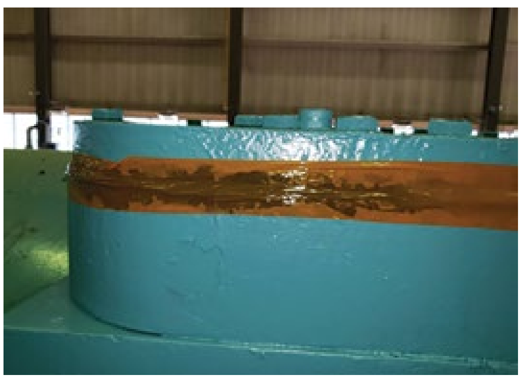
- Hardness.
- Replication.
- Dimensional measurements.

If these inspections produce no findings, the rotor is reassembled with new bolts and your engine receives a certification for an additional 50,000 FFH (one time only).

If there are findings, the speaker says the OEM is likely to suggest buying a new rotor or possibly a replacement wheel or disc, if that is the life-limiting part.

By contrast, an affordable aftermarket solution suggested by EEG probably would be to obtain a used rotor with a documented history and refurbish it in the shop. The additional life certified (from 50,000 to 200,000 FFH) depends on an engineering review. Note that for peaking units, no extensions are allowed beyond the 5000-starts limit.

Dreymala goes on to describe EEG's capability for manufacture and qualification of new rotor components as



Tape changes color (beige to black) when exposed to hydrogen. At the left is a leak at the flange for a hydrogen cooler found after a maintenance turn when hydrogen was reintroduced to the generator; at the right, the leak is at a flange in the hydrogen system might be required during the refurbishment process get the best balance between cost and additional life. Other rotor options also were presented during the webinar, which was not recorded for post-presentation viewing. However, you can write the speaker with questions and/or for a copy of his presentation at kale.dreymala@ethosenergygroup.com.

Nitto. Hydrogen leak-detection tape—a safety best practice, *Dr Nahid Mohajeri, GM advanced polymer technology, Nitto Inc.*

Depending on the type of generator cooling at your plant, and the gas-turbine fuel, a fool-proof hydrogen leak-detection program can be critical to protecting employees, the environment, critical equipment, and the overall business. This presentation presents details, data, and results of field trials of a pipe flange tape, developed for NASA, that changes color in the presence of hydrogen (photos). Thus, it provides a visual indication of a leak because it will not return to its original color once hydrogen gas flow stops.

The presentation shows that soap tests typically used to find hydrogen leaks may not deliver consistent results and provide the confidence that connections/joints are not leaking. In field trials at one utility, 38 flanges were taped. All had been soap-checked prior to using the tape. Once installed, the tape on four flanges changed color within two days. The tape was removed from the flanges and the joints were soap-checked again. Only one of the leaks was large enough to cause bubbling visible to the eye.

Plant personnel concluded that the hydrogen-detection tape worked well as a pre-emptive safety check and has stimulated proactive thinking about previously unrecognized problems. Use of the tape is now part of the plant's hydrogen-system restoration procedure following generator maintenance.

TRS Services. Gas-turbine repair planning: Create value every time, *Greg McAuley, PE, chief technology officer, and Pete Sobieski, operations advisor and board member, TRS Services LLC*

If you're involved in gas-turbine repair planning, the editors suggest you listen to the presentation by Greg McAuley and Pete Sobieski, both highly experienced in the planning and conduct of turbine repairs. Each spent a decade or more with a gas-turbine OEM and two or more decades with a major owner/operator before getting back together again at TRS and expanding the company's mission.

Today, TRS offers turbine component repairs, new-parts manufacture, and consulting services aimed at reducing downtime, minimizing total costs, and enabling new opportunities. The outcomes expected from the company's work: reduced downtime, fewer unexpected errors, lower costs, and less hassle.

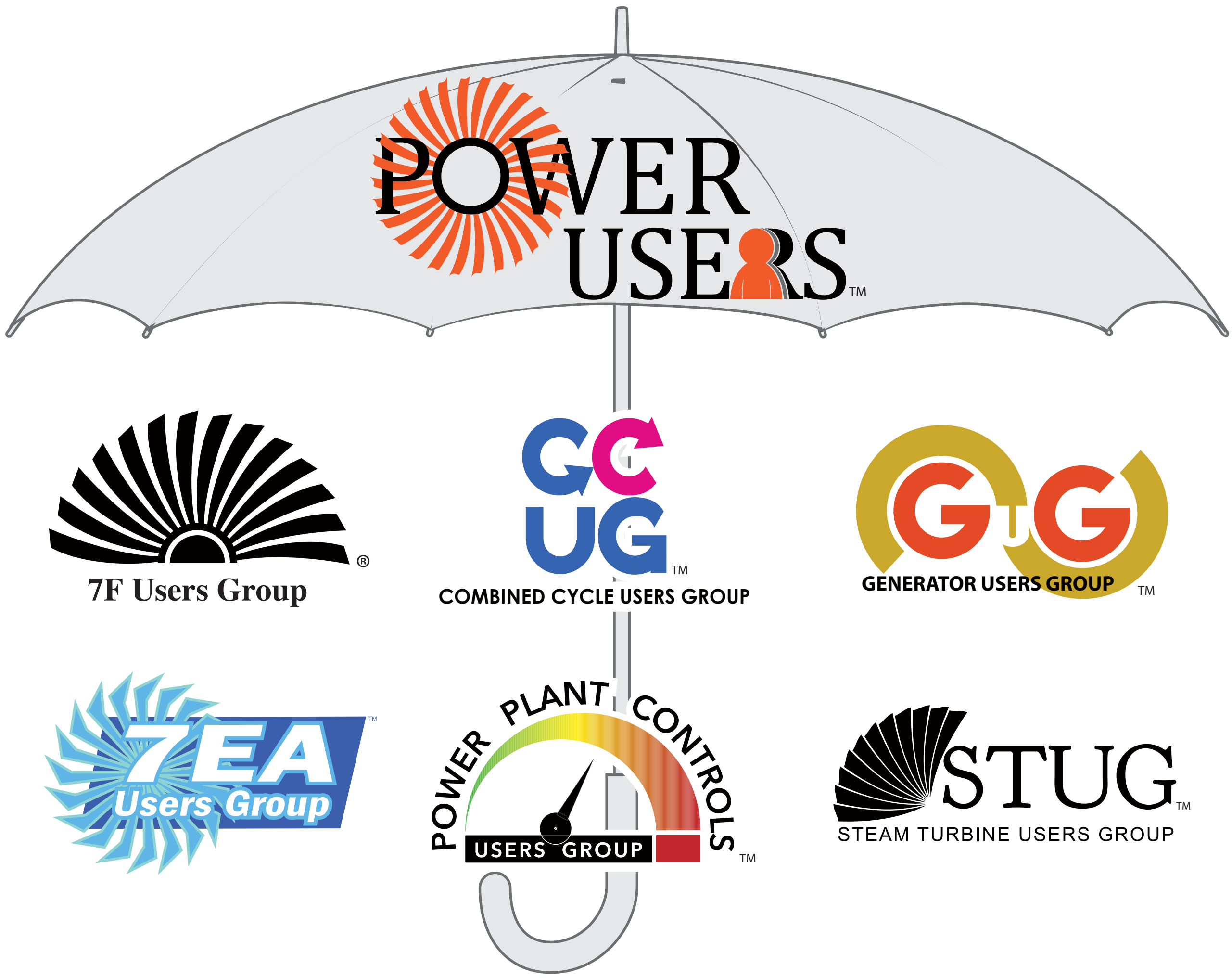
The presenters define repair planning as the process of defining the tasks important to know with a high degree of certainty what components should be retired or repaired, and to achieve the lowest lifecycle cost for parts that should and must be repaired.

McAuley and Sobieski say the five essential ingredients to successful repair planning are the following:

- Focus on lifecycle costs.
- Know parts pedigrees.
- Have a fallout plan.
- Choose the right partners.
- Start execution early.

They discussed each of these in turn. For lifecycle cost analysis, the speakers provide calculational examples for repairs to transition pieces and R1 ring segments, with service hours a primary variable. The results might startle you; certainly, they illustrate why this is a very important step in project cost control.

Power Users is the umbrella organization for managing and coordinating the technical programs for the industry's leading User groups



Conferences

- **Each year in May:**
  - 7F Users Group annual conference

- **Each year in August:**
  Four separate conferences… four different agendas
  Same dates, same location, shared meals and shared vendor fair
  - Combined Cycle Users Group
  - Generator Users Group
  - Steam Turbine Users Group
  - Power Plant Controls Symposium

- **Each year in September/October:**
  - 7EA Users Group annual conference

Forums

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

Power Users Group is a non-profit company managed by Users for Users. It is designed to help Users share information and get solutions to power-production problems.

www.PowerUsers.org

Know your parts illustrates the level of expertise necessary for an accurate evaluation of in-service components. Prior to making a repair decision the speakers say you should know lifecycle costs, hours/starts since last repair, visual appearance, repair history, the OEM's part expectations, industry experience with a similar part. Of course, your personal experience with the repair of a similar part also is important to the evaluation.

A helpful takeaway tool is the partner evaluation process which offers a price/value comparison across the partner options entered into the equation. A discussion on contingency planning and an action plan to mitigate fallout risk.

EthosEnergy. Improve availability *and* reduce costs? Your data knows how. . ., *Brady Kirkwood, technical services manager for EthosEnergy Group's monitoring and diagnostics department.*

Brady Kirkwood covered short-term (performance analytics) and long-term (advanced predictive AI) methods of how to identify degraded systems and provide quantifiable potential performance gains. Having the tools to evaluate the cost versus benefit of individual system upgrades/repairs to plant systems is critical to improving performance with today's limited maintenance budgets.

The speaker provides profiles of real events resolved by EEG, including these:

- Hidden problem with inlet fogging causing a reduction in plant output.
- An OEM "repaired" bearing oil leak causing compressor fouling.
- Slow degradation in turbine performance during a period of high demand.
- Forced outages caused by lean blowouts.
- Fouling of inlet filters caused by the increased particulate loading attributed to forest fires.

Two goals of the presentation are to identify hidden issues and predict future issues, thereby reducing reactive activities that result in unbudgeted costs. Kirkwood walks you through a plan for reducing reactive maintenance, how to conduct a thermal performance audit to identify underperforming systems, short-term versus long-term solutions, and the financial impacts of unplanned outages and lost generation.

Unfortunately, this presentation was not recorded for post-presentation viewing. However, you can write the speaker for a copy of his presentation at brady.kirkwood@ethosenergygroup.com.

EthosEnergy. Decrease cost and simplify outage planning with zero-lead-time components, *John Jensen, VP new-product commercialization, EthosEnergy Group.*

John Jensen covers the range of flexible EEG solutions geared towards improving the accuracy of your gas-turbine outage plan and reducing the risk inherent in traditional component repair services. Presentation takeaways include the following:

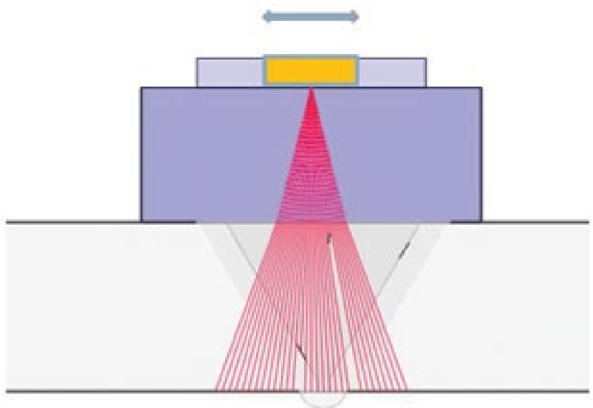
- Understand the obstacles to improving outage planning.
- How to remove component repairs from outage planning.
- EEG's commitment to supporting customers with outage planning and emergency situations.

Jensen says EEG has the depth to effectively and efficiently manage risks in repairs, parts manufacturing, rotor life extension, multi-year maintenance contracts, and plant operations and maintenance. Its capital-parts exchange capabilities eliminate lead-time risk and scope creep of traditional repairs. Repair fallout risk is mitigated by accommodating it outside the plant's schedule.

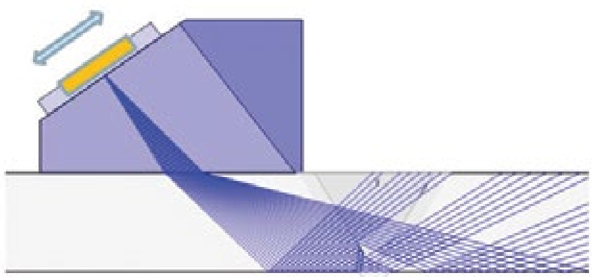
This presentation was not recorded for post-presentation viewing. Owner/operators can request a copy of the PowerPoint from john.jensen@ethosenergygroup.com. CCJ

Glimpse advances in materials, welding for new plants, inspection technologies for those in service

By Steven C Stultz, Consulting Editor



1. Beam-steering phased array allows inspection of an entire weld from one fixed position



In what was a truly international gathering of scientists and power-industry engineers, European Technology Development Limited (ETD) orchestrated and conducted a virtual conference on high-temperature plant materials, inspection, monitoring, and assessment (MIMA), October 27-28, 2020, drawing attendees from 22 countries.

Dr Ahmed Shibli, managing director of ETD Consulting, Leatherhead, England, said that “Although in the past ETD has organized many conferences and training courses throughout the world, this is a unique experience for us.

“Due to Covid-19, such exchange has become prohibitive during 2020 resulting in cancellations of many international conferences, thus limiting access to and exchange of knowledge, data, and discussions on many new and exciting developments.

“This conference is meant for materials and systems developers, plant designers, fabricators, owner/operators, and service providers, as well as researchers and inspection companies,” he continued.

MIMA 2020 was arranged in these six sessions:

1. Materials, including MarBN steels for high-temperature applications.
2. Inspection.
3. Cracking/failures of plant materials, plus operating flexibility and efficiency.
4. Weldments and monitoring.
5. Materials degradation, damage, and life assessment.
6. Risk-based inspection (RBI), reliability-centered maintenance (RCM), and stress analysis.
7. Prerecorded presentations (not discussed live) on risk-based monitoring (RBM), cracking, and modeling.

As you read through the conference highlights below and have questions, or want to dig deeper into the details, contact Shibli and his team of experts directly at enquiries@etd-consulting.com.

MarBN in the UK, Japan, Germany, Austria

Shibli opened the meeting thusly: “I would like to especially thank my Japanese colleagues who persuaded ETD to organize this conference. They said no high-temperature plant or materials event has taken place this year in Japan and perhaps ETD could bring together an international community working in this area.”

Session 1 was, therefore, dedicated to ongoing development work with MarBN steels, which are gaining traction in Japan and Europe. At the beginning of 2020, the UK government and industry began a three-year study of these materials, in a project named “Implant,” with coordination by ETD. The general goal is to develop higher-efficiency, less polluting powerplants for the future.

MarBN, a 9Cr martensitic steel with the addition of boron and nitrogen, relies on an extremely sensitive heat-treatment process (https://www.ccj-online.com/factor-european-experience-into-om-practices-at-us-combined-cycles-part-i/).

The following six presentations focused on MarBN-related material:

- Alloy design of MarBN for boiler and turbine applications at 650C/1200F (National Institute of Materials Science, Japan).
- Development of UK MarBN steel IBN1 for advanced powerplant applications (ETD, UK).
- Casting, welding, and forging of MarBN components (Voestalpine Bohler Welding, et al, Austria and Germany).
- Manufacture of large MarBN steel component castings (Goodwin Group, UK).
- Development of the matching filler metal for creep-resistant MarBN (Lincoln Electric Europe).
- Intergranular rupture of the heat-affected zone (HAZ) of welds after short-term creep rupture (Loughborough University, UK).

Below are selected highlights from the conference as they apply to today’s combined-cycle powerplants.

Materials and inspection

Session 2 compiled recent information on material inspection methods, focusing on innovative techniques.

Ignacio Marcelles, Tecnatom SA, Spain, presented an overview of inspection engineering and life assessment with both web-direct and offline access, combined with business-intelligence tools. His premise: both speed and capability of computers will increase progressively, and prices will continue to fall (Moore's Law).

Marcelles covered inspection and analysis tools including drones, and remote-operation vehicles and crawlers for buried pipelines and small pipes, as well as tank floors, walls, and ceilings. These included devices for both manual and automated data capture. New software for integrated and 3-D results focused on structural members, valves, and transformers.

Long-term inspection solutions such as these will become more widespread both during and after the pandemic as only the system operators need to be on location. Monitoring and analysis are currently remote and could remain so.

Although security concerns remain with data transmitted away from the plant, benefits are reduced cost, quality of data and analysis, and centralized plant comparison capabilities.

Phased array. John Trelawny, team leader at Uniper Technologies (formerly E.ON) in the UK, discussed an ultrasonic phased-array total focusing method (TFM) for inspection, suggesting that this could perhaps be a solution for the future. "Accuracy of flaw sizing is paramount," he stressed.

Trelawny offered an example of beam-steering phased array, which uses a probe with multiple elements, each receiving all signals. This technology, tested in both mockup and real-time onsite, allows for angular inspection. The entire weld can be inspected from one fixed position (Fig 1).

He explained TFM in three modes (2T, 3T, and 4T). TFM clarity exceeded that of standard beam steering. Lack of such clarity can cause confusion, he explained.

The presentation showed detailed comparisons of angled phased array versus offset total focusing, among others. Visuals included mockups with testing methods and options, followed by site testing experience and validation.

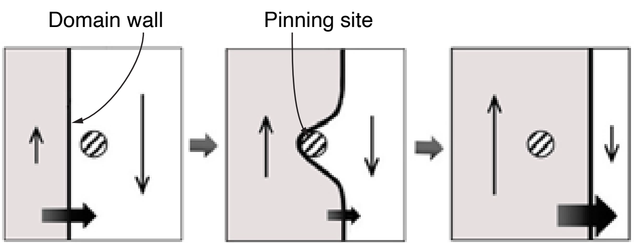
Some conclusions:

1. TFM is an advancement in ultrasonic technology.
2. For simple butt welds, TFM is superior to current techniques.
3. For complex geometries, TFM can be an advantage, but not in every situation.

Trelawny estimates that phased array is currently used in about 20% of applicable investigations; the remainder, conventional UT. Phased array/TFM is also a very repeatable technique.

Electromagnetic (EM) sensor techniques for creep cavity damage detection and assessment were offered by the Univ of Manchester, ETD, and Nippon Steel Technology Corp, Japan.

Ferromagnetic materials are comprised of polarized magnetic domains which grow and shrink with the application of an external magnetic field. Microstructural changes are based on so-called *pinning* of these walls by features such as cavities, inclusions, and dislocations. Magnetic properties reveal the microstructural properties (Fig 2).



2. Sensitivity of magnetic measurements to microstructural changes are based on pinning of magnetic domain walls by features such as cavities, inclusions, etc

Univ of Manchester's John Wilson explained the use of EM on aberrant, mis-heat-treated materials for testing—specifically Grade 91 components. The work was initially developed through the testing of cylindrical samples machined from P91 pipes. He presented the results of BH loops and Magnetic Barkhausen Noise (MBN) on some of the laboratory samples and the tests on in-service pipes, as well as the test-equipment configurations.

Background: A BH loop measures the hysteresis loop flux density (B) versus field intensity (H) of a thin magnetic film sample by applying a field to the sample and measuring the magnetic field produced by the sample's magnetization. The Barkhausen effect is a name given to the noise in the magnetic output of a ferromagnet when the magnetizing forced applied to it is changed.

A planned follow-up of this work will be an ETD Group Sponsored Project, "Early-Stage Damage Inspection, Repair, and Life Extension of Aberrant P91 Components" (http://www.etd-consulting.com/active-gsps-blog/2017/4/13/launch-of-a-new-group-sponsored-project-on-aberrant-p91-inspection-repair-and-life-extension).

The goal is improved microstructural investigation.

Challenges to industrial deployment, Wilson explained, include:

- Irregular surface geometry (tee pieces, etc) in onsite components (problematic for contact techniques).
- Some difficulty in sourcing post-service samples with varying levels of creep.
- Identifying further the effects of surface conditioning (grinding, decarb layer).

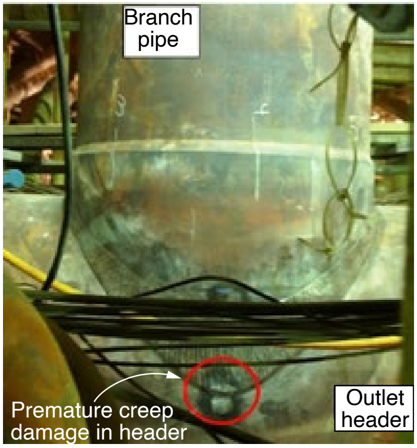
Correlations have been established between material (creep, aberrance) and magnetic properties for Grade 91 steel using laboratory measurement systems, but further work is needed on field-deployable devices. Ultimately, this application should support, and later replace, the traditional replication and reduce both testing costs and schedule impact because, unlike replication, it does not require surface preparation. Furthermore, EM can detect damage a few millimeters below the surface which is a distinct advantage over replication.

TesTex. Frank Neil of TesTex, Pittsburgh, Pa, presented three novel techniques: low-frequency electromagnetic to inspect HRSG finned tubes from the outside, the innovative *Claw* to inspect tube-to-header welds with a balanced-field electromagnetic technique, and a remote-field electromagnetic to inspect HRSG tubes from the inside. All search for corrosion cells and cracks in materials (https://www.ccj-online.com/heat-recovery-steam-generators-new-tools-for-locating-pitting-wall-loss-corrosion-cracking-in-headers-tubes-welds/).

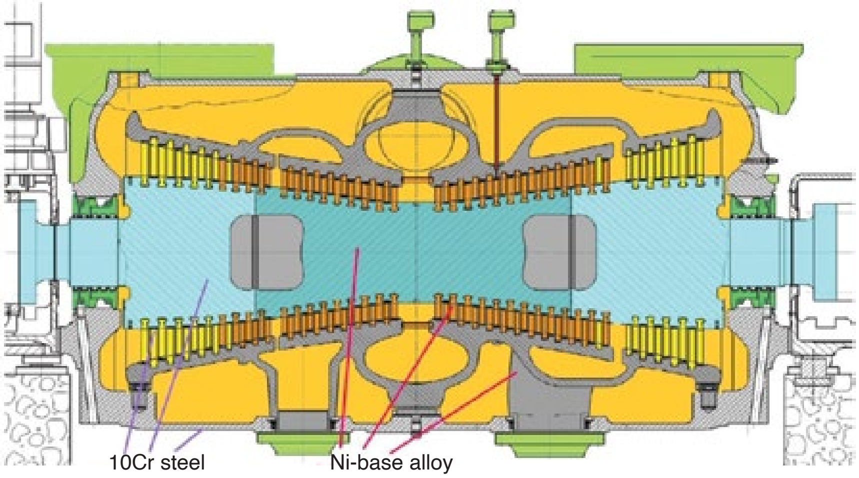
In cooperation with EPRI, various new methods are being applied in challenging areas of the combined-cycle powerplant. TesTex methods are used for condenser-tube and auxiliary-boiler inspections, thickness testing on tubing and piping, deaerator heater and storage tank examinations, assessing corrosion under insulation, and a growing number of inspections for balance-of-plant heat exchangers.

Results of specific dry inspection methods, he stated, are competitive with radiography, at reduced cost, improved personnel safety, and less schedule impact.

Life assessment. Dr David Robertson, lead metallurgist at ETD, addressed life-assessment tools and root-cause failure analysis for boiler/



3. Premature Type IV creep damage, as found on a P91 reheater outlet header



4. Example of Ni-alloy/10Cr steel DMW in a supercritical turbine

HRSG components, highlighting recent experience at various world locations.

For remaining-life assessments, ETD uses an organized, staged approach. Initial inspection-based assessments combine many techniques, often teamed with international NDE partners.

Robertson explained some of the newer techniques, including low-frequency electromagnetic methods for waterwall tubes (see TesTex above) and pulsed eddy current for feedwater piping.

His specific examples included pulsed eddy current as a screening tool to identify corrosion under insulation (CUI) and flow-accelerated corrosion (FAC) without removing insulation; borescopes for tubes and bends that are difficult to inspect from the outside; and metallurgical assessment of P91 branch connections (reheater outlet headers, for example).

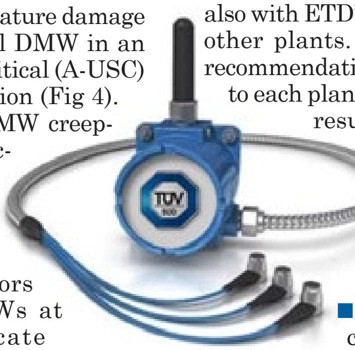
In one example, premature Type IV creep damage was found on a P91 reheater outlet header. At this position, orientation of the HAZ at the flank position of the branch weld is perpendicular to the hoop stress on the header side of the joint. This led to higher risk of Type IV creep damage (Fig 3), similar to that found on longitudinal seam-welded pipe. This was fully analyzed and the client advised to grind out the cavitated area after which the component would be fit for service for another few years.

During the RCA, Robertson reviewed typical scope of work, highlighting a vertical-path HRSG and specifically thermal-mechanical fatigue cracking at tube-to-header welds.

DMWs. Stuart Holdsworth, Swiss Federal Laboratories for Materials Science and Technology (EMPA), reviewed microstructural damage development adjacent to fusion lines of dissimilar metal welds (DMWs). He began with high-temperature damage of a Ni-alloy/10Cr steel DMW in an advanced ultra-supercritical (A-USC) steam turbine application (Fig 4).

He followed with DMW creep-rupture strength reduction and cycle/hold creep fatigue; some concluding observations:

1. Creep-rupture weld strength factors for A617/1Cr DMWs at 550C/1020F indicate that fusion-line cracking becomes increasingly dominant at lower stresses.
2. For A617/10Cr, fusion-line cracking dominates even at higher stresses.
3. At 575C/1065F, strain-controlled creep-fatigue damage develops initially in the over-tempered parent materials, with an increasing damage influence with less strain.



5. Sensor can store up to 3000 measurements

Cost and performance. ETD's Shibli focused on cost and performance analysis when operating in both base and cycling modes. Methods included performance benchmarking, top-down and bottom-up cost analysis, and the negative impacts of cycling on both performance and cost.

Presenting a detailed and comprehensive case study, Shibli stated that "Recently a utility with 11 combined cycles located in North America was looking for an increase in profitability. The head office approached ETD to assess the maintenance strategy for each of its 11 plants."

Some units had relatively low availability factors because of a large number of forced outages and excessive planned outages. These data were plotted against total maintenance costs on a five-year average, showing plant performance comparisons and ratings. Performance comparisons were compared among the 11 plants studied and also with ETD's database of about 150 other plants. Benchmarking study recommendations were then provided to each plant based on performance results and failure types.

These included the following:

- Creation of an integrated service- and maintenance-history database.
- Implementation of a condition-based maintenance strategy.
- Development of a risk-based boiler tube failure (BTF) prevention program.
- Implementation of a regional reliability-centered maintenance approach.

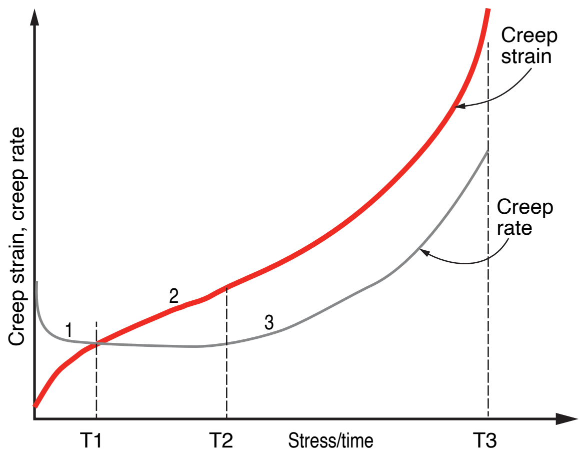
Top-down factors included the influence of market-driven cyclic operations. As Shibli explained, "Estimates of increased costs and the basic causes are vital so that utilities can better understand the true economic implications of cyclic operations."

An often-overlooked factor was also considered: high fuel consumption during startup and shutdown because of inefficient heat transfer and non-optimum heat rate.

Shibli identified these common data-collection challenges for accurate unit-specific cycling cost analysis:

- Overall plant design.
- Operational history.
- Individual major component design—including material, thickness, and related factors.
- Water-chemistry quality and procedures.
- Size and age of plant. Note: Shibli suggested that size is often more important than age.
- Previous maintenance philosophy (during baseload operation, prior to going into cyclic service).
- Plant accounting-practice comparisons.

Shibli then offered a detailed methodology matrix for cycling impact assessments: "Estimates of per-start costs use elements of a bottom-up approach, namely engineering and risk assessment to identify plant-specific critical components. Statistical analysis is used to estimate the impact of an increased number of starts on performance, reliability, and non-recurring maintenance and capital replacement costs—thus providing the current and projected per-start cost range of cycling for a defined period and operating environment."



6. Deformation versus lifetime of a component operated in the creep range

Results help to understand "how costs can be reduced by making plant design and operating changes to reduce component damage," he said.

Corrosion. Cesar Buque, TUV SUD Group, Spain/Germany, focused on the cost of corrosion, explaining current inspection practices and their limitations. His lead-in graphics showed the often-catastrophic impacts of non-detection between inspection periods. He then offered an asset health monitoring solution using sensors for wall-thickness monitoring, and the ability to detect corrosion in insulated pipes, elbows, and difficult-to-access locations.

Current practices and technologies can lead to spot measurements with a large error bandwidth, and inability to determine long-term corrosion trends. Increasing the traditional inspection frequency can lead to higher costs with haphazard trending information.

He offered one solution: continuous (ultrasonic) sensors for wall-thickness monitoring. The stated goal is to inform operators before major negative consequences arise. "Send early warnings to plant operators according to determined thresholds, and find root causes through pattern recognition," he suggested. Analysis would help determine best operating practices for asset longevity, and achieve higher plant availability over time.

This could also reduce needless early retirement of components.

Equipment shown in Fig 5 features the following:

- High and low temperature measurement: 500C to -30C/932F to -22F.
- Minimum wall thickness: 3 mm.
- Resolution: 0.020 mm.
- Probes per unit: eight to 16.
- Storage capacity: 3000 measurements (for weekly or monthly download).

Sensors also monitor each other for any malfunctions. Expected degradation mechanisms and types of equipment studied determine the number of sensors used.

Creep strain measurement.

Christian Ullrich, VGB PowerTech, Germany, followed with creep strain measurement using high-temperature strain gages.

The premise: Because components are designed for a specific lifetime under given parameters, their condition must be monitored to identify threats to component integrity. This is particularly important for P91 and P92.

Case studies explained the stages of creep graphically in Fig 6:

- Creep rate is high in first stage.
- Creep rate is linear in secondary stage.
- In third creep stage, there is an exponential behavior of creep strain. Cause is the formation of micropore chains.

Four methods of creep strain evaluation have been established. They are:

Mechanical

- Pipe expansion is measured at predefined positions.
- Results are compared with historical records to calculate creep strain.
- Criterion for end of life is 2% plastic strain.

Note that the mechanical methods identified here also have measurement uncertainty.

Metallurgical

- Material condition is compared to standards (for example, VGB S517).
- Number and configuration of pores are the main criterion.
- Continuous measurement is not possible.

Mathematical

- Lifetime consumption is calculated based on temperature, operational time, and pressure.
- Additional stresses are neglected.

Electrical

- Creep strain can be measured with high-temperature strain gauges.
- Main problems are long measurement times, high temperatures, and detection of low strains.
- Capacitive gages are the best option to measure slow deformation processes.
- Traditionally, the measurement system has exhibited very high stability.

Examples of electrical methods included these:

1. CERL-Planer gauge (horizontal plates), complex but sensitive to external mechanical effects.
2. Interatom sensor (perpendicular parallel plates).

Both measure strain only locally. In Europe, the Interatom is used most often, showing good and relatively robust behavior (long-term data up to 60,000 hours). Creep curves show good compliance with material behavior.

Case studies followed. In one study, raw data were filtered and only data generated at high temperatures were evaluated. Curves revealed that creep was within the linear range, so no short-term failure was expected.

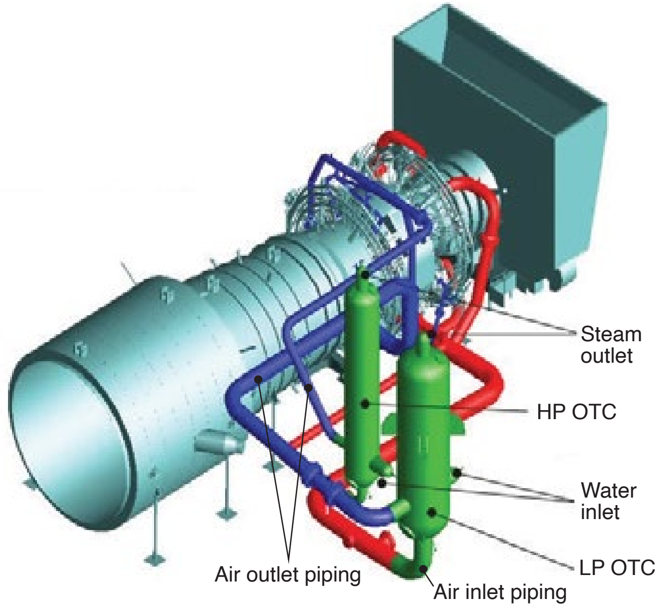
More-detailed data evaluation revealed the following:

- Component is in the range of secondary linear creep.
- Component will reach the 2% creep strain threshold (the parameter used by regulating bodies) before 200,000 hours of operation.
- The bend studied will reach 2% after 80,000 hours.
- More than 2% can likely be reached before failure.

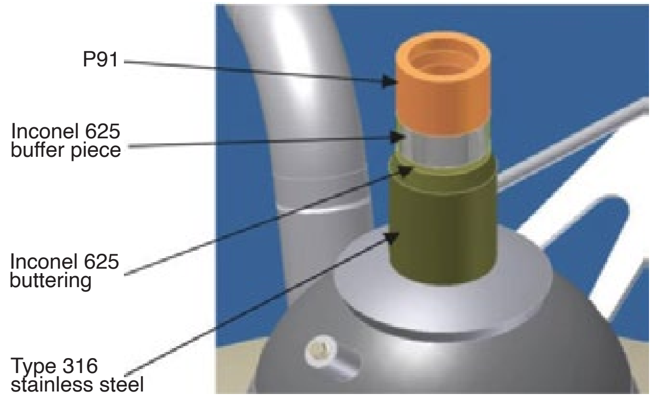
Ongoing measurement is required. Some summary benefits:

- Gages can be used to verify good condition or to help confirm that integrity remains acceptable for a specific period.
- High-temperature strain gauges are good ways to monitor components in search of specific problems.

Once-through GT coolers. Alexandros Antonatos, Public Power Corp, Greece, discussed once-through coolers for Alstom GT24 and GT26 engines. The water-cooled heat exchangers reduce the temperature of compressor bleed air for cooling critical parts of the



7. Once-through cooler (OTC) reduces the temperature of compressor bleed air to cool gas-turbine blades



8. Original dissimilar metal weld joint at OTC interface was not immune to cracking

gas turbine; steam is produced in the process. The steam outlet is Type 316 stainless steel transitioning to P91, therefore requiring dissimilar metal welds or a combination of mixed weld seams (Fig 7).

Operational stresses, including demanding steam parameters, contribute to high stress in the weld joints. "Weld-crack incidents at various sites worldwide have been reported in this transition zone," he stated.

Antonatos presented various dissimilar-metal weld joints being used in an effort to avoid creation of these cracks. In its original configuration, the transition included an In625 buffer (Fig 8). But after a few years of operation, cracks were reported.

A suggestion was to choose a location with lower system stresses (a vertical pipe section) and provide a gradual transition with 6-in. bridging pieces (Fig 9). However, cracks appeared in this "new" design at one of the weld joints.

The latest design features Alloy 800 between the In625 and TP321H segments, joined by three dissimilar-metal welds, to form a so-called "advanced flange solution" now offered by the OEM (Fig 10). The speaker said the flange has not yet been installed in the field.

Maintenance forecasting. Martyna Tomala, Silesian University of Technology, Poland, offered a review of coal-fired 200-MW units in Poland, and the effects of operational changes as they adjust to renewables. She focused on steam turbines. Prevailing concerns are turbine-blade erosion, corrosion attributed to shutdown practices, increased crack propagation (first rotor failure scenario), and low-cycle fatigue (second rotor failure scenario).

"Crack propagation is one of the most dangerous processes in the turbine rotor," she explained. "The most vulnerable area is the turbine central bore. FEM (finite element method) analysis allows determination of stresses occurring in the rotor during startup (Fig 11) and steady-state (Fig 12) operation (under creep conditions)."

She explained the components of stress during heat-up and creep relaxation. Calculations were presented for three operating scenarios with these assumptions:

- Rotor service life, 20 years.
- Operation time, 6000 hr/yr.
- Number of annual starts, 200.
- Steady-state operation time between starts, 30 hours.

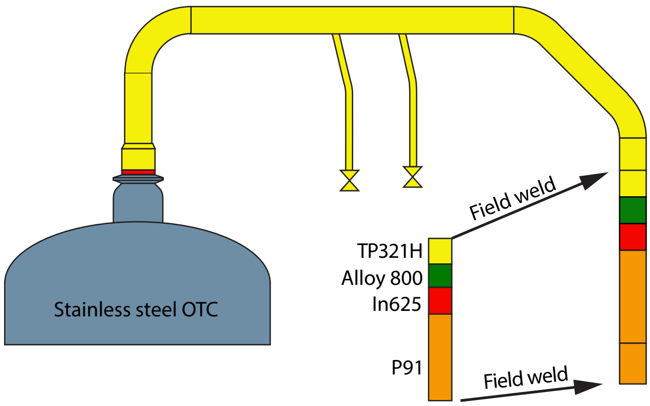
Crack propagation rates were shown based on the Monte Carlo Method (repeated random sampling to obtain numerical results). Fracture toughness was determined using non-destructive small punch tests.

This led to preventive activities planning based on avoided-risk criterion.

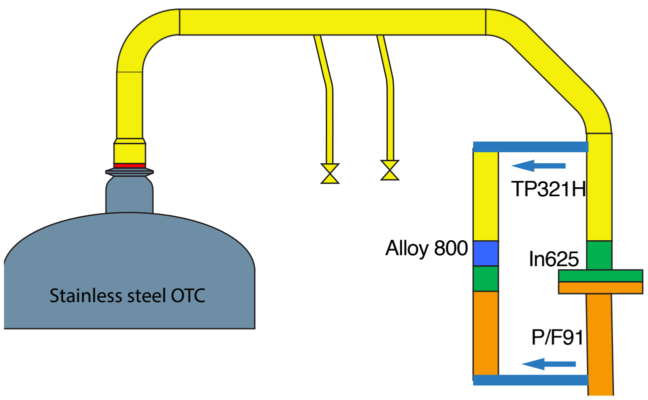
A highlight was the detailed explanation of net present value (NPV) sensitivity analysis (Fig 13), leading to optimization of preventive activities and intervals, as well as cost impact.

Also in Session 5 were the following:

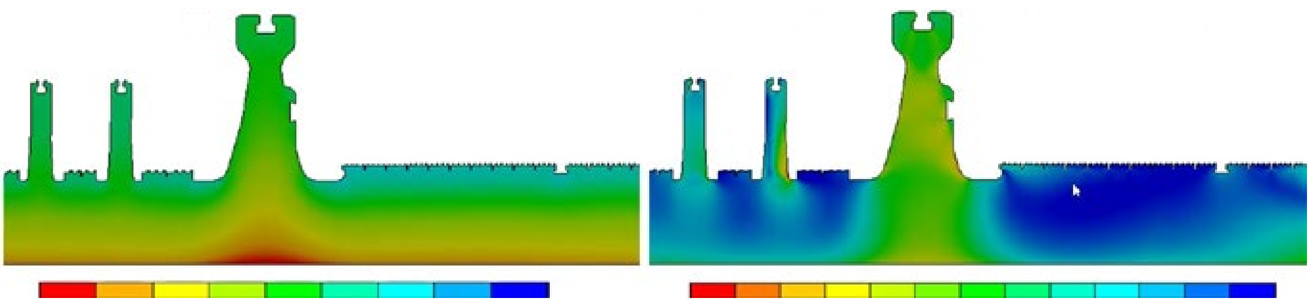
- Stress corrosion cracking in T24, VGB PowerTech, Germany.
- Hardness methodology for creep deformation and residual life, Toshiba, and Tokyo Institute of Technology, Japan.
- Creep degradation in reformer tube after 17,000 hours at 980C, TNB Research et al., Malaysia.
- Creep life estimation by crystal misorientation frequency distribution,



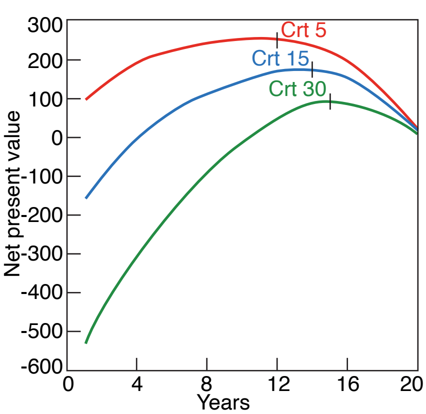
9. Revised ("new") DMW joint also experienced cracking of one weld



10. Advanced flange solution has been adopted by the OEM



11, 12. Crack propagation is one of the most dangerous degradation processes in a turbine rotor. The most vulnerable area is the central bore. FEM analysis allows engineers to determine stresses occurring in the rotor during startup (left) and steady-state operation (under creep condition) at right



13. Impact of various diagnostic testing and repair cost scenarios (Crt) and their influence on net present value

Nippon Steel, Japan.

- Development of oxide scales on inner and outer surfaces of reformer tubes, TND and Petronas Berhad, Malaysia.

In Session 6, various presenters concentrated on risk-based investigation methods and stress analysis. This included finite-element (FE) analysis of stress fields in steam pipeline components, from the school of mechanical and design engineering, University of Portsmouth, UK.

This particular presentation included residual stress analysis of pipe bending through an FE model for bending simulation, verified by published data. Featured was field-structure interaction (FSI) using ABAQUS.

Models presented simulated the pipe bending and fluid structure interaction at the pipe elbow. Further work is required to correctly capture precise stress fields in pipe under high temperatures.

In another presentation, ETD's Feroza Akther discussed risk-based maintenance and performance optimization of powerplants. Examples were taken from a recent study for a client in Canada. Planned maintenance was suggested in three categories: preventive, predictive, and proactive.

A section on recent developments in smart analyses of equipment performance included SmartCET, a corrosion monitoring technique developed by InterCorr International (Houston), now part of Honeywell Inc. Smart thermal scanning and digital radiographic techniques were also presented.

This detailed presentation ended with the following list of common aspects for a best practice risk management procedure:

- Assess credible hazards for threats to equipment based on plant experience and equipment knowledge.
- Identify failure modes and potential causes.
- Determine probabilities and resulting impacts.
- Set risk treatments or mitigation measures.
- Assign a measure of risk to each item.
- Define acceptable or tolerable risks.
- Combine risk with inspection history to determine future inspection intervals and methods.

Also presenting were Best Material Co and IMC Co of Japan discussing new software for the execution of boiler risk-based investigation; modeling of grain-boundary cavitation and rupture by the school of computing and engineering, Univ of Huddersfield, UK; and the benefits of RCM implementation in power generation by ETD.

Wrap-up

Prerecorded sessions also were integrated into the meeting. They covered Type IV failure in 9Cr weldments; defect assessment with ETD's Crackfit technology; creep rupture modeling of P92 by grain-boundary cavitation; calibration of creep cavitation modeling for 316H steel; creep cavitation by cavity histogram; and creep damage constitutive equations.

The online sessions were chaired by EMPA's Holdsworth and ETD's Shibli, Akther, Robertson, and Dr David Allen.

The conference concluded with a one-hour discussion session where all participants could switch on their videos and participate. This was a very positive feature with attendees able to see other participants and ask more questions.

Note: Based on the success of the two-day virtual conference, ETD is organizing the following three online events in early 2021:

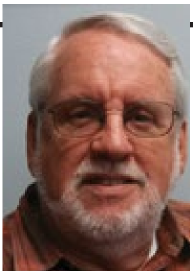
1, A two-day Boiler Life Assessment Training Course in February.
2 A three-day event focused on high-temperature defect assessment in April. This will be the eighth in the series of triennial HIDA conferences covering high-temperature plant component failure, cracking, damage, and condition/life assessment.
3. A four-day course on gas turbines.

Details are on the ETD website at www.etd-consulting.com.CCJ

TURBINE TIPS, No. 8 in a series

Test VIGVs periodically to assure reliable operation

By Dave Lucier, and **Charlie Pond** (deceased), PAL Turbine Services LLC



Lucier

Pond

Turbine Tip No. 8 from the PAL solutions library applies to General Electric 5001N, 5002B, 6001B, 7001B-EA and F, and 9001EA and F gas turbines.

Proper operation of compressor variable inlet guide vanes (VIGV) is crucial for those gas turbines that have the "variable" design. Hundreds of components comprise a VIGV set and all must function properly and in unison. The operating cylinder must stroke; the rack must rotate; the vanes must all turn together to set the proper angle in the compressor inlet air.

Should a vane gear bind and not rotate properly or should one of the blades rub on the internal side of the compressor inlet casing (bellmouth), the consequences could be catastrophic. If a vane breaks off and liberates, it would be ingested into the compressor and cause the rotating and stationary blades to fail as well. Bad news!

The VIGV set must rotate freely from the so-called "closed" to "open" position and back, depending on the turbine starting and operating design. End stops allow vane rotation through an arc of approximately 45 degrees. Free-moving vanes are vital to the proper startup, operation, and shutdown of the unit (Figs 1 and 2).

The closed, or starting condition, is set to reduce air flow during startup. This is done to mitigate compressor surge as the shaft speed and air flow increase. The VIGVs return to the closed condition during the shutdown sequence to again mitigate surge (vibration) and to prepare for the next start attempt.

During startup, as the turbine approaches operating speed (about 95% of rated speed), the VIGVs are signaled to rotate toward the open position. On most turbines, this means an angle change from approximately 44 to 87 degrees.

Fig 3 illustrates what can happen if a vane gear or bushing binds. The tear in this vane is about three-quarters of

1. Gears for inlet guide vanes are visible with UH covers and casing removed. Take note of the VIGV-angle casing pointer

2. The VIGV operating cylinder is connected to the gear rack under the dust cover

3. Binding of this inlet guide vane was the root cause of the tear visible below the tape

4. Loose vane in the center of the IGV row is conducive to failure of the airfoil

5. Hydraulic supply pump 88HC is installed on some models of GE gas turbines

6. How to adjust VIGVs without removing the rotor

In-situ extraction of a migrating 7EA S-12 shim saves owner more than $400k

It was only a few years ago that owner/operators of GE E- and F-class gas turbines learned technicians from Advanced Turbine Support LLC could extract or blend shims in the first three compressor stages in-situ—no case removal necessary. That was a big deal because shims found protruding into the compressor air stream during a borescope inspection could be dealt with immediately, preventing an offending shim from possibly going downstream and damaging rotating and stator blades.

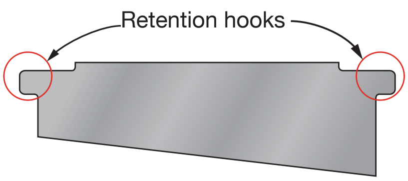
Update: A week ago, Mike Hoogsteden, Advanced Turbine Support's director of field services, called to say the company's technicians had removed in-situ a protruding shim in the 12th stage of a 7EA, saving the owner the more than $400k it would have cost to extract the shim had case removal been required.

Hoogsteden noted that the protruding shim was located above the right case break (photos) and that the peaking unit had recorded about 8500 service hours and nearly 700 starts when the inspection was conducted. He suggested that O&M personnel new to the GE E-class fleet become familiar with TIL-1562, "E- and F-Class Shim Migration and Loss," issued in January 2007. To dig deeper into the subject, consult the 7EA Users Group library on the Power Users website at www.powerusers.org, and meeting reports available in CCJ's searchable archives at www.ccj-online.com.

Advanced Turbine Support developed, patented, tested, and proved the tooling a few years ago that today allows—depending on rotor stacking—in-situ blending of compressor blades and stator vanes as far back as Stage 12 with favorable access.

The blends can be analyzed by engineering to determine any associated risks both before and after the work is done. Hoogsteden says his company recommends attempting in-situ blends on rotating blades and stationary vanes when engineering analysis confirms such repairs are preferable over immediate unit disassembly.

Concerning shim migration, he adds that once a shim has migrated to approximately 50% of its height and is protruding into the air stream, the OEM no longer considers this a low-to-medium risk condition and it should be removed or blended flush. CCJ



Shims are supplied with retention hooks as shown above. When hooks suffer wear and tear, shims may migrate out of their slots (center). When this occurs, the shims must be removed (right photo) or ground off to prevent liberation and downstream damage

an inch in length. If the vane fails and eventually liberates, it could be sucked downstream and destroy compressor rotor and stator blades. A loose vane bushing also can cause a vane to bind, break off, and liberate (Fig 4).

Periodic testing of VIGV operation—quarterly recommended—can help identify potential issues before they morph into a problem and damage the unit.

Here's a typical procedure for testing the VIGVs on turbines with motor-driven hydraulic supply pumps:

Confirm that the ac lube-oil pump **(88QC)** is operating and in manual control. This pump feeds oil to the suction side of the hydraulic pump.

Operate the ac hydraulic supply pump **(88HC)** in the manual mode to provide 1200-psig oil to the VIGV operating cylinder. Important: The 5001N engine has no **88HC,** so a temporary hydraulic pump must be used. There is a pressure tap in the hydraulic manifold where a plug can be removed and the pump line installed. A check valves prevents back-flow return to the lube system.

Force the logic or simulate the pickup of speed relay **14 HS.** Normally it is energized at 95% turbine speed.

Verify that **20TV** is energized, so the VIGVs can move to their *fully open* position. Energize and/or de-energize the solenoid and observe the action, back and forth, closed to open. Be aware that some turbines have a solenoid valve called **90TV.** One or the other is used to actuate the VIGVs between end-stop positions.

Logic-forcing methods will depend on which Speedtronic™ generation is applicable—that is, techniques will differ depending on whether the control system is a Mark I, II, IV, V, or VI. Recall that there is no Mark III system.

Measure the end-stop positions of the VIGV (open and closed) with the pointer on the IGV ring and scale on the lower half of the compressor forward casing (refer back to Fig 1).

Confirm the movement by measuring the voltage change of the linear variable differential transformers (LVDTs) associated with the travel of the VIGV hydraulic cylinder.

Put eyes inside the compressor inlet casing (bellmouth) during the test to assure the vanes are all turning correctly in unison and not binding.

If binding is observed or suspected after several stroke cycles, a thorough borescope inspection may be required. Pond and Lucier LLC has developed a technique for servicing VIGVs without rotor removal (Fig 6). The service is offered at a firm price within a two-week window. CCJ

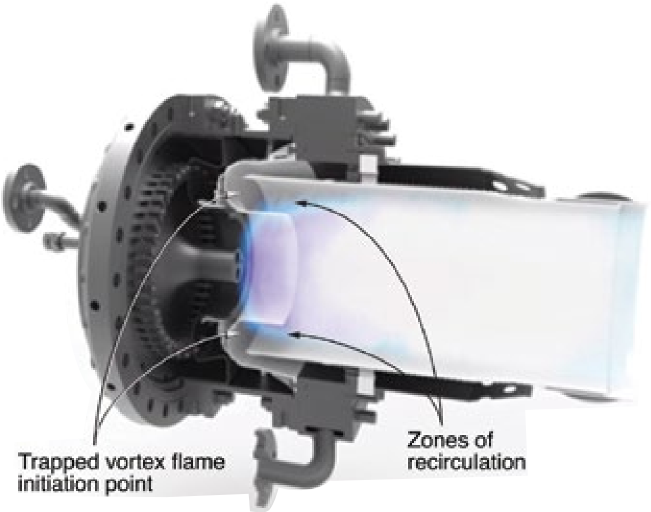
Real-world experience firing H_2/gas mixtures

Regardless of where you fall on the 3Hs of the H_2 economy—hype, hope, happening soon—everyone can appreciate a seminar which delivered information on actual experience. The webinar, "Hydrogen: Utilizing Combustion Turbines as a Solution to 'Low to No-Carbon' Initiatives," was held Oct 26, 2020.

After a quick review of global-climate headlines, Jeff Benoit and Katie Koch, PSM (Power Systems Mfg LLC), noted that while "gas turbines are a core pillar of decarbonization," the world is woefully behind in meeting 2030 and 2050 global carbon-reduction targets being emphasized by the climate-science community.

The good news, according to PSM, is that "gas turbines can be a long-term part of the eventual zero-carbon power grid, and can be 'future-proofed' sooner rather than later." If batteries and other storage systems represent grid-scale, shorter run-time options, H_2 represents a gigawatt-scale, long-term energy-storage option.

As one example, renewable energy that might otherwise be curtailed, or even excess nuclear power, can be used to power H_2 production units with the fuel stored in the same underground formations used for natural gas, other hydrocarbon fuels, and compressed air. While long-range and large-scale transport and distribution of H_2 in the existing natural gas network present challenges, such as piping embrittlement and sealing, the US and Europe have proven large-scale H_2 distribution networks connecting industrial process facilities.



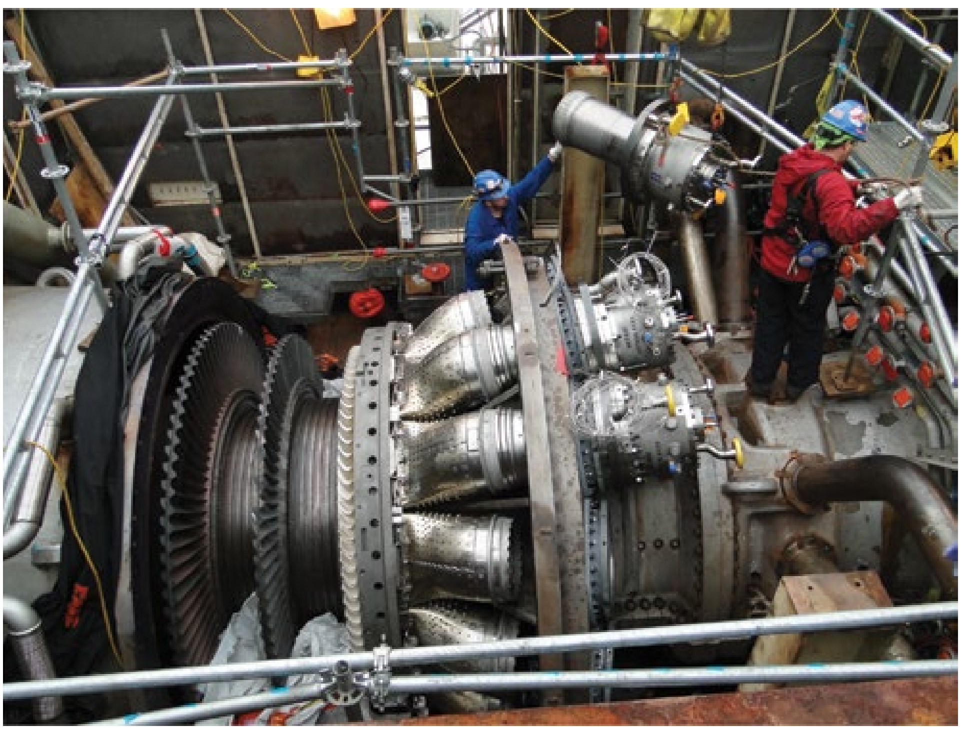
1. High hydrogen flames are "anchored" at the point of vortex and less sensitive to flame shifting position

PSM's sweet spot of experience, however, is at the combustor. At a 3 × 0 9E GT customer site in The Netherlands, being deployed specifically for H_2 combustion-technology development, H_2/natural-gas fractions from 9% to 25% (field demonstration of 35%) have been fired successfully for four years with no impact on turbine life, with NO_x emissions held to 9 ppm or below, reports Benoit.

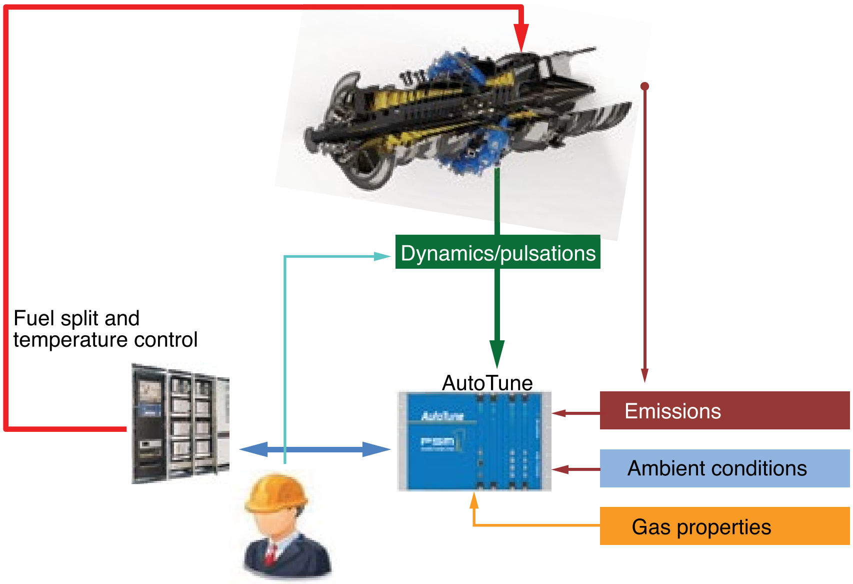
The GT is equipped with PSM's LEC-III® combustion system with the company's "fin mixer" secondary fuel nozzle. PSM's AutoTune controller logic handles the varying amounts of H_2 coming into the system.

PSM is also participating in a Dutch-government-subsidized program to develop its FlameSheet™ combustor as a "platform" for 0 to 100% H_2 firing.

"In Stage One of the program, PSM and sister company Thomasson retrofitted an existing 1.8-MW OPRA OP-16 engine with a scaled version of FlameSheet and tested it for up to 100% H_2



2. FlameSheet combustor is installed in an F-class gas turbine



3. AutoTune adjusts fuel/air ratios based on measurement of incoming fuel constituents, and thus is readily adaptable to H_2/gas mixtures. System is active from synch to baseload and can be used with any gas-turbine controller

by volume. Stage Two will be scaling the FlameSheet to additional applications." That will be followed by a demo project on additional frame units to achieve the project goal of up to 100% H_2 on units varying between 1 and 500 MW, while keeping emissions in check.

Meanwhile, an F-class unit also has been retrofitted with FlameSheet and has been field-demonstrated with a fuel mixture containing up to 5% H_2, the limit representing the amount of hydrogen available for this unit. The FlameSheet has been tested in the rig for F-class conditions at full pressure and full temperature for up to 80% H_2 by volume without emissions excursions.

Seven 501F and 7F gas turbines (with an eighth being installed in December 2020) are currently operating commercially with a FlameSheet combustor, simply described as a burner (or inner combustor) with a conical flame sheet around it that promotes a trapped vortex mechanism which allows higher flame velocities to be maintained.

The flame is said to be "anchored" at the point of vortex (Fig 1) as defined by geometry and, therefore, less dependent on fuel constituents. Fig 2 shows a FlameSheet combustor being installed in an F-class gas turbine.

In addition to FlameSheet, PSM has demonstrated that its AutoTune controls will greatly contribute to successful H_2 firing (Fig 3). At its base, AutoTune can continuously measure the constituents of the fuel mixture, then automatically adjust the combustor fuel/air mixtures to improve reliability and maintain stability. This functionality is already in practice today for a variety of shale gases with variable heating values. Even within the Marcellus and Permian regions, natural-gas heating value can vary significantly.

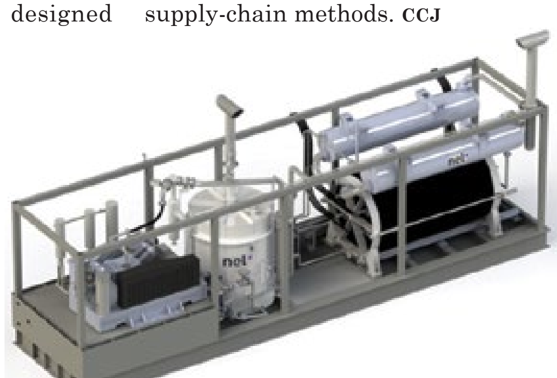
Differences in combustion properties with higher and higher H_2 fractions are not trivial, stresses Benoit. Combustors are typically designed for a narrow range of natural-gas properties. H_2 has higher reactivity, and "wants to oxidize quicker," which can lead to high flame speeds, flames migrating into the metal, and flashback.

In addition to ensuring stability of combustors firing these mixtures, AutoTune solves a variety of combustion challenges. The GT-agnostic AutoTune product is already installed on more than 80 units (total anticipated by the end of 2020)—including 9FA, 7FA+e, W501F, M501F, 6B, 7E, GT26, and 9E engines.

GT owner/operators don't want to lose their cycling and start/stop flexibility. While AutoTune has proven it can handle transient upsets, Benoit notes that "you don't want to start up or stop the machine with high H_2 fractions, so it's best not to start on H_2 from a safety standpoint, but instead transfer to an H_2/gas blend at full premix mode. He also notes that many customers purchased FlameSheet specifically to improve load-following.

Finally, maintaining low NO_x and CO emissions is a challenge with H_2, but premix combustion is key here and even more critical. Although conventional premix combustors are limited in their ability to burn H_2/gas mixtures, PSM sees AutoTune, combined with the aforementioned combustion technologies, as the key to successful firing in such GT-equipped machines.

For pragmatic entry into the H_2-to-power market, Thomassen, in conjunction with The Netherlands-based OPRA Turbines, can ready a "turnkey clean energy package" (Fig 4) that pairs a containerized 1.8-MW GT/generator with a skid-mounted, packaged proton PEM or atmospheric alkaline electrolyzer driven by low-cost or negatively priced electricity to produce and store H_2 for scheduled firing in the GT. Fuel skids qualified for hydrogen are available as well through various supply-chain methods. CCJ



4. Market-entry turnkey power system pairs a containerized 1.8-MW gas turbine (left) with a skid-mounted hydrogen fuel generator (right). All that's required is water and a grid connection. Hydrogen made by the electrolyser is captured in the high-pressure storage vessel provided as part of the system

Goal of an integrated powerplant knowledge platform nearly reached

Twenty-five years ago, at least one powerplant controls company executive articulated a vision of integrating disparate and siloed software applications into a unified whole, anchored by the distributed control system (DCS). That executive was Robert Yeager, longtime president of Emerson's Power and Water Solutions. At the company's 2020 virtual Ovation Users' Group Conference (OUG), it became clear that Yeager is tantalizingly close to achieving that vision.

"We are no longer just a distributed control system company," Yeager said in his traditional opening remarks. "With the continuous evolution of our Ovation automation platform, we are a protection and condition monitoring, failure prediction, excitation, simulator, advanced monitoring and diagnostics, data analytics, advanced visualization, and a PLC (programmable logic controller) company." For that matter, today the vision for Ovation platform now encompasses the entire electricity supply and delivery chain (Fig 1), not just the powerplant.

Indeed, not only is the Ovation platform all that, it has also become the gateway for services and expertise provided from, well, anywhere. This capability was certainly stressed-tested in the last few months as Emerson and its customers grappled with a COVID-19 ravaged landscape.

Most digital-system experts would agree that perhaps the greatest threat to Yeager's vision would be something impossible to envision back in the mid-1990s: cybersecurity. To mitigate that threat, over the past few years, Emerson developed capabilities, native and through strategic partnerships, such that Yeager could also say, "We're a cybersecurity company." One that works on other vendor control systems, to boot.

Major OUG themes on Yeager's mind this year included the following:

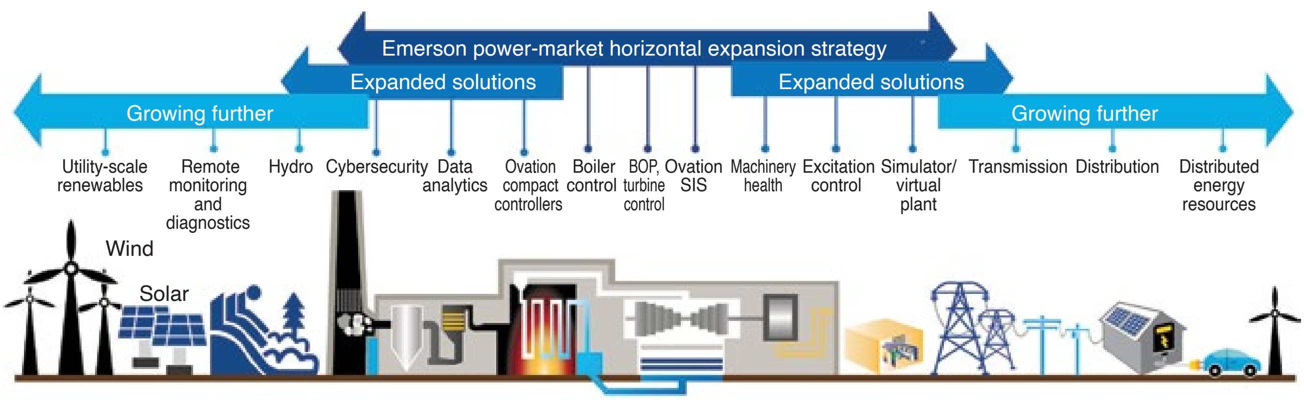
- Challenges associated with a shift toward renewables and maintaining business continuity during a global pandemic.
- Emerson's acquisition of American Governor, which brings hundreds of hydroelectric sites into the user fold.
- Expanded relationships with turbine OEMs, such as the recently announced collaboration with Mitsubishi on power industry digital transformation.
- Implementation of IEC 62443, the latest cybersecurity industry standard.
- Expanding the Ovation platform's footprint to include T&D and distributed energy resources.
- A virtual repair and enhancement center anchored by the "live" version of the Ovation digital twin simulator.

These were expanded on in the follow-on presentations.

Regarding the last and, frankly, profound piece of the puzzle, Yeager encouraged the audience to think of the repair and enhancement center as a "repair shop, saying: "Drive in if you have squeaking brakes, or your check-engine light is on." As a directly relevant example, Yeager said, "suppose you have too many alarms (or check-engine lights) on, bring your 'plant' into the shop, we'll fix your alarms, and you can upload the changes during your next outage!"

Users catch up to vision

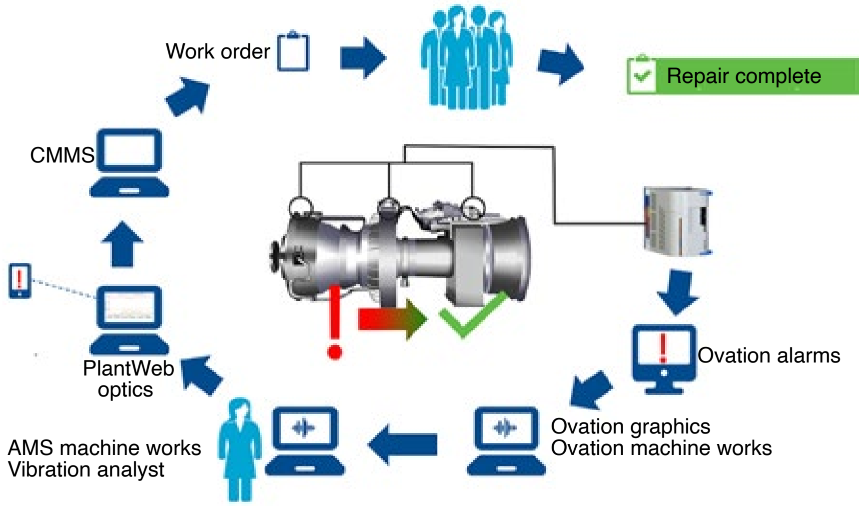
In evidence every year at the OUG, and expected, is that the "facts on the ground," or "in the field" in this case, are a few years behind Yeager's vision. One user who commented live on his plant's experience with the digital twin



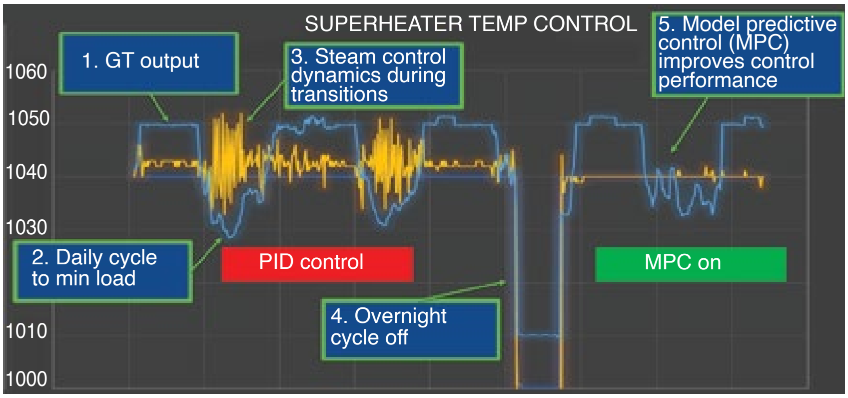
1. Vision for the Ovation platform, once focused on integrated powerplant knowledge, now includes the entire electricity supply and delivery chain

Ovation Users Group Steering Committee

President, Keith Nelson, *Mississippi Power Co*
Vice President, Carl Bayley, *Xcel Energy*
Secretary, Shawn Hawley, *Hampton Roads Sanitation District*
Outgoing President, John Maloney, *Evergy*
Bill Collins, *Exelon Generation*
Joel Erwin, *Luminant Engineering Support*
Dan Jones, *Evergy*
Jeff Majka, *Metropolitan Water Reclamation District of Greater Chicago*
Dave McMullan, *Xcel Energy*
Daniel Noles, *Tennessee Valley Authority*
Jim Rarey, *American Electric Power Co*
Wes Whitley, *Alliant Energy*
Scott Woodby, *Midland Cogeneration Venture*



2. Linking control-system alarms to a domain expert (in this case vibration) and then to work-order management is one more step towards the autonomous plant



3. Model predictive control offers dramatically reduced steam-temperature fluctuations as gas-turbine load changes

said it was primarily used for training. "Operators don't get much opportunity to train on abnormal situations, and the simulator is close to what they would get in a real situation."

Yeager noted that there are hundreds of digital twins now in service. In a later presentation devoted to technology, VP Software Solutions Rick Kephart said they were working with beta sites now on tools to keep the Ovation simulator up to date with the changes in the actual control system, and that "we are looking at a few pilot projects to achieve the 'holy grail,' synchronized simulation," or an authentic live digital twin.

Necessity is…

. . .the mother of implementation, to twist a time-worn phrase to fit the COVID-19 period. The virtual meeting applications, networks, and bandwidth to do things remotely, like Ovation training and factory acceptance tests (FATs), have been available for years. But it took a pandemic to show how ready these capabilities were for not only prime time, but *all the time*.

Working collaboratively with their customers, the Ovation project team shifted from 5% of FATs being done remotely pre-COVID to over 90% as the virus raged across the country. People familiar with that popular self-help/management book "Who Moved My Cheese?" will recognize the project team's achievement as akin to moving the state of Wisconsin.

Jaime Foose, director of security solutions and lifecycle services, during the part of the program devoted to services, noted that "educational services have seen a dramatic shift to virtual classes, and yet we've managed to maintain a 95% customer satisfaction rate." The services team experienced a reduction in calls from customers, so Emerson proactively called them to offer assistance.

The digital twin sets the stage for the Ovation platform to provide even more services virtually and remotely. Nevertheless, Glenn Heinl, VP North America lifecycle services, anticipated during the Day 2 Q&A that "[the fall] will be an outage season like Emerson has never seen. Approximately 2500 days of Ovation field services were postponed from the spring outage season to the fall and we're tapping into all of Emerson's North America and worldwide resources to provide support."

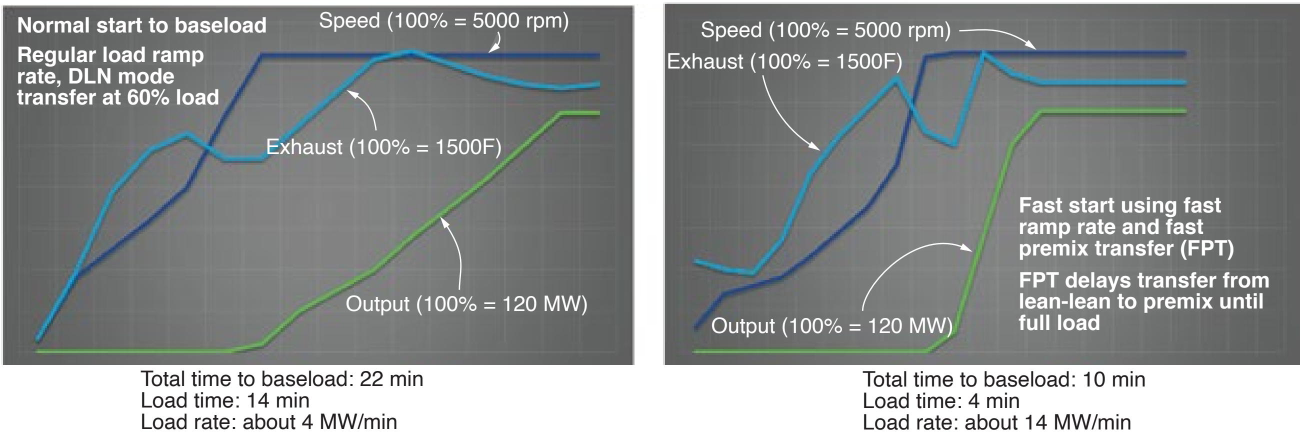
Yeager mentioned during the opening that 70% of Ovation's field engineers are still traveling to sites, "even sites with COVID-infected staff." More than 2500 onsite service days were provided from March through July. At headquarters, Emerson put a COVID preparedness team in place in early March, with one tactic dividing the HQ staff into A and B teams, with half the staff coming in one week, the other half the next week. Yeager called the onsite customer and Ovation teams "heroes."

Deck plate solutions

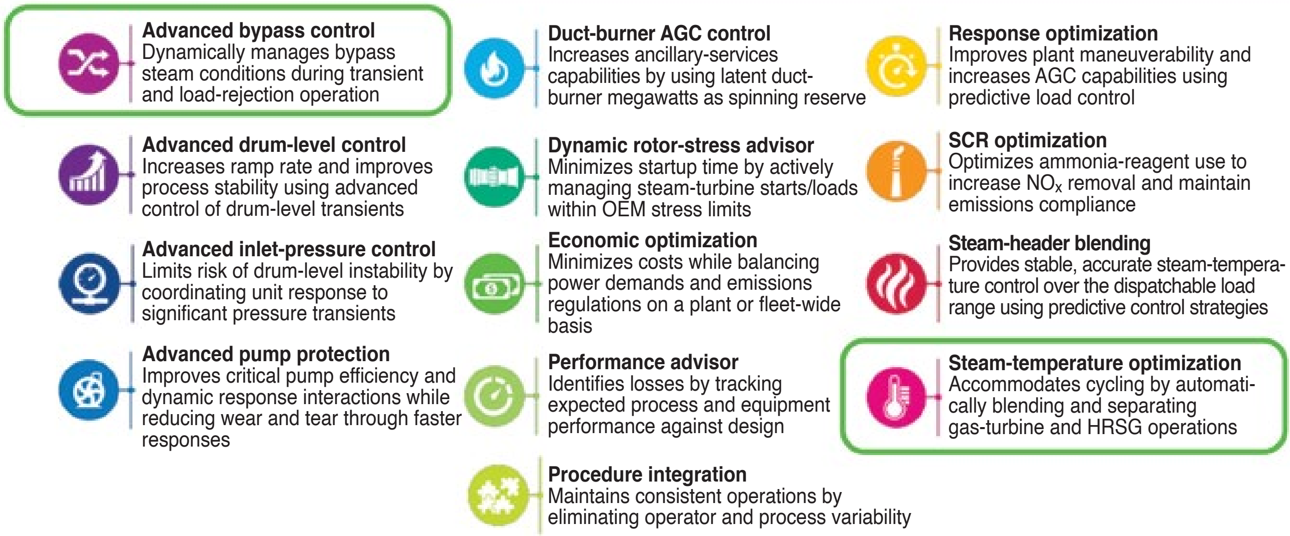
The Power Industry session covered solutions important to combined-cycle (CC) plant owner/operators.

Bearings. Jason King, manager of machinery health solutions, revealed embedded condition-monitoring (mostly vibration) features within the Ovation platform that now allow monitoring of bearing alignment, turbine balance, and bearing wear, as well as a specific bearing-rub advisory. Vibration analysis is one of the most effective condition-monitoring technologies available, and automation of analysis for turbomachinery greatly improves return-on-investment by allowing users to plan maintenance in advance, reducing forced outages and O&M spend. These features are now in beta test at one site.

On the screen, as one example, the



4. Fast premix transfer can reduce the start-to-full-load sequence by up to 12 minutes for a 7EA



5. Destination "autonomous powerplant" includes these current and future features resident in the Ovation platform

operator sees a "Q factor" for journal-bearing wear, a Q less than or equal to 4 means wear is not indicated, between 4 and 6 means repair at the next outage, and a value between 6 and 8 means repair now. Conveniently, the monitoring values from the Ovation system can be directly tied into the CMMS (computerized maintenance management system) to automate work flow (Fig 2). "This is just one more step towards the autonomous plant," King concluded.

King also introduced features included in the release of the latest version of Emerson's new advanced vibration analysis software for use with Ovation Machinery Health Monitor, called AMS Machine Works.

Generally, the Ovation Machinery Health Monitor is an eight-channel vibration module compatible with existing field sensors for the steam or gas turbine/generator and other critical rotating equipment.

Steam bypass control. Jim Nyenhuis, manager of performance consulting, covered a solution near and dear to CC owner/operators running high-starts units: steam-turbine bypass control. Specifically, the Ovation platform now includes an advanced bypass-control and steam-temperature application employing model predictive control (MPC) techniques. The actual control-system responses are constantly being compared to the model, and the system automatically adjusts accordingly in real time.

MPC has demonstrated that it can greatly reduce variations in steam-temperature control (Fig 3).

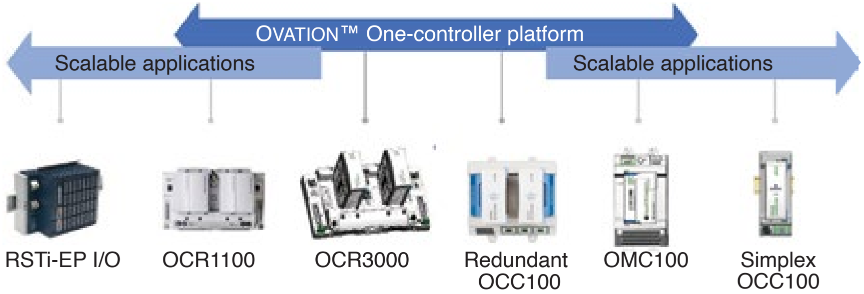
Attemperators have common installation issues, Nyenhuis continued, such as water leakage past the control valve seat, plugged nozzles, improperly sized water droplets, and localized quenching. These problems can be traced back to rapid changes in thermal energy from water injection, but the resulting time lags in energy changes impact the ability of the control system to do a good job.

In many cases, gas-turbine load reductions stress the attemperator, but even at full GT load, the attemperator can cycle between 0 and 30% of capacity if control dynamics are not managed properly. Advanced control often reveals the limitations of bypass control equipment that is improperly sized.

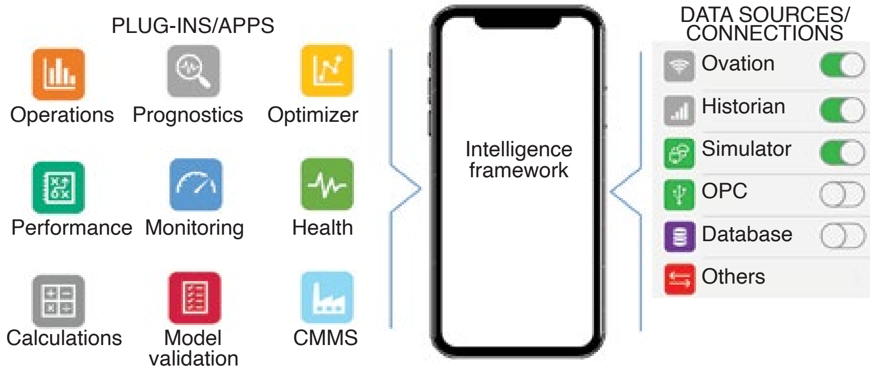
In the real world, operators usually don't have a good measurement of bypass steam flow. However, by running the live digital twin in lock-step with the plant's control system together with advanced pattern recognition (APR), the system can provide a "virtual sensor" proxy for steam flow, which in turn can be used in a more robust control strategy.

Faster starts. As gas turbine and CC plant operators respond to renewables, faster starts are necessary to take advantage of new market mechanisms like fast frequency response. Laurence O'Toole, manager of gas turbine solutions, delineated several techniques to achieve faster starts:

- Advanced steam-cycle control can minimize mechanical stresses on the HRSG during rapid CC unit startups.
- Logic added to the startup sequence for 7EA machines called fast premix transfer can take full advantage



6. Ovation controllers can be "mixed and matched to your heart's content," according to Emerson specialists. Latest addition is the RSTi-EP I/O, a small-footprint, high-performance slice I/O available through the company's broader industrial automation and controls portfolio



7. As the powerplant knowledge platform, Ovation is evolving to support a variety of applications, native or third-party

of the purge credit and increase load ramp rates from 4 to about 14 MW/min (Fig 4). Fast premix transfer allows the turbine to fast start by staying in lean-lean mode until baseload and subsequently transferring to premix mode while at base load.

- Integrating PSM's Autotune solutions into the Ovation controls, for which testing is now complete, with 10 units expected to be installed over the next year—the first in the US by the end of this year.

Coming enhancements include an online test for MOD-27 frequency response, the NERC standard ensuring that turbine frequency/MW response is accurately modeled for grid compliance. APR built into Ovation will provide shorter-term equipment trend conditions based on the high-speed data rates available in the platform.

While these three performance goals were the subject of presentations, they are only a few of the advanced power solutions being made available through the Ovation platform (Fig 5).

For the Ovation geek

Much of Day 2 of the OUG was devoted to the nuts and bolts of Ovation technology advances, generally the purview of the I&C specialists.

VP Technology Steven Schilling started by reminding the audience that what drives Ovation development are "smaller islands of control over wider geographical areas, larger system capacity, and deploying controllers in remote areas using existing networks."

Kephart and Roger Hughes, director of global hardware engineering, went deep into the characteristics of Ovation's scalable controller technology (Fig 6), starting with the OCR1100, a dual-core machine now with 2× to 3× higher processing speed, while maintaining 100% backward compatibility with earlier Ovation versions.

Emerson soon will be introducing the OCR3000, the next generation of its "flagship" controller, according to Kephart. "Both controller families have similar capabilities, but footprint and capacity are the distinguishing features." Consistency is maintained between the two families of controllers.

The OCR3000 features quad-core technology with 3× to 4× higher processing speeds (depending on the applications running), and network connections available on the backplane to make it "plug and play."

Ovation also teased its answer to a PLC, a new micro-controller that initiates a secure virtual private network (VPN) between routers, "effectively eliminating separate routers at local remote sites," according to Kephart, "and reducing the number of moving parts." Essentially, you get PLC I/O on a DCS platform, he added.

Hughes lauded the very small form factor of the I/O in the controller and noted the flexible user configurable I/O built into the design. Standard Ovation tools familiar for remote I/O are available. For example, Kephart noted that you can plug in a laptop and make changes locally.

The stand-alone version includes what Kephart called "lightweight engineering tools" based on Windows 10, a temporary database server running SQL, and an HMI available locally or from a laptop. Applications are housed in the controller itself.

Moving on to the digital twin, Kephart called it a "mature" and proven product, that now includes integrated simulation with tools that reconcile the Ovation simulator with the production or plant control system without disruption, all "being worked through beta sites right now." He called synchronized simulation, or live digital twin, the "holy grail" for which Emerson is now evaluating a few pilot projects.

Operator assistance gets really interesting when you combine the live digital twin with the Ovation Process Analytics Studio. Live simulation can be used to locate sensor failures while providing replacement data. "It's like a modern automobile when the driver swerves into another lane and the control system guides it back. The system can recognize impending equipment failures and respond accordingly, or provide expert guidance about how operators should respond."

The analytics applications are fed data from the Ovation process historian which incorporates an asset hierarchy replete with failure modes and effects analyses (FMEAs). The controllers are so powerful and fast now that APR functions (also called machine learning technology) can reside on the controller, sort out poor signal quality and bad data, and provide sensor diagnostics. This gives a cleaner, high-speed data set which can be inputted to higher-level functions at the M&D center, or used locally.

"Think of it as your iPhone applications," Kephart suggested, "and the apps don't even have to be from Emerson" (Fig 7). The practical way to visualize all of this is to realize that all of the functions—such as predictive analytics, thermal performance monitoring, alarm management, and process optimization— hanging off of, say, a siloed data historian in many powerplants, can now be run faster, cleaner, and more secure as part of the Ovation platform.

And more plug-in applications are in the pipeline, says Kephart. One example is a performance monitoring tool for control loops. "We can calculate and present a real-time 'health score' for each control loop," Kephart said.

And just to make sure the audience knew it was in Jetsons' territory, Jaime Foose tantalized the audience with a reference to an augmented reality technology that allows anyone (especially Emerson services staff) to provide direction to the plant through the screen. The technology is now being piloted in the Emerson central service region for external customer support, and is perhaps the finest example of how COVID-19 has forced everyone to reconsider how technology can be harnessed to get work done and keep the lights on during these abnormal times.

Insights from Q&A sessions

After the presentation of the Emerson facility awards (congrats to University of Texas at Austin and its campus microgrid project for winning the innovation award; project details in CCJ No. 55, p 48), Day 3 was devoted to a lengthy Q&A session, with many questions from users not surprisingly focused on COVID- and cybersecurity-related issues.

One could imagine that the audience breathed a collective sigh of relief when the Emerson team said that there had been no impact on customer support from COVID travel restrictions.

To a question about NERC cybersecurity alerts, the Emerson team responded that they monitor the alerts on a daily basis and respond to customers within 24 hours.

Users also had many questions about controllers, such as: Can the OCR3000 be used in the same network as the OCR1100? Answer: Yes, and also the OCR400; you can mix and match "to your heart's content." The flash card in the OCR400 has been replaced with an industrial-grade compact flash storage device, which can be formatted in place. This, to Emerson, is a more reliable solution because you don't have to remove flash devices.

Two questions on renewables and grid storage systems elicited that Emerson is responding to many inquiries for battery and energy management systems from engineering firms and that H_2-based system inquiries are growing. Emerson now has several combined PV solar + battery projects under its belt. Ovation systems now control approximately 3000 MW of solar in North America and Emerson has put in place strategic partnerships to address optimization and obsolescence issues with control systems at legacy wind facilities.

One user asked about lead times to replace old GE excitation systems (in this case, for a 200-MW unit), something clearly on the minds of many in the GT user community, and the answer was lead times vary based on the type of exciter being replaced (whether it is rotating or static), existing space considerations, and the bridge size required to meet the generator specific needs.

Finally, responding to a user concerned about the transition from OCR1100 to OCR3000 controllers, Emerson said the upgrade would be straightforward, 100% compatible with existing Ovation hardware and software, and lead to faster processing speeds and lower power consumption. Because the "base is 100% compatible with the old base, it's basically a swap out."

Out of adversity…

…comes opportunity, or so they say. Last year, Jim Nyquist, Emerson's group president for systems and solutions, opened the OUG by proclaiming this to be "the most challenging environment in history for power and water." Twenty-twenty has likely eclipsed 2019 in the challenge category, but COVID will undoubtedly prove to be a propellant for achieving, through the Ovation platform, the vision Yeager laid out 25 years ago. CCJ

Highlights of presentations by owner/operators, vendors, consultants

The 2020 conference of the Generator Users Group (GUG) was conducted online for the first time this year, between November 12 and December 10—too late to review in this issue.

Here the editors summarize the presentations and key points made by users and suppliers from the 2019 meeting—timeless content not covered previously by CCJ.

To help owner/operators prepare for the meeting, noted consultant Clyde V Maughan of Maughan Generator Consultants developed a four-hour review of generator design, operation, failure modes and root causes, monitoring, inspection, test options and risks, and basic approaches to maintenance. Content is from his respected 2½-day generator training program, attended by more than a thousand utility personnel over the years.

If you weren't among the more than 400 registrants for the online presentation at the end of October, access the recording on the CCJ website at www.ccjonline.com/onscreen. It is of value to users regardless of their level of knowledge on electric generators.

By way of background, GUG was formed in 2015, with Maughan guiding the launch and NV Energy hosting the first meeting in its engineering offices. Today the group operates under the Power Users umbrella, an organization run by users for generator owner/operators to enable the sharing of experiences, best practices, and lessons learned focusing primarily on design, installation, O&M, overhaul, upgrade, and safety.

A quick look at the names and affiliations of the steering-committee members below tells you if there's one meeting that can get you up "up to speed" on generators, this is the one:

- Dave Fischli (2020 chair), Duke Energy.
- Ryan Harrison, Heartland Generation Ltd.
- Jagadeesh Srirama, NV Energy.
- Jane Hutt, IGTC.
- John Demcko, EUMAC Inc.
- Jeff Phelps, Southern Company.
- Kent Smith, Duke Energy.
- Joe Riebau, Exelon.
- Craig Spencer, Calpine Corp.

To dig deeper on the topics that follow, access speaker PowerPoints on the Power Users website at www.powerusers.org which are available to registered owner/operators only. If you don't already have a "library card," register today. It takes only a few minutes.

User presentations

Replacement of bushings. The focus of presentations by owner/operators was near equally divided among stators, rotors, and inspection/testing/general. One concerned the replacement of bushings on a nominal 265-MW (1980 COD) hydrogen-cooled generator that runs only four to five months annually at baseload. The well-illustrated presentation covers testing and repairs conducted to enable decision-making, issues faced during replacement (confined space, terminal plate bonded to the bushing plate, etc), and challenges post replacement—including the loss of hydrogen and a blown isophase connection.

Stator, rotor rewinds. The same user also presented on the rewind of both rotor and stator on a 65-MVA, 13.8-kV generator. Periodic maintenance testing revealed a high dc leakage value (120 microamps leakage at 1.25 times the dc value) and a winding resistance unbalance of more than 5%. Plus, rotor inspection revealed shorted turns and loose blocking.

During the rewind, one of the contractor's staff got a drop of glue in his eye and the use of goggles was made mandatory. After the rewind, the end-winding was re-blocked.

Return to service was not smooth, the unit tripping within one second after start attempts. The gremlin: The shorting cable installed on the CT circuit was not removed after generator testing.

Then issues surfaced in the excitation system. Personnel found one diode wired incorrectly on the rotating diode bridge. It took three days to rewire the diode bridge.

EMI testing. A hot topic in generator circles continues to be electromagnetic interference (EMI) testing to detect failing electrical connections—in particular, those inside generators and bus systems. Two significant presentations were made on the topic at the 2019 GUG meeting, with the dialog continuing at the 2020 conference.

EMI has been used since the 1950s, possibly earlier, to locate defects in power lines that cause radio and TV interference. Application to powerplant equipment began in about 1980, motivated by the work of several Westinghouse engineers who found that energy discharges in electrical equipment—such as arcing and partial discharge—produce a broadband high-frequency emission pattern. The radio-frequency (RF) currents produced, the engineers said, flow in the machine neutral connection with a magnitude and spectrum signature that can be recognized and differentiated from other RF signals which may be present.

"EMSA [electromagnetic signature analysis] Training," the first of the EMI presentations last year, is highly recommended by the editors for the background it provides. A significant portion of the presentation is devoted to work done since 2015 by National Instrument and a major utility to develop an affordable instrument for "continuous" monitoring of EMI in generators and transformers.

Fast forward to today, the utility has installed the instrument developed on more than 80 generators and 120 transformers in its fleet. A full-spectrum reading, taken about every 15 minutes, produces data for trending.

The presentation is particularly valuable for what the utility has learned over the years. Here's a summary of that experience across the four frequency bands of primary interest:

- 30 to 500 kHz. In this region, diode and SCR/Thrystor firing patterns are seen and the following issues can be identified, among others: dirt contamination on diodes, SCRs, and Thyristors; loose excitation cables/connections; missing SCR firing patterns, etc.
- 500 kHz-5 MHz is where issues in the core slots of motor and generator windings likely would be identified—including loose wedges, slot discharge, and back-of-the-core arcing.
- 5 to 30 MHz. Issues associated with motor or generator endwinding structure are likely identified in this frequency band—including loose winding basket, corona in the endwindings, broken strands, etc.
- 30 to 100 MHz. In this frequency band, issues associated with the generator output bus and isolated-phase bus generally are found. Look for cracked insulators, insulator contamination, water intrusion, etc.

Another resource on the subject is the article "Simple EMI Test Detects Failing Joints, Promotes High Plant Availability," by Consultants Clyde V Maughan and James E Timperley, published in CCJ No. 60 (2019), p 20. You can access it by using the search function on the CCJ home page at www.ccj-online.com.

The second presentation last year on electromagnetic interference, "EMSA and IPB," is a case history spanning several years that probably would be of interest to anyone having had to deal with moisture and other issues associated with isophase bus (IPB). In the end, EMI testing confirmed the generator was not the source of the problem as suspected by most "experts"; rather, it was a defective through bushing from the IPB to the B-phase potential transformer.

Field vibration, thermal sensitivity. One user presented several case histories, each with one or more detailed graphs of meaningful operating data and several highly instructive photos. The first case of an instantaneous increase in generator field vibration was caused by loss of mass. A step change in vibration was noted during a routine startup of the gas-turbine driver. Amplitudes were acceptable to allow the unit to remain in service until a planned shutdown about two days later.

Investigators found a liberated fan blade and stator winding damage when the generator was opened for inspection. The root cause: Improper installation of the bolt locking tab on the affected fan blade.

A second case history presented by the same user also concerned the liberation of a fan blade—this time in the generator coupled to the steam turbine. Once again, the unit was allowed to remain in service following the step change in vibration until a planned shutdown, this time in four hours. Inspection revealed a liberated fan blade and stator winding damage, plus many other bolts well below the design torque value. The root cause was high bending stresses on the bolt which led to fatigue cracking. Note that the fan was designed with a single bolt per blade.

A change in mass distribution caused a step increase in vibration (typically about 2 mils) on yet another generator, but here it was because one of the retaining rings was pushed off-center by the copper winding under certain operating conditions. This has occurred periodically for many years. Correction: Bring the unit to turning gear, then back to speed to reset the retaining ring in the proper position.

Thermally induced vibration attributed to end-turn blocking was experienced by a large 2-pole field with eight coils per pole. Root cause: Blocking between the No. 8 coil and centering ring rotated out of position during installation. At high field current, the vibration increased by 1 to 3 mils and was not consistent in behavior. Multiple compensation balance-shot attempts were made over a five-year run.

Thermally induced vibration attributed to copper binding in slots was the subject of another case history. Investigators found copper yielding in the slot exit area of three coils exceeded the design clearance in the slot. Looking at the generator's operating history, engineers found the unit had experienced full-load rejection (FLR) a couple of times during the tuning of a new control system.

They believed that over-speed during the FLRs caused the position of the copper to shift relative to existing worn grooves in the slot liners. Copper expansion was limited and vibration increased/decreased proportional to field current. The field was rewound and the affected copper turns replaced.

Accidental energization. Your generator is designed to guard against inadvertent energization, but owner/operators should be aware unusual conditions that bypass the protection scheme for your machine can occur. And even with protection in place, the speaker said, there is no certainty that an inadvertent energization event will not cause at least minor damage. He noted that energization even for a few cycles is conducive to high current flow and possible arcing.

This introduction to the subject should provide the incentive to read on.

First the background: Accidental energization occurs when 3-phase voltage is suddenly applied to the generator terminals. Such an event is classified as "severe" when the rotor is at standstill or on turning gear.

What happens upon energization is that a rotating flux at synchronous frequency is introduced into the field. High-amplitude currents, similar to negative-sequence currents, circulate in the rotor. The generator behaves like an induction motor and the rotor attempts to accelerate. The result is rapid and excessive heating, particularly at locations of high current density and/or high-resistance connections—such as wedge-to-wedge and retaining-ring interference fits. Damage typically is associated with the rotor forging and rotor components, not the field winding, stator core, and stator winding.

Industry experience, the speaker continued, suggests that inadvertent energization events that are cleared quickly—within one second—will cause minimal damage—possibly no damage at all. However, events longer than a second are almost certain to cause damage, severe damage if the event is more than a few seconds in duration.

The case history presented, supported with many high-resolution photos, describes an inadvertent energization event that occurred when the subject 224-MVA, 20-kV generator (COD 1958) was on turning gear. The machine has a field winding with eight coils per pole and is of the tight-fit wedge design. The field had been rewound in 2003.

The details: A disconnect switch was closed onto a live bus and the stator winding was immediately energized; the normal protection scheme was bypassed. The rotor attempted to accelerate and instrumentation revealed that a speed of 285 rpm was reached. Duration of the fault was 2.1 seconds.

Calculations were made in an attempt to compare the event with values that engineering standards indicate a machine should be able to withstand for a negative sequence event. Engineers concluded that this event may have exceeded the requirements established by the standards but not necessarily at levels that would suggest severe damage occurred.

Limited visual inspection by experts revealed surface heating, as evidenced by burned paint, had occurred between adjacent slot wedges. Thus, some damage had occurred. Heat-affected metal was expected but couldn't be assessed without disassembly. Investigators recognized that damage to the forging was possible, but viewed the tight-fit wedge design as having a positive impact.

The consensus conclusion was that the unit could be returned to service provided start/stop cycles were restricted until repairs could be made following a thorough inspection at the next outage in about a year. It appeared that the risk of continued service was not that a catastrophic failure might occur but rather that crack initiation and propagation might worsen the damage and increase the repair scope.

That's about what happened. Disassembly about 14 months after the event revealed a greater number of burn marks than the optimistic best-case projections based on the partial inspection. Surface discoloration suggested worst-case heat-affected regions were concentrated at wedge-to-wedge interface areas rather than wedge-to-forging areas.

Topics addressed by other user presentations included the following:

- Dc resistance testing provides the capability to detect high-resistance joints, corroded conductors and connections, poor-quality connections, and shorted turns, a highly experienced engineer told the group. Instrumentation capable of very low resistance measurements with sufficient accuracy, precision, and resolution is required and the speaker provided desirable specifications. Next, the expert outlined a test procedure and reviewed three case studies.
- Endwinding looseness in small machines was the subject of another presentation available in the Power Users library. It covers inspection findings, planning, analysis, repair, and recommendations.
- GVPI (global vacuum pressure impregnation) stator ground fault. Lesson learned concerned the need to inspect NGT cable for shielding and grounding.
- Brushless exciter component failure. This is a "how it really happened" case study that begins with the generator protection relay tripping the unit on "loss of field." The root cause of the problem was found to be a diode module that had failed in such a manner the generator field was shorted out of the circuit. The diode modules were rebuilt with new diodes and fuses.

  Lesson learned by the presenter was that the sizing of fuses for this application was not so simple as one might expect. In this case, the extended exposure to heat created a condition in which the diode shorted but the fuse did not open.
- In-service failure of an AeroPac II generator attributed to a breach of FME (foreign material exclusion) procedures. No obvious findings were in evidence from an initial visual inspection but electrical testing revealed a grounded phase. The field was removed and metal BBs and other debris was found at the bottom of the frame under the core of the generator in the 6 o'clock position. A section of the core had melted. A dead-blow hammer was discovered midway in the stator and determined to be the cause of the failure.

  The second half of the presentation covered repair options and plan of action. The path taken: The extent of the failure and unknowns in restacking a GVPI unit prompted the owner to swap out the failed generator stator (and rotor) with a spare available in company storage. The equipment, manpower, and schedule required for this effort are detailed in the presentation. FME controls at the owner's plants were reviewed to avoid a repeat.

Vendor presentations

"Generator Inspection Outages—Contingency Planning," *Jamie Clark, AGT Services.*

Jamie Clark's message was simple: Increased cycling of ageing gas-turbine (GT) assets, both simple cycle and combined cycle, is causing problems for owner/operators. The proof: Service providers say as much as 60% of their shop effort during outages now

1. Core damage found after emergent field removal

is emergent work (Fig 1). "We're running older units harder than ever," he continued, "harder than they were ever designed to run."

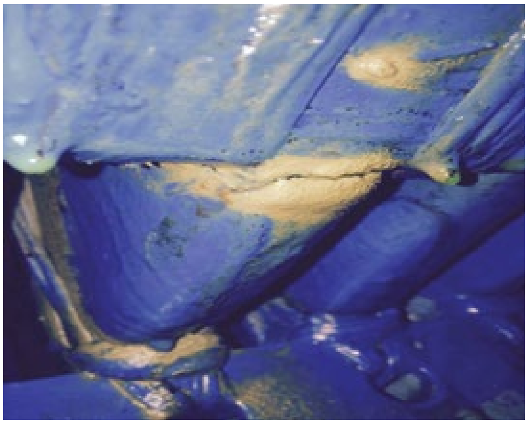
The speaker recommended that attendees follow the *latest* guidelines regarding periodic inspections. These have changed recently, he said. One example: The most recent OEM guidance has no reference to field removal unless prior robotic inspections dictates via findings, or operational events—such as motoring, sync out of phase, generator trips, etc—warrant.

He also suggested users do the following before the outage:

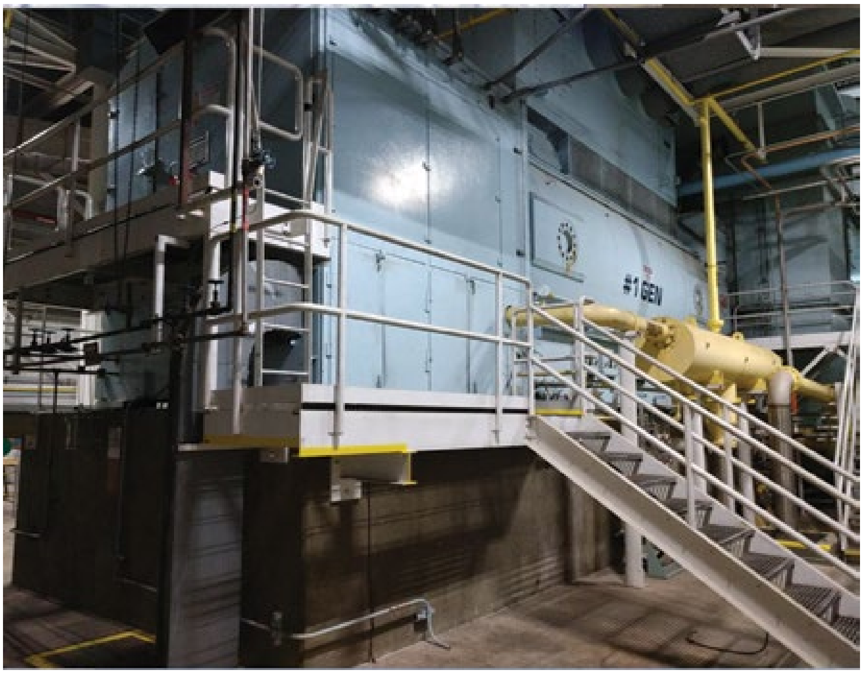
- Take flux-probe readings.
- Do EMI testing (refer back to the third item in the section above on user presentations).
- Conduct partial-discharge testing.
- Review reports from, and since, the previous outage to review what was *not* done as recommended.

Clark next discussed the pros and cons of robotic inspection. At the top of the "pro" list is that robotic inspection avoids the cost and risk of field removal/reinstall. However, findings might suggest field removal, in which case you pay twice unless it's possible to postpone work until the next outage.

The speaker called attention to the fact that robotic inspection equipment is a limited resource, especially with competent operators and generator



2. Endwinding looseness sometimes can be corrected with the field in



3. Generator access is almost always an issue

specialists guiding the work. He suggested releasing robotic-inspection RFPs at least six months prior to the outage and ensuring service-provider commitments are in hand within three months of outage start.

Clark then reviewed reasons for pulling the field and explained work that can be done with the field in. The latter seemed particularly helpful to attendees. Here's what he said regarding the stator: Minor endwinding repairs (tightening, partial-discharge damage, for example) are possible (Fig 2), as is belly-band tightening and possibly even core tightening—provided EL CID validation is possible.

Concerning the field, collector-ring grinding and replacement typically are possible, along with brush-rigging repairs and upgrades. Retaining-ring NDE also can be done, in addition to a few other tasks.

If it becomes necessary to pull the field, Clark reminded, be sure the proper tooling is accessible—including coupling/journal shoes, skid pan, body shoe, slings, turnbuckles, and rigging from stator ends. Don't overlook the benefits of field extraction platforms—for 7FH2s in particular, and possibly AeroPacs. This is not "incidental equipment, requiring possibly two 53-ft tractor trailers. Cranes are another consideration: A 7FH2 field weighs more than 75,000 lb, a GE 324 field about 50 tons. How close can the crane you need get into your unit? Access is almost always an issue (Fig 3).

Clark continued, "So now your field is out and you'll be shipping it offsite, what do you need to know?" Come up to speed on permitting procedures and details. Figure it will take a couple of weeks to get a permit and line up trucking for the optimal route. Be aware of the permit time required and on-road time, the speaker said, advising that it's rarely a good idea for an owner to manage shipping.

Doing field repairs? Figure seven to 10 days minimum, 30 days maximum for these typical repairs:

- Main-lead repair usually requires a No. 1 coil (both poles)—a partial rewind. But keep in mind that if you opt for this plan, the remainder of the field is "old."
- Crossover repairs may require a full rewind.
- Slot armor delamination requires a full rewind.
- Turn shorts usually indicate a global condition: Rewind.

An exchange field might be the best course of action if operating commitments are firm. Keep in mind, the speaker said, that while all 7FH2s and 324s are the same mechanically, they can be different electrically—for example, in numbers of coils and turns per coil, etc. A few points to remember: Only accept an exchange with current high-speed balance and at-speed flux probe data, no turn shorts, high-quality vibration data, and assurance of interchangeability.

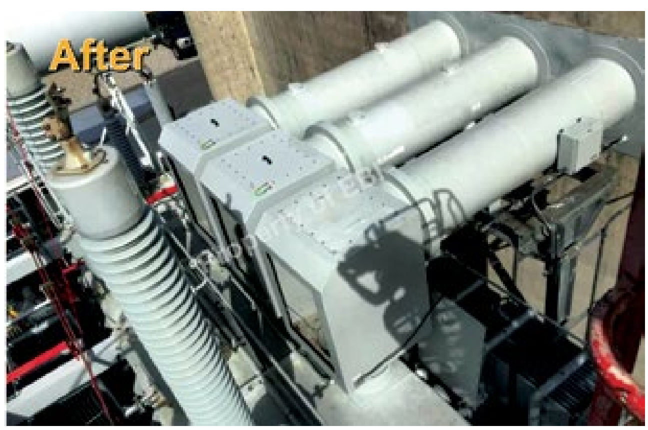
If field removal is in your plan, think about what stator repairs are prudent. Clark concludes his presentation with recommendations for rewedging, repairs to endwindings and connection rings, and a complete stator rewind. The last typically takes between 20 and 35 days, but may go to 12 weeks if bars must be replaced and they're not available off the shelf.

"Rotor Turn Insulation Failure,"

Tyler Foutz, EthosEnergy Group.

Tyler Foutz' short presentation concerned a rotor with 22k hours of run time that was exhibiting intermittent vibrations and flux-probe data discrepancies. Turn shorts were suspected and confirmed. The retaining rings were removed and endwindings inspected (Fig 4). Decision was to rewind. A root-cause analysis confirmed insula-

4. Retaining rings were removed to inspect endwindings



5. Isolated-phase bus systems have no backup and if a failure occurs the plant can't operate tion failure and side-wall interference. Repair quality was confirmed by high-speed balance/flux probe.

"What You Need to Know About the New IEEE Standard to Extend the Life of Your Existing Electrical Bus System," *Steve Powell, EBI-Electrical Builders.*

Steve Powell, known to users for his insightful presentations at annual meetings, reviewed the design, construction, testing, and performance of bus systems, as established by IEEE C37.23-2015 for metal-enclosed gear. He covered voltage ratings, rated insulation levels, continuous current, rated short-circuit and momentary withstand current, short-time withstand current, and temperature limits.

Powell reminded users that isolated-phase bus systems have no backup and if a failure occurs, the plant will be offline until the bus is repaired (Fig 5). He urged attendees to follow the OEM's recommended service schedule (annually during a normal shutdown or every 18 months) and to confirm what you think you see (or don't) with EMI testing and thermal imaging. He also discussed the value of periodic offline inspection and cleaning.

"Modification of a Westinghouse Stator from Diamond Coil to Bar Design," *Andrew Adam, PE, EthosEnergy Group, and Caleb Munholand, The High-Voltage Coil Manufacturing Co.*

The RFQ for a generator stator rewind stated there would be no changes allowed to the nominal 54-MVA (13.8 kV) three-decades-old design except for insulation class (B to F). This stator was one of the largest diamond coils ever manufactured and the OEM and only one vendor still made the component. EEG, currently the OEM for legacy Westinghouse gas turbines and generators with access to original design prints and parameters, was the successful bidder.

EthosEnergy faced manufacturing challenges, as described in the well-illustrated presentation, motivating conversion to a Roebel bar configuration; design and manufacturing details are summarized in the slides. Because overall performance and output of the generator is largely dictated by the field, the speakers said, overall generator capability remained essentially unchanged. The new winding has the same number of turns as the original, resides in the same core iron, has the same amount of copper (or more), and has equivalent losses.

The stated advantages associated with specifying the three-turn Roebel bar design over the three-turn diamond coil are these:

- Elimination of top-strand heating. Temperatures within the winding are evenly distributed because of roebeling.
- Elimination of installation issues associated with the diamond-coil design mitigates significant user schedule and performance risks.

"Fiber Optic Generator Monitoring," *Derek Hooper and George P Dailey, PE, BPhase Inc.*

Better techniques and instrumentation for monitoring the performance powerplant equipment are always welcome. The presenters focus on the use of fiber optics for reducing the risk of generator in-service issues caused by high core temperatures and loose wedges. The presentation includes many slides on development history for those interested in how the technology has evolved.

The stated value of the BPhase developments is the following:

- The core monitoring system can detect any excursion from normal core operating conditions. The data allow plant personnel to see a core thermal event in progress, enabling a controlled shutdown before serious damage occurs.
- The wedge tightness analysis system allows maintenance personnel to follow the degradation of the wedge package over time, enabling the planning of rewedging without need for disassembly or robotic inspection. This can predict coil wear through mechanical vibration and core damage through slot pounding—as the condition will be detected before significant damage can occur.

While acknowledging that fiber-based systems cannot perform visual inspections, the presenters say they can certainly reduce operational risk from wedge tightness and core-related issues, thereby reducing overall risk during extended operation as necessary.

6. Hydrogen explosion attributed to inadequate purging procedures caused the loss of one life and blew out plant windows

"Generator Degassing and Purging: Best Practices for Safe Plant Operation," *Christopher Breslin, Environment One Corp.*

Hydrogen is explosive, colorless, and odorless, as well as difficult to contain. Yet it has been used widely as a generator coolant since the late 1930s because its windage/frictional losses are less than for air and it has excellent heat-transfer characteristics.

It is essential for plant personnel to know and understand the hazards associated with hydrogen and that all equipment for handling and storing this gas must be certified and maintained in top condition (Fig 6). Finally, because purging is an inherently complicated exercise, and can be dangerous if performed improperly, all personnel involved must be well trained, non-sparking tools must be used, carbon dioxide must be readily available in sufficient quantity, appropriate safety signage must be in evidence in critical areas, and keyed lockouts must be provided for "air" and "hydrogen."

Chris Breslin, known by users for his practical and valuable presentations, reviews primary elements of the hydrogen auxiliary system, including useful one-line diagrams, provides guidelines for the purging process and best practices for safe plant operation, and reviews requirements/considerations for automated de-gassing. Consider the presentation for a lunch-and-learn session in the plant conference room.

"Comparison of Low- and High-Frequency Partial-Discharge Measurements on Rotating-Machine Stator Windings," *G C Stone and H G Sedding, Iris Power (Canada).*

The speakers are among the industry's top experts in the partial-discharge (PD) testing of electrical equipment. They draw the following conclusions in their relatively short but informative presentation: Low- and very-high-frequency PD detection methods in machines each have very different advantages. For offline applications, it is clear that low-frequency testing is preferred because PD can be better detected regardless of where it occurs in the winding.

7. **Damage to stator winding** (shown) forced generator out of service

8. **Sniffer** is convenient, effective for locating partial discharge and EMI

For online testing, of transformers for example, the very-high and ultra-high methods are preferred by users because the risk of false indications caused by noise is lower; therefore, test credibility is higher.

To dig deeper on the subject, read "PD Monitoring Helps Guide Stator-Winding Maintenance," by G C Stone, Iris Power (Canada), published in CCJ No. 61 (2019), p 100. You can access it by using the search function on the CCJ home page at www.ccj-online.com.

"Realities of Global Vacuum Pressure Impregnated (GVPI) Impregnated Generator Stator Repair and Rewind," *W Howard Moudy, NEC-National Electric Coil.*

Howard Moudy may have made more presentations at user-group meetings in the last decade than anyone else—in the process covering all types of generator failures and their fixes. At the 2019 GUG conference his topic was the repair and rewinding of a GVPI stator for a 13-yr-old, 100-MVA, air-cooled generator serving a geothermal plant in Indonesia. The unit tripped with damage to the winding and core (Fig 7). Contributors to the failure as determined by a root-cause-analysis investigation included the following:

- Endwinding vibration/resonance.
- Core looseness/hot spots.
- Key-bar deterioration at the core exit—groundwall fretting and thermal deterioration, and strand fatigue.
- Vibration transmitted from the phase-ring assembly.

The owner expressed preference for mechanical removal of the winding despite NEC's deep experience with the generally preferred water-blasting process. The contract was awarded to a local company with NEC in an oversight role. The local firm was able to complete the job with NEC's help and tooling. However, other findings created uncertainties in the customer's mind that led to replacing the entire core. A couple of dozen photos describe the work.

NEC came away from the project with the confidence in its ability to rapidly rewind/rebuild air-cooled GVPI stators anywhere in the world. In this case the time to manufacture a new stator winding and ship it to Indonesia was 38 days.

In his concluding remarks, Moudy acknowledged that the initial cost of GVPI generators is attractive but that there are maintenance concerns and limitations associated with a decision to go with GVPI. Finally, he said that with proper engineering and planning, GVPI generators can be rewound effectively to a coil VPI design that is more easily maintained and conducive to long-term reliable operation.

9. **Magnetic field** is measured in the vicinity of 480-V switchgear

Consultant presentations

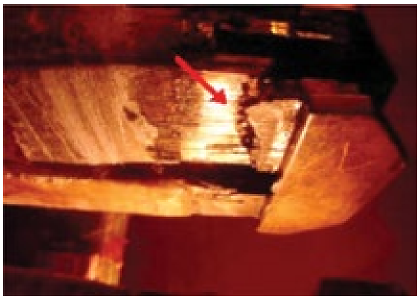
"Detecting and Identifying Generator System Conditions with Radiated EMI Measurements," *James E Timperley, Charles Taylor Technical Services.*

Jim Timperley is highly respected for his knowledge on the use of radiated electromagnetic-interference (EMI) measurements for identifying abnormal conditions in generators and associated electrical equipment. Partial discharge and arcing are among the more than 60 conditions radiating radio-frequency energy that can be identified with the handheld EMI detector known as the "sniffer," shown in Fig 8. It is designed to measure frequencies from 35 kHz to 390 MHz.

The sniffer, Timperley told attendees, provides information on the physical location of developing deterioration and helps pinpoint where maintenance activity is required to prevent failures and lost production. He offers case studies of generator, bearing, exciter, bus, transformer, and turbine problems in his presentation—ideal for a lunch-and-learn in the plant break room.

To dig deeper on the subject, read "Simple EMI Test Detects Failing Joints, Promotes High Plant Availability," by Consultants Clyde V Maughan and James E Timperley, in CCJ No. 60 (2019), p 20. You can access it by using the search function on the CCJ home page at www.ccj-online.com.

"Magnetic Field Measurements in Powerplants and How This May Limit Workers with



10. Stator windings are high on the list of generator problem areas. Shown here is stator-bar strand cracking (left)

11. Collector-ring fires generally can be avoided with a robust inspection and repair program (right)

Pacemakers,” *James E Timperley, Charles Taylor Technical Services.*

By some counts, Jim Timperley says, more than 300,000 electronic medical devices—such as pacemakers, defibrillators, cochlear, and neurostimulators—are implanted in Americans annually. This means that perhaps 1% of all people entering a powerplant may have some kind of electronic medical device. Providing a safe working environment for these individuals is very important (Fig 9).

Electrical interference can pose a serious problem: It can disable any of these electronic devices. This danger can be from high-voltage electric fields, as in a switchyard, or high magnetic fields near large generators, bus systems, and/or transformers. Plant personnel normally are protected against dangerously high voltages by secure fences or metal structure.

However, high magnetic fields are another matter. Signage warning to maintain a safe distance is a necessity. Timperley offers guidance on where to place signs or limit personnel exposure. The editors suggest that you access it on the Power Users website at www.powerusers.org.

Alternatively, read “Working Safely in a Powerplant with a Medical Implant,” by James E Timperley, in CCJ No. 64 (2020), p 110. Access by using the search function on the CCJ home page at www.ccj-online.com.

“Combined-Cycle Plants: Most Significant Generator Reliability Issues in 2019,” *Bill Moore, PE, Electric Power Research Institute.*

Bill Moore, well known in the electric power industry, currently is EPRI’s technical executive for generators. His resume reveals years focused on generator inspection and repairs at a leading third-party services provider.

In 2019 he surveyed subject-matter experts at EPRI member companies, asking them to identify their Top Five combined-cycle generator issues. Responses were received from 59 SMEs at a dozen major utilities around the world.

Moore told attendees at the 2019 GUG conference that GE’s 7FH2 generator dominates in the combined-cycle market and that more than a thousand of these machines have been manufactured. One utility responding to his survey has more than 50 7FH2s in its fleet (total of generators in combined- and simple-cycle units), another more than 20.

The leading generator problem areas identified are rotor field winding, mentioned in 24% of the responses; stator winding, 20% (Fig 10); collector rings, 8% (Fig 11); and oil ingress, 7%. Fourteen more issues were identified in 24 of the responses, all at less than 7%.

The EPRI executive lists specific issues identified in each of the leading problem areas—such as J-strap, main-terminal stud-connection, and main lead failures on field windings. He then provides details for some of the issues and makes recommendations to users experiencing field failures.

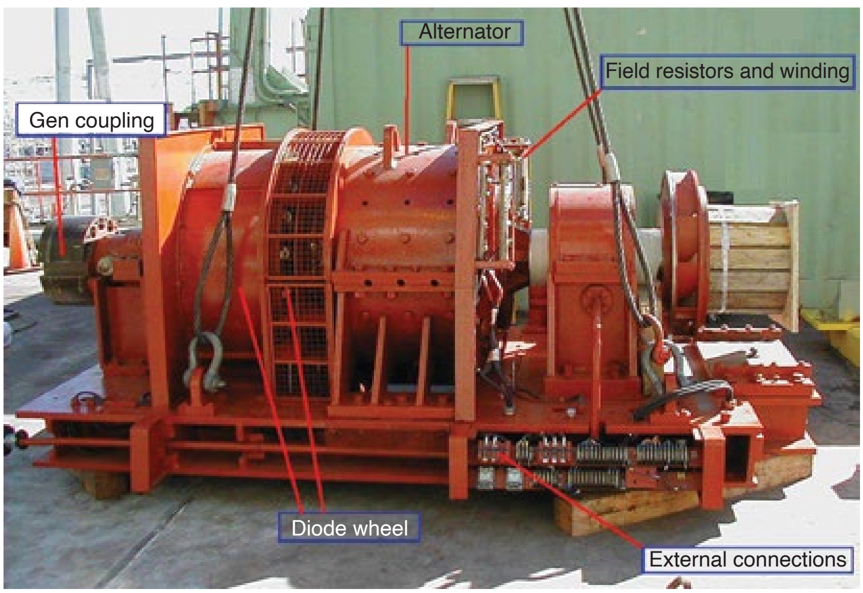
Regarding the last point, Moore suggests owner/operators determine if the rotor field winding is susceptible to failure and if the winding design is sufficiently flexible for the service profile. One recommendation: Inspect connections at 500 starts if the generator is cycling on/off and if it is in “flexible” service.

Asset managers, plant managers, and maintenance managers at plants with 7FH2 generators may benefit greatly from reviewing Moore’s presentation, available on the Power Users website.

“SF_6 in Hydrogen-Cooled Generators,” *Neil Kilpatrick, GenMet LLC, and James Bellows, James Bellows and Associates.*

The presenters shared their knowledge on the injection, into generator hydrogen, of small quantities of SF_6 to enhance coolant leak detection. Some in the industry, they said, question the advisability of leaving the tracer gas in the generator after testing is complete given concerns with its decomposition products hydrogen fluoride (HF) and hydrogen sulfide (H_2S). Recall that both are aggressive acids with adverse health effects.

SF_6 has a high density compared to hydrogen and tends to collect in the H_2 circuit’s dead zones where it can cause problems. One mentioned by Neil Kilpatrick and James Bellows: Decomposition product H_2S is known to be associated with stress corrosion



12. Brushless exciters have no brushes to wear out or check, but diode-wheel fuses must be closely monitored cracking in high-strength steels—such as retaining rings, blower hubs, rotor-forging tooth tops, and high-strength threaded fasteners.

Given the importance of safety in the workplace, the speakers focus on SF_6 decomposition and toxicology in half their slides to help you objectively evaluate the use of the tracer in your plant. In their opinion, there is reason to have concern for safety, given the potential for damage conducive to a tooth-top rupture or retaining-ring failure; plus, the potential for occupational exposure to SF_6 decomposition byproducts.

Concerned? What are your options? Kilpatrick and Bellows suggest a thorough purge of SF_6 from the generator after leak testing and before operating; alternatively, use another tracer gas.

"Excitation Systems 101," *John A Demcko, PE, EUMAC Inc.*

John Demcko opened his valuable primer with the question: What's an exciter? He answered the question thusly:

- A source of magnetizing current for the synchronous generator's rotor.
- Control of generator voltage.
- Supply or absorb reactive power (VArs) from the grid.
- Enhance power-system transient stability.

Demcko then described the types of excitation systems, using his decades of utility experience to review the pros and cons of each. Circuit diagrams and photos facilitate understanding of the technical material presented.

Static excitation has no rotating components, but collector rings and brushes are present and require close monitoring. Pros: (1) Very fast response, enhancing generator transient stability. (2) Can be made completely redundant up to the collector rings. (3) Simpler to understand and troubleshoot than a brushless system. (4) Field-ground detection systems also are simpler, and potentially more reliable than on brushless systems. Cons: Demcko identifies 10 cons—such as not being able to mix brush types and manufacturers—that make dealing with brush rigging and collector rings as much an art as it is a science. Access his presentation on the Power Users website at www.powerusers.org.

Brushless excitation pros:

- No brushes to wear out or check (Fig 12).
- No collector rings to fail, wear, or imprint.
- Reduced inspection and maintenance requirements.
- Less personnel exposure to dangerous equipment.
- Exciter power supply is immune to

system voltage dips/sags compared to a bus-fed static system.

Cons:

- Complicated system to understand and troubleshoot.
- Must closely monitor diode-wheel blown-fuse indicators.
- Limited redundancy (only in stationary elements).
- Field-ground detection systems more complicated and expensive than for static excitation.
- Usually slower performance than for an equivalent brushed exciter.
- Alternator maintenance can be expensive and require expertise.
- Forced outages can extend for periods longer than expected.

Rotating alternator/dc generator excitation systems are discussed by Demcko to make his primer complete. But their day has passed, generally dating back half a century or more. The upgrade of some systems to modern digital regulators may have postponed a few retirements, but with the closing of ageing solid-fuel-fired fossil units this class of exciters is disappearing.

"Generator Copper Braze Joint Application Fundamentals, *Neil Kilpatrick, GenMet LLC.*

Neil Kilpatrick, a materials expert, opened his insightful presentation by acknowledging that copper braze joints are key to the successful performance of large generators. No argument there. Continuing, he said, "In the present day they provide high reliability and mostly maintenance-free operation." No argument there either.

Then Kilpatrick hammered home the reason for his presentation: "This has not always been so over the history of large generators. This discussion on application fundamentals covers things that have been learned over the past 50 years or so." Best practices and lessons learned regarding copper braze joints for gas- and water-cooled configurations is why you want to review Kilpatrick's slides. Avoid remaking mistakes aleady corrected.

The challenge for electrical joints in large generators is that they must also serve as mechanical joints. While copper has outstanding electrical qualities, its structural capabilities are relatively poor. Kilpatrick walks you through the following:

- Braze-joint functions.
- Braze-joint configurations.
- Braze-joint internal conditions.
- Hydrogen embrittlement of electrolytic tough pitch (EPT) copper.
- Braze-joint failure modes and mechanisms—electrical overload/overheating, mechanical overload, and fatigue. CCJ

KNECHTIONREPAIR®

"connection repair"

A uniquely designed tool that will repair your cross threaded industrial Swaged type compression fittings in seconds!

KnechtionRepair tools are designed to make thread repairs to both the internal/female and external/male threads of industrial standard two ferrule Swaged type compression tube fittings. With its uniquely designed holder and hollow bore tap, damaged threads are easily repaired.

Available now tap and die repair kits for 1/4", 3/8", 1/2", 5/8" and 3/4" tube fittings. Coming soon repair tools for your Hydraulic JIC , Aircraft AN fittings and turbine T/C fittings. KnechtionRepair also takes special orders for your problem connections.

KnechtionRepair tools are 100% manufactured in the USA. Order your tools today and save on fitting replacement , down time and money! To view a video demonstration of the thread repair process and watch a live pressure test visit us at www.knechtionrepair.com

For more information and to place an order email info@knechtionrepair.com or phone (907)688-5051
www.knechtionrepair.com

Hot topics: Valves/piping, outage management, bearings, lubrication, insulation

The 2020 conference of the Steam Turbine Users Group (STUG) was conducted online for the first time this year, between November 11 and December 9—too late to review in this issue.

Here the editors summarize the presentations and key points made by users and suppliers from the 2019 meeting, and a couple from the 2018 conference—timeless content not covered previously by CCJ.

By way of background, STUG was founded in 2014. What began as an annual conference focusing on GE A10 and D11 steam turbines for combined-cycle plants is now a meeting covering steamers of all makes and models used in the production of electricity.

The group operates under the Power Users umbrella, an organization run by users for owner/operators to enable the sharing of experiences, best practices, and lessons learned focusing primarily on design, installation, O&M, overhaul, upgrade, and safety.

A quick look at the names and affiliations of the steering-committee members below tells you if there's one meeting that can get you up "up to speed" on steam turbines, this is the one:

- Eddie Argo (2020 Chair, Southern Company.
- Jess Bills, Salt River Project.
- Gary Crisp, NV Energy.
- Jake English, Duke Energy.
- Jay Hoffman, Tenaska.
- John McQuerry, Calpine.
- Matt Radcliff, Dominion.
- Lonny Simon, OxyChem.
- Seth Story, Luminant.

To dig deeper on the topics covered below, access speaker PowerPoints on the Power Users website at www.powerusers.org, which are available to registered owner/operators only. If you don't already have a "library card," register today. It takes only a few minutes.

1. Stellite liberated from a large block valve was captured by a strainer protecting the steam turbine

User presentations

The speaker making the first technical presentation at the 2019 meeting discussed damage to the first three stages (blades and diaphragms) of his steamer caused by what he termed "magnetite throw"—a way of describing solid-particle erosion. An attendee mentioned that strainers were added to bypass valves at his plant to protect the turbine against such damage but he couldn't contribute operational information to testify to the efficacy of this approach.

Trying to get meaningful discussion going early, a member of the steering committee asked attendees: "What's the correct way to test the emergency overspeed trip?" He said the OEM had over the years assisted in checking the functionality of the overspeed trip. Recently he had heard that GE was writing software into the Mark VI to confirm trip operability without physically shutting down the machine. No one offered a comment.

A participant representing a 2 × 1 combined cycle said one of his plant's heat-recovery steam generators (HRSGs), on an all-volatile treatment program, was showing high silica readings—and they were increasing over time. An attendee suggested that drain valves might not be operating properly. The affected user was urged to post a question on the HRSG Forum on the Power Users website. That online forum is chaired by Bob Anderson, chairman of the leading user group serving HRSG owner/operators, the *HRSG Forum with Bob Anderson*.

Valve seat delamination. The session moved on to a user describing damage suffered by a 262-MW D11 turbine at a 2 × 1 F-class combined cycle because of seat delamination associated with HRSG steam valves (Fig 1). The clue that something was amiss: Following a routine valve test, operators recognized that throttle pressure had to be increased by 70 to 80 psi above "normal" to maintain desired output—symptoms consistent with possible steam-path fouling or damage.

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

Three run-versus-repair options were considered for the steam turbine:

- Repair now (reliability outage). This lowest-risk option would require extending the current outage by six weeks and would result in significant unbudgeted expenses. Plus, the potential for additional discovery could add to both the time and cost of the outage.
- Run short and repair when new buckets arrive. This would permit increased time for planning the optimal outage. However, the recommendations by experts would include a reduction in steam pressure (reducing output by about 12 MW) and no cycling of the unit offline. Plus, there is a risk that unidentified cracks might propagate.
- Run until the major maintenance outage planned for spring 2019. Essentially the same pros and cons of running short, except a higher likelihood of cracking and damage because of the longer time between the outages.

Recommendations made to station management was to run until the spring 2019 major and order new buckets and diaphragms from GE for the first four stages of the unit. Important, too, was to monitor the unit for noticeable changes in operation that would indicate additional damage. Also recommended was initiation of a fleet-wide program to inspect and replace similar stellite valve parts and assemblies.

2. Trailing-edge erosion in evidence on last-stage turbine blade was attributed to operation at low load

3. Hydraulic actuators for steam valves are considered by some experts as the "most overlooked" component in a powerplant. Actuator here is secured in a custom shipping container for a shop visit

L-0 experience. A user discussing the design, operation, and maintenance of late-model L-0 buckets suggested that plant personnel track blade condition and failure probability over time to answer questions posed by corporate financial staff regarding operational risk. He reported finding indications on six L-0 blades extending from 0.25 to 0.33 in. from the trailing edge. One bucket was found with a 1.25-in crack starting in an area impacted by erosion.

An EPRI presentation complementing this experience urged station personnel to identify and track locations of erosion and to identify the source of the water. The speaker said erosion is heavily impacted by the angle of droplets hitting the bucket. He added that liquid droplet erosion can be found on leading and trailing edges on last-stage blades while operating in normal and off-design conditions (Fig 2).

The speaker encouraged the development online monitoring and inspection tools to identify damage on rotating equipment and to track the progression of LSB erosion. It was said that plants operating baseload can avoid erosion problems by using titanium L-0 titanium blades.

The topic of intervals between minor and major steam-turbine inspections was brought before the group. One user said he had two turbines running 80k hours to majors but said this might not be a time-based function for at least some machines. Depending on how your turbine operates, he said, you might want to schedule inspections based on operating hours adjusted by a starts factor. One practical suggestion was to check steam-turbine valves during 32k gas-turbine majors (Fig 3).

More on valves. The steam-turbine main stop and control valve presentation by an offshore user is especially valuable for its thoroughly labeled design and construction drawings and notes on how the valves operate. This introductory material facilitates understanding of the valve problems discussed in the remainder of the presentation. Used alone, the design and construction slides could serve well as a lunch-and-learn presentation and/or as a pre-outage primer for those involved with steam-turbine valve inspections.

Valve problems discussed by the presenter included the following:

- Valve sticking during operation/testing.
- Control valve closes during test but opens again.
- Stop valve closes during test but opens again.
- Turbine rolls off turning gear when stop valve opens.
- Stop valve over-travels during closing.

Possible causes associated with the stated valve problems:

- Oxidation buildup on the bushing/stem section.
- Oxidation buildup on the balance-chamber section.
- Valve internal damage.
- Actuator issues.

Sticking problems with steam valves are mentioned frequently in STUG meetings. This user's data from 2016 indicate why. He said the number of times control valves did not close below 95% open while performing online daily testing numbered six during a calendar year for one of his turbines, nine for another, and 10 for the third.

He then illustrated by way of several photos the valve dismantling procedure typically used to gain access to address the cause of the sticking problem. For the valve shown, there was oxidation buildup on the balance-chamber section—between the outside surface of the control-valve and the balance chamber.

The measured clearance at one location was 1 mil, not even close to the design clearance of 19 mils. Clearances before and after cleaning were provided at seven points along the disc's path from close to open and vice versa. Clearances after cleaning were 18 or 19 mils at each location.

The root-cause analysis provided an interesting result. Poor steam chemistry was an early suspect, but all documentation received from the laboratory indicated that steam quality was perfect. What many readers may not know, the presenter said, was that the 12-chrome material used by GE in its steam-turbine valves has a short oxidation life—typically two to three years.

And, as you might have suspected, valve tests were not being performed daily and the valve operated in the full-open position for months—against the OEM's recommendation and a cause of a more rapid rate of oxide buildup than normal. Daily testing would have helped to break up/remove the oxide layer forming and keep the valve operating freely for a longer period.

Three short presentations with both user and supplier participation addressed various aspects of cyclic-operation effects on stop/bypass valves designed for baseload service. The valves discussed feature a wear-resistant stellite inlay on the stem. Historically they operated reliably (no stem failures) with maintenance intervals of 24k EOH (equivalent operating hours). Stems were replaced at that interval because of erosion in the inlay region and/or bending at the threaded end of the stem that engages the stop-valve (SV) bypass disc.

But the wear and tear contributed by the shift to intermediate/cyclic operation dictated a change from traditional thinking. As a first step, a high-temperature diffusion coating process was implemented to increase the resistance to SPE (solid particle erosion) of the valves, which were manufactured with stellite 6 weld inlay in the erosion region of the bypass disc skirt. The coating increased to 130 hours the service interval for SVBP valves.

Note that service hours here are calculated by adding the SV bypass pre-warm hours and SV bypass online hours. As a frame of reference, consider that in baseload operation the SVBP valves might accumulate about 60 service hours during a 24k EOH maintenance interval, but in cyclic operation, with more hours in full-arc mode (throttling on SVs rather than control valves), that number might increase four-fold.

Manufacturers have responded with upgraded valve designs to improve the resistance of main-steam turbine stop valves to SPE. These would increase maintenance inspection intervals beyond the 130 hours provided by the diffusion coating. A non-OEM supplier presented on its design, compatible with legacy system requirements, noting that a redesign does not eliminate the underlying problem—solid particles released in the boiler—rather it reduces the effect particles have on valve components.

The OEM also offers an improved erosion-resistant design for the D11 fleet of stop valves currently being inspected on an 18-month interval. The design modification, it was said, incorporates a 50-deg seat/disc angle and changes the internal steam flow characteristics to redirect the particles away from the valve stem during throttling and high steam-flow velocities. In the design described, erosion occurs on the valve pressure-seal head assembly, which is hardened and reportedly erosion tolerant.

Given the recent valve developments, the presenter said his company has two cost options to consider:

First, it can perform stop-valve

maintenance with outages at 130 SVBP service hours and replace steam-valve wear parts without inspecting the control, reheat, or intercept valves. At the following interval, the valve outage would include maintenance on the steam, control, reheat, and intercept valves. This would involve purchasing a set of spare stop-valve subassemblies and rotating of the spare assemblies into stock as repairable items. The repair of spare SV subassemblies would be done on straight time during off-peak shop hours.

Second, retrofit the stop valves with an improved design that would allow longer maintenance intervals and return to a traditional maintenance cycle with all valves inspected and repaired. Note that the second option eliminates the stop-valve-only outage required by the first option.

"D11 Main-Steam Lead Piping Cracks" is a timeless presentation that all O&M personnel should consider reviewing. The detailed case history begins, as you probably would expect, with deck-plates personnel noticing a small steam leak—in this case, in the HRSG steam supply line at the tee where it splits to go to the turbine's two main-steam stop valves.

The steamer was taken out of service, insulation removed, and the pipe inspected visually. Cracks were found at the tee-to-reducer weld on one side of the pipe. The 12 × 14 reducer was removed. Then the tee, and the piping on the turbine side of the reducer, were checked visually. Of course, more cracks were found: How often do you find only one?

A crack was discovered on the inner wall of the tee at the horizontal-to-vertical transition. It was ground out and a penetrant inspection confirmed it had been removed. While NDE technicians were onsite, PT was conducted at the bottom of the tee, at the low-point drain junction. More cracks were found there. The still more cracks were found in the exposed sections of the steam piping. The result: The tee and 12 × 14 reducers on either side of it were replaced. Still more cracks were found later in several welds, including a couple of through-wall cracks.

An engineering review of system history was conducted. The piping had been exposed to approximately 730 startup/shutdown thermal cycles since COD, plus nearly a thousand transitions from 2 × 1 to 1 × 1—likely more severe transients than designers would have expected.

No PM records having being found, investigators concluded that inspections of main-steam-system welds had not been conducted after plant construction—perhaps because historical industry experience suggested this was a low-risk system. They also concluded that the root cause of the cracking was water intrusion.

Supporting this conclusion was that the steam-seal spray-water control valve and associated automated blocking valve had suffered erosion damage and/or seat degradation. This was already known and the unit was operating with the steam-seal spray-water manual isolation valve closed until an outage opportunity.

The leaking valve allowed water to enter the main-steam piping. During normal operation, the leak-by would have flowed to the steam-seal header, where drains removed it from the system. Erosion across the steam-seal spray control-valve seat likely was the result of excessive cycling. The seat was replaced.

The RCA investigation dug into the details, confirming that the cause of cracking in the main-steam system was thermal fatigue crated by cool water inadvertently entering the pipe while the unit was online or shortly after shutdown. Leaking valves in the steam-seal spray-water system were the source of the water. The investigation also determined that valve operating logic, the PM strategy for the valves, and startup procedures/testing for leaks all required improvement.

Engineers then set about creating a list of action items, as suggested by the RCA, to prevent a recurrence of the problems identified. The list included the following:

- Install skin-temperature thermocouples at select locations and collect real-time operational data to support ongoing analysis.
- Obtain additional samples from the full circumference of failed pipe to support additional analysis. Also, try to date the failure using the oxide layer.
- Evaluate the current PM strategy for high-energy piping systems, giving consideration to reducing inspection intervals and expanding the inspection boundaries.

4. D11 internal laser alignment is conducted by ACQUIP personnel

5, 6. Store diaphragms in a rack like the one above for inspection and light maintenance. It offers easy crane access to facilitate reinstallation of diaphragms in the turbine (right)

Some of the actions taken to date include these:

- During minor and major steam-turbine outages, a robotic inspection of the main-steam piping adjacent to the valves will be performed.
- An annual PM will be conducted on the steam-seal attemperator valve to check for leak-by.
- Other units in the company's fleet will be inspected similarly. Thus far, some cracks were discovered on another unit at the same site.

Finally, the experts believe cracking initiated about seven years before the steam leak was noticed by deck-plates personnel. A similar experience at another plant was reported in CCJ No. 48 (1Q/2016), p 6, "Pipe-Repair Odyssey." You can access this using the search function on the CCJ home page at www.ccj-online.com.

"Lessons Learned to Shorten a Steam Turbine Major and Valve Outage," has value to most, if not all, plant and headquarters personnel assigned to ST outage planning—especially those who haven't been involved in this exercise previously. It is based on one owner/operator's experience, so all points made might not apply to your specific situation.

It begins by suggesting both the responsibilities of personnel managing the outage, and the progress reviews and discussions among the parties that should be conducted, to ensure success. Next comes a slide on how/why to perform a steam-plant audit, which focuses on performance losses—recoverable and unrecoverable—attributed to both the thermal and structural condition to the steam path. The audit enables informed decision-making on components/parts that should be repaired or purchased new.

The speaker said that another benefit of collecting data for the steam-path audit is identifying the actual rotor location within the stationary components (Fig 4). This information may prove invaluable later if realignment is necessary.

Other lessons learned/best practices that you might find useful include these:

- If your steamer is a D-11, purchase and/or repair decisions will be required for dished diaphragms. Suggestion is to purchase ahead of the outage new diaphragms for stages identified with a high risk of dishing (one to five and 12 to 16 in the case presented) and send the dished ones removed to a third-party vendor for restoration and use in a sister unit.
- Consider using a third-party vendor to supply and install packing and spill strips, and to do laser alignment. For the seal work, a contractor with a portable machine shop to support field fit-up activities might be your optimal choice.
- Arrange for turbine-deck storage racks and onsite machining to support diaphragm activities. The storage racks optimize floor space and minimize the use of a crane to move diaphragms between the time they're pulled out of the machine and reinstalled (Figs 5 and 6).
- Install a temporary freight elevator outside the steam-turbine building if one is not available inside and crane access is limited.
- Consider not flipping over the HP shell and performing necessary repairs with the casing top side up (Fig 7).
- Shorten your steam-turbine valve outage by having spare valve assem-

blies onsite. So doing, this user reduced valve outage time from a typical 14 to 21 days to five to 10 days. Spare assemblies help reduce your valve parts inventory as well as the cost of inspection and repair of valve assemblies because they are done off-peak.

If there are budget concerns, the speaker suggested a low-cost option for a spare control valve consisting of just the stem and disc; for a spare main-steam stop valve, just the stem, disc, and pressure-seal head. Several drawings and photos presented in the PowerPoint provide details.

- Valve seat: Buy new or lap? For those opting for the latter, recommendations were given for lapping tools.
- Final advice: Try bars are important.

There are several more user presentations from the 2019 STUG meeting that you can access in the Power Users library, including the following case histories:

- "HP-Turbine Blade Liberation."
- "Failure of a Main-Steam Control Valve to Shut on a Turbine Trip."
- "KN Steam Turbine Fleet Issues."
- "Asset Preservation Program Using Data Analytics to Drive Steam-Turbine Maintenance."
- Lessons Learned During a D11 Minor Outage."
- Lessons Learned During the Major Overhaul of a 416-MW GE D8 Steamer (LP Section) and Valve Inspection."

"Ask an Engineer"—an open forum. This was one of several discussion sessions strategically integrated into the agenda to provide attendees feedback on topics of interest.

There was a great deal of discussion on valves throughout the meeting. In one exchange, the topic of fine-mesh stop-valve strainer baskets was brought before the group. Several users suggested their installation ahead of work planned on the steam path from the boiler outward. They will collect grinding/welding debris. But don't forget to remove the baskets before the unit is returned to service: They can plug over time, collapse, and go through the machine.

Strainer basket rotation was cited as another problem. The group was reminded that there is a pin for correctly positioning the basket. However, several incidents of pins snapping off

7. Some outage managers recommend performing repairs with the HP casing top-side up to save on crane costs. Rigging technique shown demonstrates how to flip an HP casing with one crane

because of negligent work practices.

A best practice for seat inspection on a combined control/stop valve: Don't use a penetrant because you won't see a crack when the valve is hot.

A user recommended conducting actuator outages every six years or at every other valve outage. At his plant, actuators are removed, crated, transported to the selected shop, overhauled, and returned. To dig deeper, read "How to Prevent an Actuator Failure from Tripping Your Plant," CCJ No. 55 (4Q/2017), p 40. You can access this using the search function on the CCJ home page at www.ccj-online.com.

Another participant opted to forego a major on his KN steamer at 120,000 hours because several colleagues said their units did not work properly after their majors.

Vendor presentations

"Steam Turbine Repair Planning and Execution," *Bryan Grant, Advanced Turbine Support LLC.*

Whether you inspect/repair your plant's steam turbine or contract out those services, Bryan Grant's presentation is a valuable reference for O&M personnel, one possibly worthwhile reviewing ahead of your ST inspection/maintenance outages. It's available on the Power Users website 24/7 at www.powerusers.org.

Grant offers tips on repair planning, blade replacement, J-seal installation, when to repair/when to replace nozzles, and final inspections. Plus, he stresses the importance of final FME (foreign material exclusion) close-out inspections prior to unit closure.

One of the speaker's messages: Be prepared, especially when finger dovetail replacements are involved. Some of the retention pins will hang up during removal, he explained, but most can be persuaded to come out with a hilte or peening gun. Those that remain often must be machined out. This can be a risky operation because it's easy to damage dovetails.

Risk mitigation during finger dovetail installs demands close attention be paid to the availability of parts and reamers. This entails verifying the sizes of pin holes as designed and to be aware of any oversize holes identified during previous outages. Grant said the lead time for the all-important reamers is upwards of about two months. How many should you order? His rule of thumb is to restrict reamer use to 20 holes. When reinstalling pins, he continued, start at the bottom hole and work your way up.

J seals received significant air time. Not every turbine has them, and all J-seal designs are not the same, Grant went on. Inspections for straightness and crush checks were described. Make sure the J seals are installed correctly with respect to steam flow, he noted. If installed backwards the steam flow acts to pull out the seal. Remember, you want a small gap where the two hemispherical sections of the J straps meet. Photos in the slides show what to look for during J-strap inspections.

Regarding hardware inspections, Grant urged attendees to replace: Never reuse old hardware. Photos described the proper procedure for conducting balance-weight and L-0 mid-span inspections. Staking of balance weights was said to be "incredibly important" to assure weights do not escape during operation. Decisions on diaphragm repair versus replace also were illustrated by way of photos.

"Fluid Film Bearing Visualization," *Dr Lyle A Branagan, Pioneer Motor Bearing Co.*

Lyle Branagan is a familiar face/voice at user-group meetings in person and online. His well-illustrated presentations typically cover the design basics of journal and thrust bearings for motors and gas and steam turbine/generators, materials, lubricants and lubrication systems, machine dynamics and performance, installation/operation/maintenance, the importance of quality control, etc.

If you're new to the business of power generation, listening to or thumbing through the slides in one of Branagan's presentations is a good way to get introduced to bearings. If you've been on the deck plates for several years and haven't been exposed to bearing work recently, his PowerPoints and videos are a good refresher.

Branagan's presentation before the 2019 STUG meeting is available in the Power Users library, a video of his 2020 7F Users Group presentation can be accessed at Power Users and in CCJ's webinar library at www.ccj-online.com/onscreen.

"Failure Modes for Hydraulic Components and Control-Valve Actuators for Steam- and Gas-Turbine Applications and Strategies to Mitigate," *Ralf Bentfeldt and Tom LaCombe, Rexroth, a Bosch company.*

This is another presentation available on the Power Users website that you might want to link to for your personal library of troubleshooting best practices.

Valve actuators typically are an afterthought until they suffer an operational hiccup or must be removed for inspection and maintenance. That probably doesn't happen more than once a year, so it can be difficult to remember everything you should.

The speakers mentioned that 70% of hydraulic-component replacements are attributed to surface degradation—from abrasive, erosive, adhesive, and fatigue wear—and that 71% of these causes of mechanical wear can be associated directly with hydraulic-fluid condition. That means they are within the user's ability to monitor and control.

Common fluid issues impacting mechanical wear of hydraulic components are temperature and viscosity, water ingression, air entrainment/cavitation, and contamination. The presenters cover each of these mechanisms individually, offering best practices and rules of thumb to improve outcomes on the deck plates. Example: One chart that illustrates the impact of low viscosity on component wear and the optimal fluid temperature to minimize physical contact between internal parts.

"Benefits of an Alternative Material for In-situ Hardfacing of Valve Seats," *Joerg Schoepp, Power Service Group.*

Cobalt chromium hardfacing alloys 6 and 21 have been used to overlay high-wear components—such as steam-turbine valve seats—for decades, protecting against oxidation, impact damage (valve closing), solid-particle erosion, and friction-related wear.

Industry requirements that valves be fast-acting while operating at temperatures approaching 1100F in some plants are linked to delamination of the CoCr layer from the high-chrome (9% to 12%) base material. Liberated metal causes downstream damage to components in the steam path.

A buffer layer between the base material and hardfacing has worked in some cases, but it creates additional steps in manufacturing and refurbishment of valve seats, increasing both cost and time. Plus, some recent valve designs have the added complexity of seats that cannot be removed for refurbishment, dictating in-situ seat replacement.

Several slides provide key steps for in-situ seat replacement (photos are included) and attest to the challenges of hardfacing in the field.

To dig deeper, read "Inspect Steam Valves for Stellite Delamination," CCJ 1Q/2013, p 106. You can access this using the search function on the CCJ home page at www.ccj-online.com.

Joerg Schoepp speaks to the company's positive experience in using a single layer of Inco 625 for valve seat protection. By eliminating the buffer layer, the company's general manager of repair services says, "greatly reduces outage duration and variability" while also mitigating the risk of the hardfacing layer to liberate from the base material.

"Technical Considerations for Optimizing Steam Turbine Startups," *Matthew P Scoffone and Thomas R Reid, PE, TG Advisers Inc.*

The consultants consider both vintage and modern steam turbines in their presentation. Regarding the former, they identify the following as possible impediments to faster starting for economic benefit: HP/IP creep and embrittlement concerns, solid particle erosion, rotor bow, and casing cracking; for the LP section, stress corrosion cracking and water-droplet erosion.

Modern and retrofit steam turbines are characterized by less accumulated fatigue damage, a more aggressive duty cycle (cycling service, for example), turbine inlet steam temperatures of 1050F and higher.

The presentation offers insights on how vintage rotors age, the importance of correct hold speeds, pre-warm to reduce the mismatch of steam and metal temperatures, clearance considerations for cycling, and startup modifications.

The presenters assure that opportunities exist to safely reduce cold start times without capital upgrades. They are identified by use of recent inspection results, finite-element analysis, and modern fracture mechanics principles. In their experience, cold-start times on legacy turbines typically can be reduced by 25% to 50% while still adhering to critical OEM design parameters and requirements.

"Fundamentals of Steam-Turbine Valve Maintenance," *Mark A Cohen and Scott Cavendish, PE, Independent Turbine Consulting LLC.*

Mark Cohen and Scott Cavendish dig into the details of steam-turbine valve maintenance, touching on valve sticking and oxide management, in-service monitoring of valves, extending maintenance intervals, balance-chamber failures, and valve actuators. The presentation is heavily illustrated with meaningful photos. For example, the photos of valve oxide and stuck valves were taken immediately after valve outages where the oxide was not properly removed and the valves had to be taken apart again to correct the failed attempt.

Cohen, a hands-on maintenance expert who probably has forgotten more than many have learned in their careers, is an engaging bareknuckle speaker who maintains your attention with a seemingly inexhaustible supply of anecdotal case histories. Thus, the formal presentation posted on the Power Users website doesn't cover all that he shared at the meeting.

Restoring design clearances to original dimensions was the first topic. The speakers said 80% of valve sticking incidents is traced to incorrect high-temperature oxide maintenance—such as not honing and using try-bar go/no-go checks. Attendees were warned that grit blasting does *not* remove oxide, it only polishes surfaces. Reason: Oxide deposits are harder than the grit. When asked about the proper valve maintenance interval, Cohen said it depends on the oxide growth rate. Scale, he continued, is like bark on a tree: It keeps growing until you remove it.

He stressed that oxide removal to bare metal is tough hand work typically using nominal 60-grit bricks; higher doesn't work, Cohen assured. A couple more best practices shared:

- Never change a part unless it really must be changed because you could make an error in replacement and make a good thing bad.
- On bolting up valve connections, stud tightening must be done until you see sealant squeeze out. Leaks on 1960s machines that never exist-

8. Best solution, upper casing (on and above the split line): Heater on metal mesh baffle. Advantages are easy removal, good contact, covers large surface area (above)

9. Best solution, lower casing: Heater on casing. Advantages are good contact to casing (good heat transfer), robust cable, cable welded with steel foil. Disadvantage: Difficult to remove (left)

ed previously, it was said, testify to today's lax work procedures.

- In-service operational monitoring can detect only stuck valve, not insufficient clearances caused by oxide buildup.

"Don't Do That to My Steam Turbine" was the second part of the presentation by Cohen and Cavendish. It focused on operating procedures to avoid turbine damage, including the following:

- Adhere to starting and loading temperature matching to minimize life expenditure and avoid cracked shells and distortion of hot parts. Remember that metallurgical life cannot be restored. Example: Cracked shells cannot be fully repaired back to new metallurgy, only temporarily patched. And when shells are patched it's even more important to temperature-match.
- Quenching during an improper shutdown causes the most damage; it puts metal surface in tension. During shutdowns, avoid low/no-load operation with a hot rotor. On a hot restart, avoid quenching hot parts.

An example of quenching damage to valve parts was presented. Boiler producing 1000F steam tripped with a resultant drop in steam temperature to 750F-800F. Inspection revealed cracking to three valve seats and stems. Keep in mind that the differential expansion of stellite is twice that of the base material.

Some podium time was dedicated to turbine layup and the corrosion damage and stress corrosion that can result if proper procedures are not followed. Avoid moisture entry into the casing and oxygen-induced corrosion with dehumidification, inert gas and sealed casings, heat, and covered storage, the group was told. Periodic rotor rotation and filming amines were among the suggested actions.

"Advanced Single-Layer Turbine Warming System Improves Startup Flexibility," *Pierre Ansmann and Norman Gagnon, ARNOLD Group.*

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

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

The duo reviewed the different warming-system arrangements, rejecting those integrating the heating circuits in insulation blankets, installing the heater on a thin mattress below the blanket, and using gas-fiber-insulated heating cable. The optimal system for the upper casing, they said, is heater on metal mesh baffle (Fig 8), for the lower casing, permanent mounting of heating cable below the split line (Fig 9).

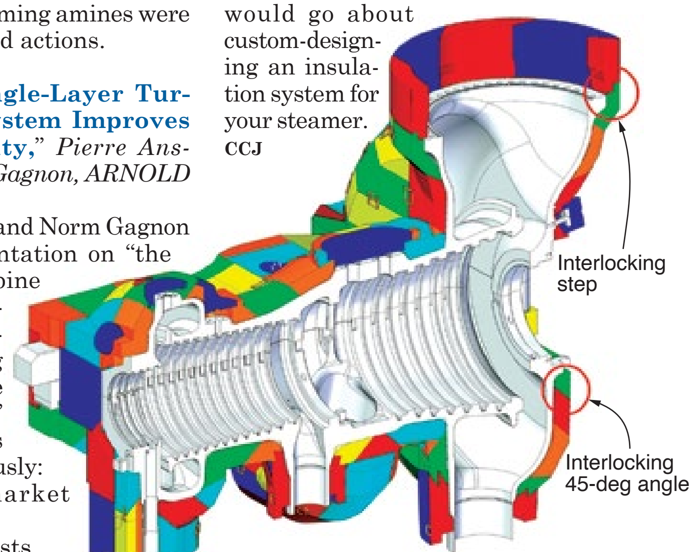
The ARNOLD system features interlocking high-performance blankets which conform perfectly to the turbine surface as shown in Fig 10.

High-quality materials and manufacturing, and long-term high-temperature resistance, allow the company to guarantee reuse of its insulation system for 15 outages without a decrease in efficiency. The completed insulation system for a 330-MW GE steam turbine is on the first page of this report.

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

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

Access a copy of the presentation at www.ccj-online.com to learn more about ARNOLD's control system and blanket design. Plus, how company technicians would go about custom-designing an insulation system for your steamer. CCJ



10. Three-dimensional-shaped insulation blankets illustrate perfect fit-up to the turbine casing

PROFESSIONAL SERVICES

COMBINED CYCLE Journal

CCJ No. 65 (2021)

Index to advertisers

Your direct connection to CCJ's Online Buyers Guide

at www.ccj-online.com/bg

Products and services from over 60 companies support new unit construction, retrofit and maintenance activities at existing facilities, and plant operations. Solutions span gas and steam turbines, HRSGs, pumps, valves, piping, cooling towers, condensers, etc

Advanced IAQ Care USclеanblast.com

Dry ice blasting of HRSGs, stators, rotors, turbines, substations, and other power equipment. ISN "A" rating for safety. 21 years of references from plants including Emera, NRG, Dominion, NY /NJ plants, NAES, and EthosEnergy. Price competitive and guaranteed excellent results.

Advanced Turbine Support

Has delivered unbiased fleet experience and superior customer service for more than a decade. Company provides users high-resolution borescope inspections, cutting edge ultrasonic and eddy-current inspections, and magnetic-particle and liquid dye-penetrant inspections in accordance with OEM Technical Information Letters and Service Bulletins.

Aeroderivative Gas Turbine Support

AGTSI offers a full range of aeroderivative gas-turbine, off-engine, and package parts from the most basic to the most critical. An expansive inventory of spares and replacement parts is maintained at our warehouse for all models of GE LM2500, LM5000, LM6000, and LMS100, as well as P&W GG4/FT4.

AGTServices

Over 200 years of combined, proven OEM engineering, design, and hands-on experience; known in the industry for its schedule-conscious, cost-effective solutions with respect to generator testing and repairs.

American Chemical Technologies

Provides state-of-the-art synthetic lubricants to the power generation industry. Founded more than 30 years ago in the US, ACT has grown to become an international supplier of value-added lubricants that provide superior benefits to equipment, the environment, and are worker-friendly.

AP+M

One of the largest worldwide independent stocking distributors of both heavy-duty and aeroderivative gas turbine parts. A reliable partner with an extensive inventory of more than 10,000 parts quickly delivers genuine OEM parts for operators, end-users, depots, and repair facilities.

ARNOLD Group

With more than 550 installed insulation systems on heavy-duty gas and steam turbines, company is the global leader in designing, manufacturing, and installing the most efficient and reliable single-layer turbine insulation systems.

Bearings Plus Inc

Provider of repairs and custom technology upgrades for turbomachinery. Designs and manufactures an integrated solution to meet specific requirements for every operating environment, applying the latest fluid film bearing and high-performing seal technology to legacy equipment to optimize performance.

Black Start LLC

Provides multi-discipline technicians for industrial start-up, commissioning, and outage field services. We are a veteran owned business, based in the Pacific Northwest, and proud supporters and alumni of Perry Technical Institute.

Braden

Global leader in the power generation industry for design, manufacture, installation and retrofit of auxiliary equipment for GTs and has established itself as the most experienced and trusted name in the design of auxiliary systems for GT power plants.

Bremco

Full-service industrial maintenance contractor since 1976. Company experience in combined-cycle projects includes header, tube, and complete panel/harp replacements. We also have significant experience in liner repairs/upgrades, duct-burner repairs, penetration seals, and stack-damper installations.

C C Jensen Oil Maintenance

Manufactures CJC™ kidney-loop fine filters and filter separators for the conditioning of lube oil, hydraulic oil, and control fluids. Our extensive know-how ensures optimal maintenance of oil systems and equipment reliability.

Caldwell Energy

Power augmentation, including inlet fogging and wet compression solutions, boosts the output and efficiency of gas turbines. With more than 400k hours of operating experience in power generation, these systems offer proven performance and are backed by a three-year warranty.

Camfil

A world leader in the development, manufacture, and supply of clean air and noise reducing systems for gas turbines. A correctly designed system minimizes engine degradation, leading to lower operating costs, optimum efficiency, and less environmental impact.

Catalytic Combustion Corp

Designs, engineers, and manufactures the catalyst – the heart of an effective emissions system. CCC also manufactures the housing and all the critical components at our Midwest facility. Our process of producing folded catalyst substrates is a proven method to quickly manufacture robust catalysts.

Chanute Manufacturing

Contract fabricator of HRSG products—including finned tubes, pressure-part modules, headers, ducting, casing, and steam drums.

Crown Electric Engineering & Manufacturing

Engineers, designs, fabricates, and installs isolated phase bus, large bus duct systems, and outdoor switchgear. Specializes in rapid response needs such as IPB for GSU change-outs, quick-ship fabrication, and emergency on-site service needs.

Cust-O-Fab Specialty Services

Provides the latest technology in exhaust plenums, exhaust ductwork, and exhaust interior liner upgrades that will drastically reduce external heat transfer, making the unit safer and more efficient and easier to operate and maintain.

Cutsforth

Our experience and innovative designs have brought best-in-class brush holders, collector rings, shaft grounding, and onsite field services for generators and exciters to some of the world's largest power companies.

DEKOMTE de Temple

Manufactures fabric and metal expansion joints which compensate for changes in length caused by changes in ductwork temperature. Axial, lateral, or angular movements can be compensated for. Company has gained a global reputation for ingenuity of design and quality of products.

Donaldson Company

Leading worldwide provider of filtration systems that improve people's lives, enhance equipment performance, and protect the environment. Donaldson is committed to satisfying customer needs for filtration solutions through innovative research and development, application expertise, and global presence.

ECT-Engine Cleaning Technologies

Offers R-MC and PowerBack gas turbine and compressor cleaners to eliminate compressor fouling. Additionally, ECT designs specialty nozzle assemblies and custom pump skids for the proper injection of chemicals and water for cleaning, power augmentation, and fogging.

Environex Inc

Engineering and consulting experts in post-combustion NO_x and CO control technologies. Primary focus is SCR and oxidation catalyst testing and system maintenance, catalyst management and selection, troubleshooting, and design.

Emerson Automation Solutions

Ovation™ control system offers fully coordinated boiler and turbine control, integrated generator exciter control, automated startup and shutdown sequencing, fault tolerance for failsafe operation, extensive cyber security features, and embedded advanced control applications that can dramatically improve plant reliability and efficiency.

EthosEnergy

This JV between Wood Group and Siemens is a leading independent service provider of rotating equipment services and solutions. Globally, these services include EPC; facility O&M; design, manufacture, and application of engineered components, upgrades, and re-rates; repair, overhaul, and optimization of gas and steam turbines, generators, pumps, compressors, and other high-speed rotating equipment.

Groome Industrial Service Group

Offers a variety of SCR and CO catalyst cleaning and maintenance services nationwide and has formed strategic alliances with industry experts and catalyst manufacturers to ensure that Groome offers the most widely supported, comprehensive, turnkey service available.

Hilliard

The HILCO® Division cost-effectively brings fluid-contamination problems under control and engineers a full-range of filters, cartridges, vessels, vent mist eliminators, transfer valves, reclaimers, coolant recyclers and systems, and membrane filtration systems.

Hydro

Engineered solutions enable combined-cycle plants to achieve pump reliability and reduced O&M costs. As the largest independent pump rebuilder, Hydro works hand-in-hand with pump users to optimize the performance and reliability of their pumping systems.

Hy-Pro Filtration

Provides innovative products, support, and solutions to solve hydraulic, lubrication, and diesel contamination problems. Company's global distribution and technical-support networks enable customers to get the most out of their diesel, hydraulic, and lube-oil assets. ISO 9001 certified.

IC Spares

Specializes in the supply of new, remanufactured, and repair services of GE Speedtronic turbine controls for GTs, STs, and drive controls with an extensive stock of new and remanufactured parts available for next day delivery and backed by 2-year warranty.

IOT Integration Services

Many years of experience in power generation building and deploying industrial networks and configuring control systems and plant data historians while ensuring network and security structures support the transfer of your information.

JASC

Engineers and manufactures actuators and fluid-control components for power generation, aerospace, defense, and research applications to improve operational capability and performance.

KnechtionRepair Tools

Manufactures tools designed to make thread repairs to both the female and male ends of cross-threaded compression fittings. In most cases, the repair will be accomplished without removing the tube from the system.

Kobelco Compressors America

Provides robust, high-efficiency fuel-gas compressors for use with all major types of gas turbines—including GE, Mitsubishi, Alstom, Siemens, Rolls-Royce, and Solar. Over 300 of the company's screw-type compressors have been supplied for gas turbines.

Lambda Technologies

Providing complete surface enhancement solutions and specializing in understanding, measurement and control of local residual stresses, Lambda is an established leader in materials testing and life extension technology. An integrated total solutions approach improves component life and performance.

Liburdi Turbine Services

Advanced repairs employ the latest technologies and are proven to extend the life of components for all engine types. Company specializes in high-reliability component repairs and upgrades for blades, vanes, nozzles, shrouds, combustors, and transitions.

Mechanical Dynamics & Analysis

One of the largest turbine/generator engineering and outage-services companies in the US. MD&A provides complete project management, overhaul, and reconditioning of heavy rotating equipment worldwide.

Mitten Manufacturing

Leading fluid system packager for numerous OEMs, EPC firms, utilities, and plant operators all over the world offering a number of value-added designs, spare parts management, and field services.

National Breaker Services

Industry leader in switchgear life optimization, life extension, and system upgrades. Manufactures new, highly customized low- and medium-voltage switchgear and provides on-site troubleshooting, maintenance, and testing of existing systems.

National Electric Coil

Leading independent manufacturer of high-voltage generator stator windings with expertise in design and manufacturing of stator windings for any size, make, or type of generator. This includes diamond coils, Roebel bars—including direct cooled, inner-gas, and inner-liquid cooled bars—and wave windings.

Nord-Lock Group

World leader in secure bolting solutions, strengthening industrial and public infrastructures with high-quality, safe, and innovative solutions. Products include wedge-locking washers, mechanical tensioners, hydraulic tensioners, and expander systems.

Parker Hannifin Gas Turbine Filtration

With over 50 years of experience delivering innovative solutions for GT inlet filtration and monitoring fleet-wide performance data, our industry and applications experts will select the appropriate filter for your site designed to meet specific operating goals.

Power and Industrial Services

P&I was founded in 1978 with the goal of providing improved replacement parts for the electric utility market. P&I offers a complete range of duct burner solutions from simple replacements to complete turnkey projects as well as a complete line of HRSG access door solutions.

Praxair Surface Technologies

Leading global supplier of surface-enhancing processes and materials, as well as an innovator in thermal spray, composite electroplating, diffusion, and high-performance slurry coatings processes. Company produces and applies metallic and ceramic coatings that protect critical metal components such as in gas turbines.

Proco Products

Global leader in the design and supply of expansion joints for piping/ducting systems. For over 30 years, Proco has manufactured the highest quality rubber and molded PTFE expansion joints, braided flexible hose assemblies, low torque sealing gaskets, and rubber check valves.

PSM

Full-service provider to gas-turbine equipped generating plants, offering technologically advanced aftermarket turbine components and performance upgrades, parts reconditioning, field services, and flexible Long Term Agreements (LTAs) to the worldwide power generation industry.

Rentech Boiler Systems

International provider of high-quality, engineered industrial boiler systems. Rentech is a market leader in providing HRSGs for cogeneration and CHP plants. It is in its second decade of designing and manufacturing high-quality custom boilers—including HRSGs, waste-heat boilers, fired packaged boilers, specialty boilers, and emissions control systems.

Sargent & Lundy

Provides complete engineering and design, project services, and energy business consulting for power projects and system-wide planning. The firm has been dedicated exclusively to serving electric power and energy-intensive clients for more than 120 years.

Schock Manufacturing

Designs and fabricates filter houses, inlet ducting, inlet silencers, exhaust diffusers/plenums, exhaust systems, exhaust silencers, turbine enclosure doors, and expansion joints.

Siemens Energy

A leading global supplier for the generation, transmission, and distribution of power and for the extraction, conversion, and transport of oil and gas. Leadership in the increasingly complex energy business makes it a first-choice supplier for global customers. Known for innovation, excellence and responsibility, company has the answers to the sustainability, flexibility, reliability, and cost challenges facing customers today.

SSS Clutch Company

Clutches enable operators to disconnect generators from simple-cycle turbines for synchronous-condenser service. Clutches also find application in CHP plants and in single-shaft combined-cycle facilities where operating flexibility is beneficial.

TEC-The Energy Corp

Our skills and experience assist GT owners with front-end engineering, procurement of major equipment, and management of engineering, construction, and commissioning of new facilities. From due diligence to detailed design, TEC covers all phases of complex power projects.

TEi Services

Offers a full range of heat-transfer products and services and fully trained, certified maintenance personnel. Provides world-class emergency repair services, underpinned by a 75-yr history in the design and manufacture of condensers, feedwater heaters, and heat exchangers.

TesTex Inc

World leader in electromagnetic non-destructive testing (NDT). We continually define the state-of-the-art for the testing of ferrous and non-ferrous materials and structures through applied research and development.

Trinity Turbine Technology LP

Provides innovative, cost-effective and reliable gas and steam turbine maintenance solutions to industrial operators worldwide. We provide high quality and reliable turn-key outage support and component repairs with unmatched responsiveness and dependability.

Umicore Catalyst

Our air pollution technology includes a series of unique catalysts for Selective Catalytic Reduction (SCR) systems for the control of nitrogen oxides (NO_x), and the reduction of carbon monoxide (CO) and volatile organic compounds (VOCs), from stationary and mobile sources.

ValvTechnologies

Global leader in the design and manufacturing of zero-leakage metal-seated ball valve solutions for severe service applications. Committed, dependable partner providing the best isolation solutions to ensure customer satisfaction, safety and reliability, and improved process and performance.

Vogt Power International

Supplies custom-designed HRSGs for GTs from 25 to 375 MW and has extensive experience in supplementary-fired units. Scope of supply includes SCR and CO systems, stack dampers, silencers, shrouds, and exhaust bypass systems.

Young & Franklin

Premier fuel control supplier for combustion turbines for both long-term hydraulic solutions and, more recently, innovative all-electric controls solutions. Product scope supports natural gas, liquid, syngas, and alternative fuels as well as providing air controls to provide proper fuel to air mixtures.

Zokman Products

Distributor of ZOK27 and ZOKmx gas-turbine compressor cleaning detergents. ZOK27 is a single cleaner and inhibitor in one that cleans and protects the engine—and also inhibits corrosion. ZOKmx is a power cleaner formulated to replace solvents providing exceptional cleaning without the health and environmental risks associated with solvents.