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PERSPECTIVE

State of the Industry, 2019

In these days of heightened uncertainty in the power industry, it's easy to have amnesia about long-term prospects in the electricity business. The opportunities may be shifting, for a few perhaps like the ground underneath you during an earthquake, but the long-term opportunities remain excellent.

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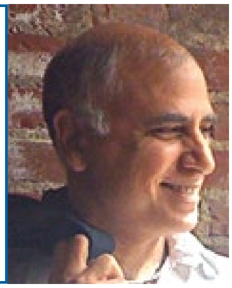

The short version of the State of the Industry is that electricity demand continues to grow, along with population; the sources for supplying that electricity are "decarbonizing"; electric transportation represents a significant source of new demand; and future activity is shifting towards the customer end of the supply and delivery value chain.

The only subsectors of the power industry that face an existential threat are nuclear- and coal-fired generation, and even that is tempered somewhat by activity in Asia.

According to the "Exxon Mobil 2018 Energy Outlook," world population will grow from 7.4-billion to 9.2-billion in 2040, but 1-billion people don't have access to electricity *today*. The International Energy Agency (IEA)'s World Energy Outlook notes that 40% of world energy is consumed by Europe and North America and 20% by Asia. By 2040, these percentages are expected to reverse.

Asia also represents 50% of global natural-gas growth, 60% of renewables growth, 80% of petroleum growth, and 100% of coal and nuclear growth.

The run of historically low natural-gas prices in the US still has a way to go, according to experts, although it now appears that LNG exports and displacement of petroleum by natural gas for hydrocarbons processing and heavy manufacturing are poised to chip away at the supply glut. At some point, this trend will have to impact prices.

Because electricity demand growth is still anemic in most parts of the country, new generation capacity will be driven by decarbonization policies at the state level, a gauntlet of other environmental laws choking coal, resiliency, and operational flexibility. You can sum that up in a meme: "must run renewables, must follow gas."

Ironically, the deregulation and competition programs of the last 30 years have resulted in regulated utilities with protected distribution functions. As impressive as technical and economic progress have been with solar PV, battery storage, micro grids, so-called "smart" homes, and the like, distribution utilities seeking their traditional regulated rate of return on invested capital are likely to drive the distributed energy sector.

Unless electricity demand growth roars back, this likely will be where utilities focus their efforts.

Large-scale storage remains the wild card for the future. If gas prices escalate and battery costs decline, the peakers of the future may not be simple-cycle gas turbines. If home-battery storage prices decline rapidly, then large swaths of ratepayers may opt for rooftop solar PV + storage to supply the bulk of their electricity.

Storage is such a wild card because it can "play" across the electricity supply and delivery chain, including inside an electric vehicle (EV). With continued battery cost declines and effective management of safety aspects (for example, the catastrophic fire hazards often associated with lithium-ion batteries), one can envision a multi-year period during which tens of thousands of megawatt-hours of storage are added to the US grid, in much the same way as 1997-2002, when 200,000 MW of gas-fired capacity was added.

Continued on next page

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The death spiral, articulated in a 2013 EEI report, "Disruptive Challenges: Financial Implications and Strategic Responses to a Changing Retail Electric Business," of customers leaving the grid appears to be coming to pass. That is, as more and more industrial, commercial, and residential electricity customers opt for some form of onsite generation, utilities must spread the costs of maintaining the grid across a shrinking customer and kilowatt-hour demand base. That increases prices, which forces more customers off the grid, a destructive feedback loop.

For this reason, some believe it inevitable that regulated utilities must "control" the distributed-energy rollout and the retail space, or face an existential threat of their own (CCJ, No. 58, 3Q/2018, p 4).

However, it's critical to realize that everyone still needs electricity. What is in question is which entities will be providing it. The opportunity isn't going away, it's just shifting.

A good example is a university in New Jersey (see following article). It replaced and expanded an old combined-heat-and-power facility in 2011 and then added a microgrid that started up last year. Two main project drivers: (1) enhanced resiliency, avoiding reliability issues on the utility side of the meter; and (2) avoiding escalating rates from the local utility resulting from fee adders for bringing more renewable energy to the service territory.

"Must-follow" gas plants present their own slate of opportunities, especially for service firms. Harsher and less predictable operating tempos, combined with shrinking O&M budgets, mean that owner/operators have an appetite for lower-cost solutions for repair and upkeep. And the new H and J machines coming into the supply side will inevitably proceed through their own teething and O&M issues in the early years of the model lifecycle. They are designed for faster and even more frequent cycling than their F-class predecessors.

While those in the fossil-fuel side of the business tend to shudder at the renewables + storage paradigm, adding the third parameter to the equation may be even scarier. Digital technology is transforming society in much the same way as electrification did one hundred years ago. Consider that 60% of adults under 30 don't even have a driver's license! They are content, apparently, using digital sharing platforms like Lyft and Uber, or mass transit.

Digital automation and optimization are, in short, making everything we do that requires electricity more efficient and making commerce frictionless, to use a popular word from the economists' lexicon. At the same time, digital infrastructure is an electricity hog of its own.

Pioneering utilities are using demand-side management programs, often mandated by the PUC, as a stepping stone towards a full-service platform for customer services in electricity. Smart utility management will simply consider the distributed electricity infrastructure on "the other side of the meter" as part of the grid and earn a return investing in it.

Electric-vehicle infrastructure surely will be an integral part, too, as people get more acclimated to at least one vehicle with a limited driving range. This shouldn't be too difficult for a generation who isn't eager to obtain a driver's license at age 16, is saddled with mortgage-like college debt before their first job, and generally takes the climate-change peril as gospel.

Ultimately the renewables + storage + digital transformation leads to zero marginal fuel costs, zero marginal carbon, zero marginal O&M costs (static electrical components rather than huge mechanical and rotating machines, high-energy fluid flows, etc), and zero marginal resiliency impacts from the grid.

Utilities with a traditional mindset, and product/service firms dependent on them, also face an existential threat. Because the renewables + storage + digital transformation also leads to zero marginal need for utility-supplied electricity and gasoline-powered transportation.

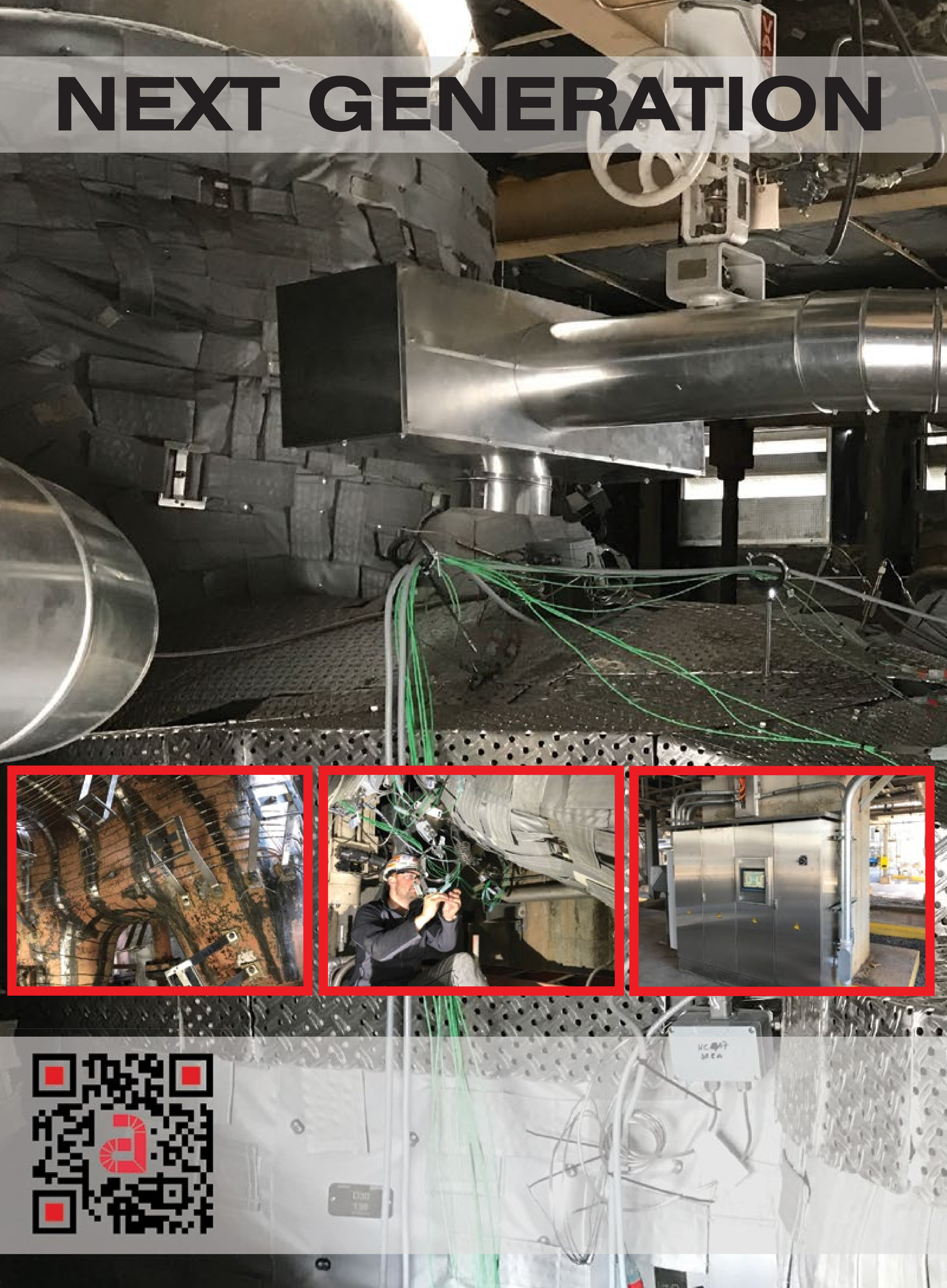
The transformation will not be televised.

In the meantime, the world still needs electricity, population is growing, and the "West" is no longer the "center" of the energy universe. Asia is. In the US, new coal is dead, old coal is dying, and new nuclear is deader.

For the CCJ world in the foreseeable future, though, it's must run renewables, and must follow gas, with pockets of opportunity for new gas to replace dying coal and nuclear. CCJ

This column was adapted from a presentation given by the CCJ content team to the Groome Industrial Annual Sales Meeting, St. Kitts, Jan 8, 2019. If you think CCJ would add value to your company's meetings, please contact General Manager Scott Schwieger (scott@ccj-online.com).

NEXT GENERATION



Get onboard now for the 2019

The world's largest meeting of 7F gas-turbine users happens soon at the Schaumburg Convention Center, May 20-24. It is a must-attend event for owner/operators of this frame. Register today at www.powerusers.org and arrange for a room in the Renaissance hotel, which is connected to the convention center. Recall that the 7F Users Group, hosts about 250 users at its annual meetings and more than that number of commercial attendees representing the nearly 150 companies participating in the vendor fair over two evenings.

The technical program for this conference is directed by an all-volunteer steering committee of 16 engineers with deep 7F experience. They represent 83 sites with a total of 246 engines. Bryan Graham of Entergy Corp is the 2019 chairman, Matthew Dineen of Duke Energy Corp is in the second seat (sidebar). SV Events, headed by Sheila Vashi, manages the business side of the meeting.

The conference opens on Monday, May 20, at 2 pm with a four-hour workshop conducted by PSM. Key topics include the following:

- Hardware reliability. A review of nagging fleet issues—for example, those associated with aft-compressor stators and fuel-nozzle end-cover insert cracking—and their root causes and solutions.
- Rotor lifetime extension. Inspections, analyses, and repairs recommended for LTE. Plus (1) life-limiting considerations for hours-based and cycling engines, (2) replacement-wheel and swap-rotor options, and (3) a review of findings from multiple LTE inspections.
- Operating reliability. Why variable natural-gas properties present tuning challenges for DLN2.6 combustors and how operators can mitigate this risk.
- Startup and shutdown optimization. A review of what limits ramp rates and overall startup cycle times and the options available for faster ramping to more quickly bring assets online.
- Upgrades to improve performance and extend maintenance intervals, including results from multiple user sites.
- Outage best practices and lessons learned.

The Tuesday and Wednesday programs feature user presentations and discussions from 8 am until 3:30 on the compressor section, safety practices/lessons learned, controls, auxiliaries, combustion section, turbine, and generator. These sessions are held in high esteem by plant personnel, delivering unbiased O&M experience you can't get anywhere else.

7F USERS GROUP

2019 Conference and Vendor Fair

Renaissance Schaumburg Convention Center Hotel
Schaumburg, Ill • May 20-24

Steering Committee

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Vice Chair: Matthew Dineen, Duke Energy
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Justin McDonald, Southern Company Generation
Peter So, Calpine Corp
Chuck Spanos, Dominion Energy
Eugene Szpynda, New York Power Authority
David Such, Xcel Energy Inc
Christa Warren, Tenaska Inc

Vendor presentations, invited and vetted by the steering committee, follow on both days in 45-min sessions from 3:45 to 4:30 and from 4:45 to 5:30. Three presentations are conducted in parallel in each time slot, allowing participation by a dozen suppliers and consultants. Here are the topics:

- 7FA.04 HGP design, manufacturing, material, and coating changes from 7FA.03 which redefine the ability to repair.
- Reliability impacts of evolving operating profiles for cycling and baseload engines.
- Load commutated inverter and exciter issues.
- GT upgrades and their impact on HRSGs.
- Contingency planning for 7F generator inspections.
- Benefits of electromechanical valves and actuators.
- Third-party S1B repair developments for the 7F.04.
- NFPA 85 HRSG purge credit: Option selection, benefits, and economic evaluation.
- Advanced NDT protocols for GT end-of-life assessments.
- 7F DLN tuning guidelines (case studies).
- Better integration of turbine health monitoring for gas and steam turbines.
- How to use operating data for making catalyst O&M decisions.

A three-hour vendor fair, immediately following the vendor presentations on both days, provides the opportunity to dig deeper into topics presented earlier. About 75 equipment and services providers will be exhibiting each evening; top sponsors will be available both days, the others one night only. Be sure to peruse the conference program in advance to identify your must-see exhibitors and locate their booths on the floor map—this to avoid getting sidetracked by the hors d'oeuvres and adult beverages.

Thursday is GE Day. It kicks off with a two-hour general session at 8 am and concludes with a second general session from 4 to 5:30. Sandwiched between them are a series of five 50-min breakout sessions (and lunch).

Industry newcomers—those with fewer than about five years of deck-plates experience—will benefit greatly from this well-organized technical program and be better able to contribute to operating-plant solutions. For more experienced personnel, it is a worthwhile refresher. Amazing how much one can forget in a short time.

The breakout themes are root cause analysis (RCA), advanced gas-turbine topics (GT 201), and operations. Here are the details:

RCA

- *Turbine and compressor* sections. Open discussion on the latest compressor, turbine, and exhaust-frame RCA updates, new solutions,

meeting of 7F owner/operators

and Q&A with the OEM's experts.

- *Combustion section.* Up-to-date field experience with the DLN 2.6e and DLN 2.6+ combustors, plus combustion operability best practices and Q&A with the GE team.
- *Generator and electrical systems.* Maintenance and inspection best practices, including what's involved when pulling a field.

GT 201

- *Controls* design considerations, evolution and advanced troubleshooting.
- *Compressor* design considerations, evolution, and advanced troubleshooting.
- *Combustion section* design considerations and advanced troubleshooting.
- *Turbine* design considerations, evolution, advanced troubleshooting.

Operations

- *Outage execution,* beyond the procedures. What does it take to execute a world-class CI, HGPI, MI? Open discussion with GE and FieldCore experts who will share their experience and best practices.
- *Repairs.* How the OEM's repair team is improving quality and timeliness, how to check on your parts during the repair process, etc.
- *O&M best practices.* What operators should be looking for on their rounds, how to troubleshoot leaks, trend deltaP to maximize air-filter performance, common leading indicators on the HMI—including exhaust-temperature spreads, bearing temperatures, and blower amperage.
- *Make my plant better.* An interactive discussion of recent experience with mods and upgrades focusing on recent pain points across the fleet.

Friday's program consists of three 45-min breakout sessions branded as GE's "7F Grad School," a conference segment that has steadily grown in popularity since its introduction a few years ago. You'll be able to attend three of the following six programs:

- *Safety.* An open dialog on outage and site safety—including often-overlooked problems.
- *Batteries* in power generation. An overview of battery technology, its applications, and an open discussion on how batteries may impact thermal generators.
- *3D printing.* An overview of additive manufacturing, today's applications, and how 3D printing is disrupting everything from the supply chain to new product design.
- *Troubleshooting* off-normal performance. How the OEM's performance team troubleshoots unexpected performance issues—such as loss of output following a major inspection.
- *Backgrounder* on the 7F.05 and 7HA. Compare the design and operation of advanced frames to that of their predecessors.
- *Flange-to-flange* upgrade considerations. What's involved? How do the extractions change? What happens to the control curve? How will the BOP respond?

A compelling program from start to finish. Register today at www.powerusers.org! CCJ

Owner/operators share

The 7F Users Group is a big supporter of CCJ's Best Practices Awards program. For the last two years, entries from owner/operators affiliated with this organization outpaced participants representing other frame and aero models. In 2018, fourteen 7F plants (chart) shared 26 best practices with their colleagues industry-wide. Recognize that the lion's share of this material also pertains to most other types of gas turbines.

This report summarizes the best practices submitted by Talen Energy's Barney Davis and Nueces Bay Energy Centers, OGE Energy Corp's McClain Power Plant, Calhoun Power Co, and Woodbridge Energy Center (owned by CPV Shore LLC and operated by CAMS). A special feature based on fleet experience of Competitive Power Ventures with special software to speed access to best practices and lessons learned, incorporating work done by CPV's 7F-powered Woodbridge and St. Charles Energy Centers, was published in CCJ 1Q/2018.

More 7F best practices included here describe work done at Bastrop Energy Center, MEAG Wansley Unit 9, Nuevo Pemex Cogen, and Rath-

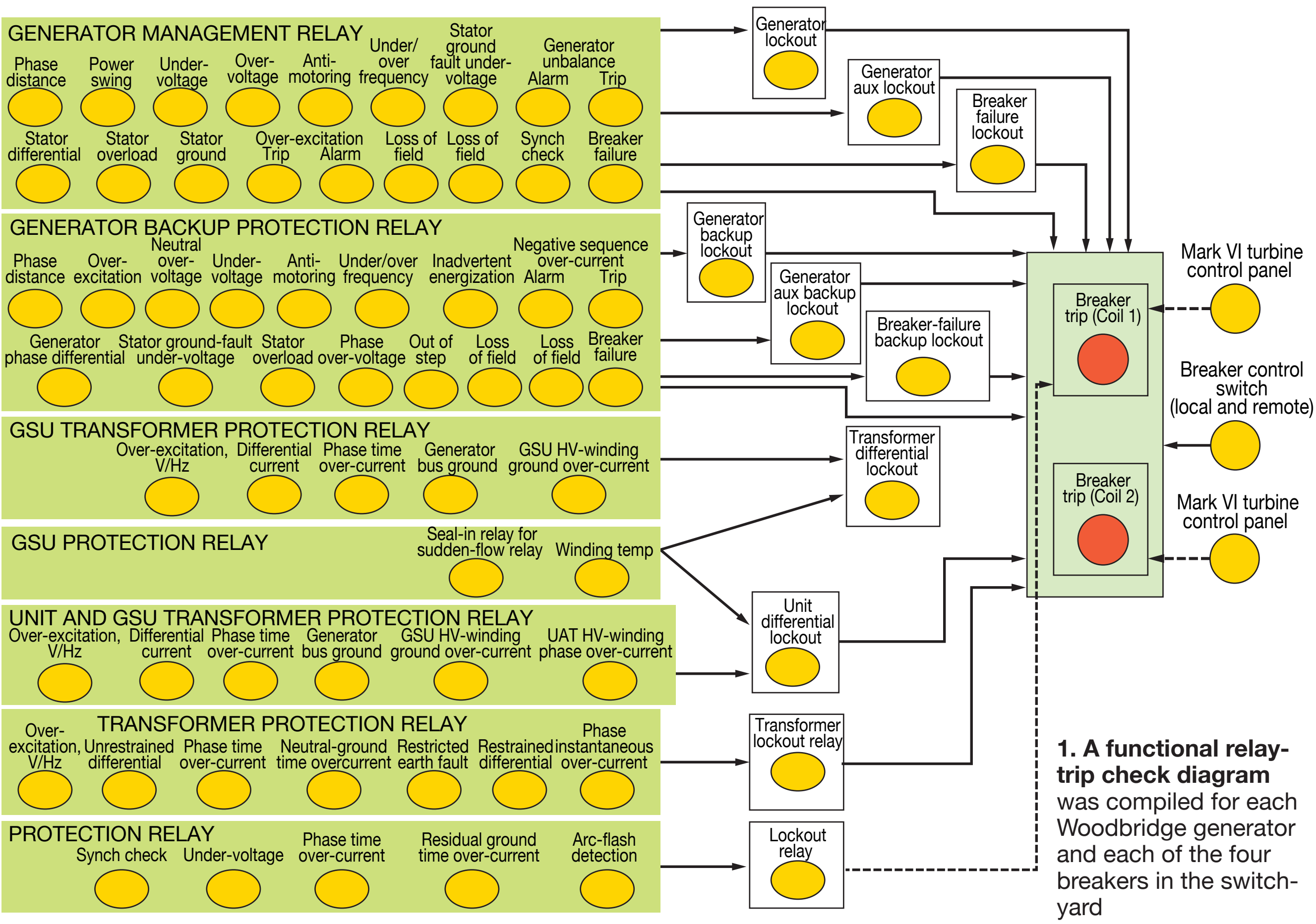
Woodbridge Energy Center

Owned by Competitive Power Ventures

Operated by Consolidated Asset Management Services

725-MW, gas-fired, 2 × 1 combined cycle located in Keasbey, NJ

Plant manager: Kenneth Earl



1. A functional relay-trip check diagram was compiled for each Woodbridge generator and each of the four breakers in the switchyard

best practices

drum Power LLC—all operated by NAES Corp.

The 7F recipients of 2018 Best of the Best Awards were recognized in CCJ 2Q/2018:

- Effingham County Power.
- River Road Generating Plant.
- Hermiston Generating Plant.
- Green Country Energy.

The sharing of actionable information on gas-turbine O&M beyond CCJ best practices is ongoing in this user group via its vibrant forum, webinars, impromptu telephone and email exchangers among members, and of course, the annual conference—the world's largest gathering of 7F users. Registration is open for the 2019 conference, May 20-24, at the Renaissance Schaumburg (Ill) Convention Center Hotel. Sign up online at www.powerusers.org.

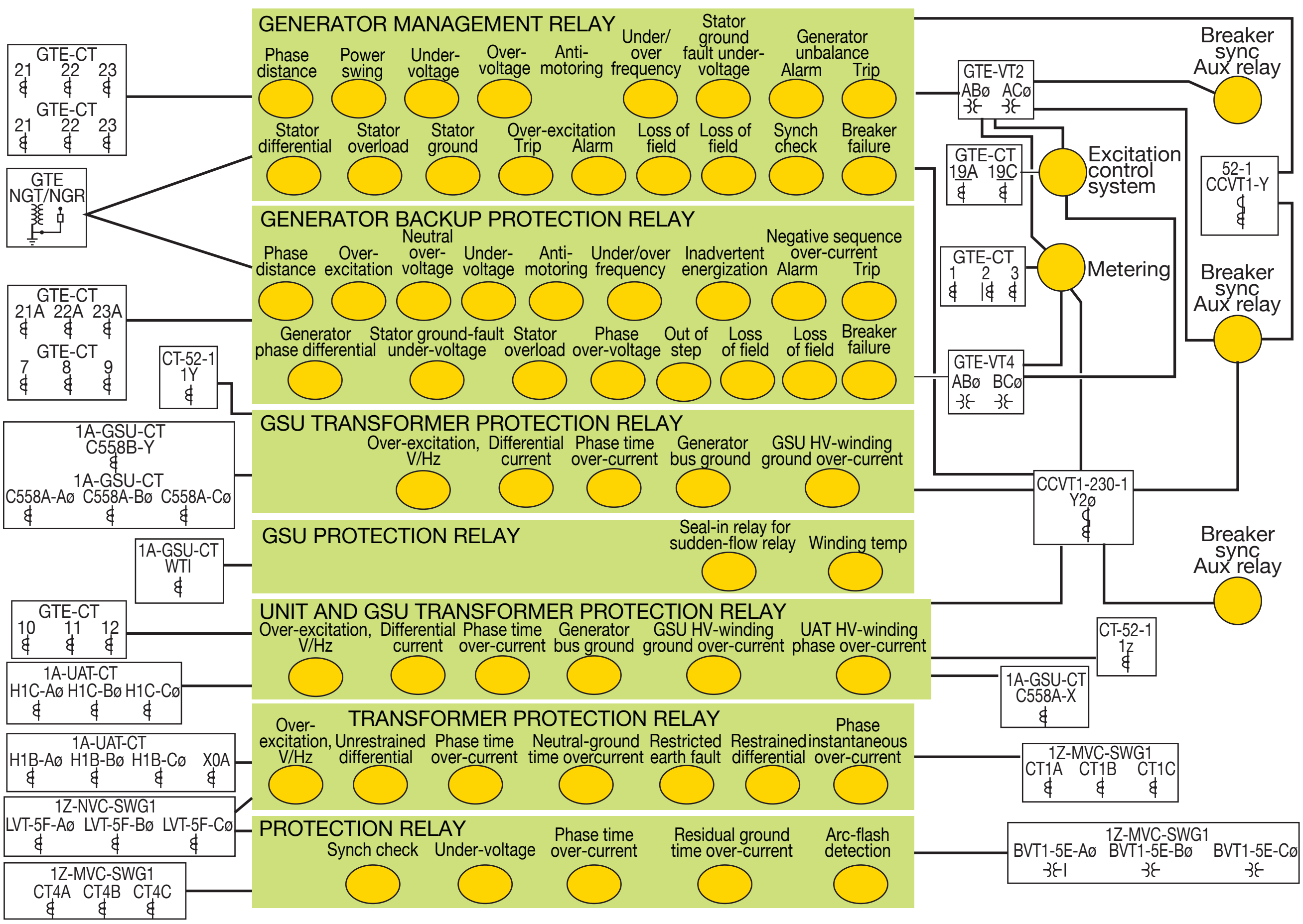
Relay-trip check and connectivity diagrams

Woodbridge Energy Center is registered as a Generator Owner (GO) and Generator Operator (GOP) with the North American Electric Reliability Corp (NERC) in the ReliabilityFirst (RF) region. Like many registered GO/GOPs, Woodbridge must comply with NERC Standard PRC-005 which requires the site to develop a Protection System Maintenance Program (PSMP).

In developing the PSMP for this newly constructed site it was evident from the beginning that supporting documentation for relay operation and CT/VT connectivity to the relay was difficult to follow because of the many drawings provided by suppliers and manufacturers, the number of relays and CT/VTs, and the many possible relay operating scenarios.

Without a relay engineering background, operators found it virtually impossible to understand how the

2. CT/VT relay-connectivity diagram- provides additional visibility to the location where a relay is connected to sense voltage or current. As for the FRTC diagram shown in Fig 1, plant personnel developed one diagram for each generator and one for each of the four breakers in the switchyard



protection system functioned and/or how the system was interconnected. The complexity of the system also made troubleshooting a relay operation very difficult.

To decipher the route dc circuitry takes for any given relay an operator must understand multiple manufacturer drawings and symbols before actually locating the equipment in the field. This is a time-consuming effort.

Example: If a gas turbine in base-load service trips and you look at the front panel of the generator protection relay and see the notation "Under-voltage," presumably this is under-voltage at the generator terminals. But by the time you access the drawings from the multiple manufacturers involved, learn all the symbols, figure out where the equipment is located, dig into the relay coordination study, understand the relay flex logic, etc, the unit is in a forced outage.

Plant management wanted operators to know how the protection system functions and to assist in troubleshooting. To achieve this goal it was necessary to start with the basics and put operators with diverse backgrounds "on the same page" with respect to NERC PRC-005 requirements. This involved bringing the drawings together to develop a language of symbols, names, and devices common in the industry and familiar to operators without having to look at a manufacturer's drawing index which may have pages of symbols.

Once a common language was established for devices, so-called Functional Relay Trip Check (FRTC, Fig 1) diagrams were developed. With three units onsite, it was necessary to compile three unique diagrams, one specific to each generator, and diagrams for each of the four breakers in the switchyard because of the complexity of relay coordination.

A simple diagram for each relay shows the given relay with its potential functioning modes, a line denoting the dc circuitry connected in most cases to a lockout relay, and the trip coil for the breaker. Simple, intuitive symbols illustrate a complete path for each relay.

At a glance, an operator can review an FRTC diagram without having to pick up a single one-line or manufacturer's drawing. He or she can find the aforementioned under-voltage relay on the sheet and follow simple lines to see how and where this relay could trip the generator breaker.

Woodbridge has three lockout relays connected to one generator protection relay; not all trigger in any event. With this diagram personnel can verify trip positions of the lockouts, verify the pertinent data prior to coming offline and feel comfortable in determining a list of potential causes prior to resetting a relay. Previously, much of this work would have been delegated to an electrical testing or relay engineering contractor.

In an effort to provide additional visibility to the location where a relay is connected to sense voltage or current, staff developed a CT/VT Relay Connectivity diagram (Fig 2). As for the FRTC diagrams, personnel had to develop three unique diagrams, one specific to each generator, along with four specific diagrams for breakers in the switchyard because of wiring complexity. Staff can now reference this diagram, instead of, in some cases, up to 30 separate manufacturers' drawings, to understand the complete dc circuity path.

On a single sheet of paper technicians and engineers can see how every CT and VT is connected to any given relay within the facility. Now to troubleshoot the aforementioned under-voltage relay, technicians are not wasting time guessing which CT/VT set the generator protection relay is connected to in order to investigate relay operation and make an informed decision about the cause of the relay issue.

Troubleshooting may determine that a true under-voltage event occurred, or technicians might possibly find the junction box was not properly secured by the electrical testing contractors and water was getting inside and sending a false current.

The bottom line: Better-informed operators are motivated to troubleshoot relay operations. Time is not wasted on trying to understand relay engineering jargon and where to find information on drawings from multiple manufacturers.

Project participant:
Michael Armstrong

GO-BOX promotes safety, consistent job performance

In every combined-cycle plant, operators develop and use documents intended to help workers complete routine and/or non-routine tasks. These documents may include O&M procedures, work authorizations, job-hazard analyses, and safety data sheets.

A few challenges have become apparent regarding the use of such documents, including the following: the availability and convenience of such resources, the awareness of when to refer to a procedure or additional resource (such as a job-hazard analysis), new employees being unfamiliar with an infrequent maintenance activity and needing additional resources, and the elimination of tribal knowledge for completing tasks.

Woodbridge staff was challenged with identifying a way to make resources more readily available to workers in the plant. If you've spent any time in a state or national park, you're probably familiar with outdoor literature boxes for trail maps and other helpful information. Staff's idea was to purchase literature boxes and place them in convenient, highly visible locations where jobs are commonly conducted.

This allows the plant to bring procedures and safety resources right to the worker, hence the name "GO-BOX." Not only does the GO-BOX eliminate a barrier for seeking out a helpful resource, it makes employees aware that a specific procedure must be followed while working on a given piece of equipment, or additional personal protective equipment is required.

Bringing new employees up to speed on more than 65 O&M procedures at Woodbridge is a daunting task. While new personnel go through extensive

3. Emergency GO-BOX at the site muster point contains the emergency response plan, facility plot plan, facility contact list and safety data sheets for major chemicals

4. This GO-BOX contains the CCW heat-exchanger strainer-basket removal operating procedure which involves use of 11 different tools and requires 24 steps from start to finish

training, it is unrealistic for them to retain all pertinent information right away and it is incumbent on management to ensure necessary resources are available to improve safety and efficiency.

The GO-BOX also combats reliance on tribal knowledge by providing specific plant procedures to personnel with the intention of improving consistency in how to perform specific tasks.

To date, staff has installed 10 GO-BOXES around Woodbridge in locations where potential hazards exist or specific procedures must be followed when performing certain tasks. Example: A GO-BOX was installed at the emergency muster point, located at the main access gate to the facility (Fig 3). This particular GO-BOX holds the emergency response plan, facility plot plan, facility contact list, and safety data sheets for the major chemicals onsite. Finally, while GO-BOXES are a good resource for plant personnel, they also increase the awareness of contractors and first responders to plant procedures and safe practices.

Another task benefitting from the GO-BOX is strainer cleaning for the closed-cooling-water (CCW) heat exchanger.

To perform this task, strainer baskets must be removed, which requires appropriate tooling (socket and ratchet sets, impact driver, hoist, ladder, etc). Strainer cleaning can be as frequent as once or twice weekly, depending on operating conditions.

When plant personnel were observed completing this task, it became apparent that almost every operating shift was performing it in a different way. Depending on which shift staff was on, or who did the training, personnel were subject to tribal knowledge on how to complete this task. Engineers discovered rigging practices that were unsafe, improper use of tools, and working in precarious or unsafe positions during work observations.

Staff developed a guidance document for completing this task, making the CCW heat exchanger the ideal location for a GO-BOX (Fig 4). It brings the resource to plant personnel, ensuring appropriate tools are used and standard operating procedures are followed. This has resulted in more knowledgeable personnel and eliminated the tribal knowledge that once plagued this specific task.

The goal for Woodbridge is to continue to identify more locations for the GO-BOX to increase overall staff awareness and deploy resources effectively.

Project participant: Ryan Bullock

ΔP gages alert to fouling of motor air filters

Woodbridge, constructed near the shoreline of New Jersey's Raritan River, is surrounded on three sides by marshland. Immediately after COD in January 2015, staff began following manufacturers' recommended maintenance procedures for all plant equipment.

The facility has two boiler feedpumps for each HRSG. The recommended interval for cleaning the pumps' motor air filters is semiannual. In spring 2016, one pump tripped on high winding temperature. Dirty filters were not suspected because they had been cleaned only a few weeks earlier.

But after troubleshooting the motor protection relay and confirming there were no failed RTDs, one of the motor filters was removed and found packed full of seed heads from the phragmite plants indigenous to the area (Fig 5). Filters for the three remaining pump motors then were inspected and also found packed fairly tightly with the same seed heads. Action taken: The maintenance interval was adjusted to account for seasonal variations in the amount of pollen, seed heads, etc, in the air.

Knowing that the differential pressure across the filters could be directly correlated to air flow through the filters, staff added pressure taps on both sides of each set of motor air filters and connected them to a differential-pressure gage (Fig 6). Today, when ΔP is more than 0.5 in. H_2O above the baseline value, the filters are cleaned.

Since installing the ΔP gages there have been no motor trips/alarms caused by high winding temperature. Additionally, the gages have saved man-hours because use of condition-based maintenance principles eliminates the need to remove filters simply for inspection purposes.

Project participant: Melchor Ortiz

5. Seed heads from the phragmite plants, indigenous to the area around Woodbridge, plugged filters and caused overheating of motors

6. Differential pressure across the filters installed in boiler-feed-pump motor drives correlates to air flow through the filters

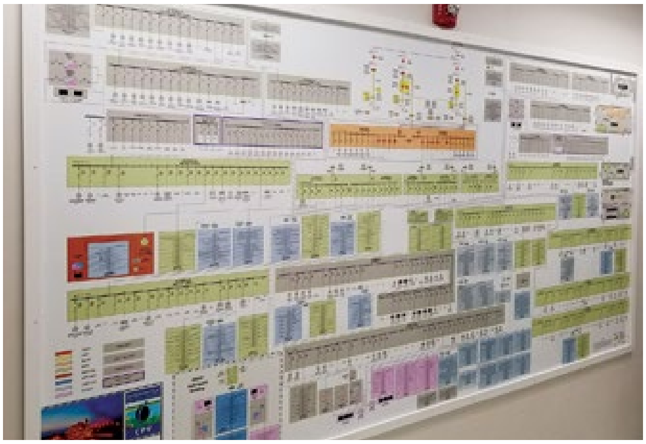
Comprehensive one-line diagrams facilitate training, troubleshooting

Woodbridge Energy Center was constructed by a single EPC contractor with multiple equipment suppliers, thereby creating various scope-breaks between pieces of equipment. Staff found that following the electrical one-line diagrams and mechanical P&IDs for each system was a daunting task. At each scope break there is a line break in the drawing which references another drawing, this process could occur three to four times within one system making the review of a single system very cumbersome.

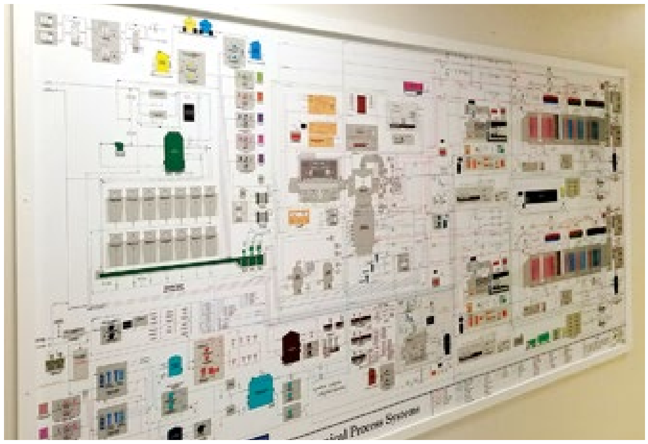
When referencing electrical one-line diagrams, technicians would find it difficult to grasp how the 230-kV power generated or imported would be stepped down and distributed within the facility. Like most electrical drawings it would only show one voltage level , such as 230 kV; another drawing would show 18 kV, still another 5 kV, etc.

During times of de-energizing or training for "what if" scenarios it was difficult to understand how bringing down one side of a switchgear could affect a system of lower voltage level without having to scour multiple drawings.

When referencing mechanical P&IDs, the same issue exists and requires having to pour through multiple drawings to understand the system completely from beginning to end. A single system could have up to seven drawings. Plus, all device numbers are based on the individual P&ID drawing number, which meant that if you



7. **Electrical one-line diagram** color-coded by voltage level



8. **Mechanical one-line diagram** color-coded for each system

located a valve in the plant and referenced its ID number you would have to know seven ID numbers for what is actually the same system.

First step in resolving the issue described was to pull every as-built electrical drawing and verify its integrity. During this process, personnel found multiple drawings with many revision levels based on changes that occurred during construction; however, not all changes made it to the panels or switchgear as a real change or the panels/switchgear labels were not updated to reflect this information.

Once the accuracy of all drawings was confirmed, Powergen Publications Inc was engaged to aggregate all of this information into a single diagram. Starting from 230 kV, a single one-line diagram was created showing each breaker, disconnect, power panel, transformer, switch, etc, until the system was developed down to 120 V (Fig 7).

Every voltage is represented by a different color so when referencing a drawing you know at a glance which voltage level you're working on. The diagram also incorporated 125 V dc down to 24 V dc, information that is invaluable when trying to keep critical protective systems available for service during various O&M scenarios.

The same idea was used to build out a mechanical system diagram from flange start to flange end (Fig 8). The diagram is color-coded for each system, which came in handy when referencing various steam systems—such as HP, IP, LP, etc. Chemical systems onsite—like acid, sodium hypochlorite, ammonia, etc—each had a unique color coding to help distinguish among the systems.

The diagrams immediately raised the confidence level of staff in recognizing the effects of components being removed from service, both electrically and mechanically. They also contributed to efficiency and time savings when planning and hanging plant LOTOs, troubleshooting, and for training.

The diagrams have helped streamline the staff's ability to properly operate and maintain the facility because the complete picture of electrical and process flows can be seen in one picture. The diagrams also serve as a proper tool to train on "what-if" casualty scenarios where the technicians can see the effect one system has on another all on one diagram.

Project participant:
Michael Armstrong

Managing hydrogen trailer inventory

Talen Energy's Barney Davis and Nueces Bay plants are located about 30 miles apart in Corpus Christi, Tex; each is equipped with a 2 × 1 combined cycle. The close proximity of the generating assets and their similar equipment promote joint resolution of operating challenges. The following illustrates this point.

The preparedness plan for a rapidly approaching hurricane specified a plant shutdown and purging of hydrogen from the gas- and steam-turbine generators. It was not possible to receive a fresh hydrogen supply trailer before the storm hit.

Among the unknowns facing station personnel:

- Hydrogen supplier was not sure when a new trailer could be delivered given expected infrastructure damage in the area.
- Uncertainty as to whether the generators could be refilled with hydrogen from gas remaining in the onsite trailer and operate until a replacement trailer was received.

Hydrogen available in tanker, scf

Initial trailer pressure, psig (columns); Final trailer pressure, psig (rows)

	2500	2400	1200	1100	1000	900	800	700	600	500
500	101584	98404	36254	31075	25896	20717	15538	10358	5179	0
450	106173	10099	38844	33665	28485	23306	18127	12948	7709	2590
400	108763	10358	41433	36254	31075	25896	20717	15538	10358	5179
350	111352	10617	44023	38844	33665	28485	23306	18127	12948	7769
300	113942	10876	46613	41433	36254	31075	25896	20717	15538	10358
250	116531	11135	49202	44023	38844	33665	28485	23306	18127	12948
200	119121	113942	51792	46613	41433	36254	31075	25896	20717	15538
150	121711	11653	54381	49202	44023	38844	33665	28485	23306	18127
100	124300	119121	6971	51792	46613	41433	36254	31075	25896	20717
50	126890	12171	59561	54381	49202	44023	38844	33665	28485	23306
0	129479	12430	62150	56971	51792	46613	41433	36254	31075	25896

Days of hydrogen available (1 × 1)

Initial trailer pressure, psig (columns); Final trailer pressure, psig (rows)

	2500	2400	1200	1100	1000	900	800	700	600	500
500	115	109	40	35	29	23	17	12	6	0
450	118	112	43	37	32	26	20	14	9	3
400	121	115	46	40	35	29	23	17	12	6
350	124	118	49	43	37	32	26	20	14	9
300	127	121	52	46	40	35	29	23	17	12
250	129	124	55	49	43	37	32	26	20	14
200	132	127	58	52	46	40	35	29	23	17
150	135	129	60	55	49	43	37	32	26	20
100	138	132	63	58	52	46	40	35	29	23
50	141	135	66	60	55	49	43	37	32	26
0	144	138	69	63	58	52	46	40	35	29

Days of hydrogen available (2 × 1)

Initial trailer pressure, psig (columns); Final trailer pressure, psig (rows)

	2500	2400	1000	900	800	700	600	500	400	300
500	86	82	22	17	13	9	4	0	0	0
450	88	84	24	19	15	11	6	2	0	0
400	91	86	26	22	17	13	9	4	0	0
350	93	88	28	24	19	15	11	6	2	0
300	95	91	30	26	22	17	13	9	4	[illegible]
250	97	93	32	28	24	19	15	11	6	2
200	99	95	35	30	26	22	17	13	9	4
150	101	97	37	32	28	24	19	15	11	8
100	104	99	39	35	30	26	22	17	13	5
50	106	101	41	37	32	28	24	19	15	[illegible]
0	108	104	43	39	35	30	26	22	17	13

Nueces Bay Energy Center

Talen Energy

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

Plant manager: Norm Duperron

Barney Davis Energy Center

Talen Energy

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

Plant manager: Bill Smith

The options:

- Refill only two of the three generators and run 1 × 1 to minimize hydrogen consumption and maximize operating time.
- Refill all three generators to maximize short-term operation and risk running out of hydrogen before a replacement trailer arrived onsite.

Staff realized the financial impact of its decision could be significant because the market was reacting to the aftermath of the storm and forced outages at other facilities in the ISO. Rigorous analysis was necessary.

Plant personnel knew the ideal gas law (PV=nRT) could be used to convert the difference between current hydrogen trailer pressure and the pressure at predicted exhaustion to an available scf (standard cubic foot) value. Plus, the OEM provides expected hydrogen leakage rates, as well as equations for performing leakage tests. Dividing the available scf by the hydrogen leakage rates of the generators (performing leakage tests provides a more accurate result) gives the approximate amount of time gas will be available.

Using this approach, staff determined there was sufficient hydrogen available to re-gas all three generators and still have the inventory to operate until receipt of a new trailer (sidebar). Benefit: Plant offered the market its full 2 × 1 capacity rather than the 1 × 1 alternative.

Project participants:

David Van Bibber, NBEC operations manager

Robert L Garza, BDEC operations manager

Vincent Powers, plant performance manager

Calculations assure sufficient gas for 2 × 1 operation until a new trailer is available

First step was to determine the hydrogen leakage rate. For the Nueces Bay and Barney Davis Energy Centers these values are a nominal 300 scf/day for each gas-turbine generator and 600 scf/day for the steam-turbine generator. This means 900 scf/day of hydrogen is required to replenish that lost in 1 × 1 operation, 1200 scf/day for 2 × 1 operation.

From the OEM's generator manual find that it takes 8382 scf of hydrogen to recharge a GT generator; 12,516 scf to recharge the ST generator. Thus, 20,898 scf is required to recharge for 1 × 1 operation, 29,280 scf for 2 × 1.

Next step: Determine the pressure of the hydrogen remaining in the onsite trailer and the pressure at which no more hydrogen can be withdrawn. Staff found hydrogen-trailer pressure was 1200 psig (horizontal axis in the charts at the left) and the minimum trailer pressure required was 500 psig (vertical axis).

The tables, specific to the Nueces Bay and Barney Davis sites, then were developed. Using the top table, find 36,254 scf of useable hydrogen was in the trailer based on the actual trailer pressure of 1200 psig (horizontal axis) and the final tanker pressure of 500 psig on the vertical axis.

Operating in a 1 × 1 arrangement would leave 15,356 scf of hydrogen available to accommodate leakage (36,254 – 20,898). Using the top chart once again, find that the hydrogen trailer pressure at this volume of gas following the re-gassing evolution would be about 800 psig.

Using the middle table, find that the plant could operate for 17 days before running out of hydrogen.

Refilling all three generators to enable 2 × 1 operation would leave 6974 scf of hydrogen in the trailer. Using the top table again, find the trailer pressure after re-gassing would be about 600 psig. Entering the lower table at that pressure shows sufficient hydrogen for four days of operation at rated plant output.

McClain

CO_2 risk mitigation

McClain Power Plant

OGE Energy Corp

550-MW, gas-fired, 2 × 1 combined cycle located in Newcastle, Okla

Plant manager: Tony Shook

Fire-suppression system is active at left, CO_2 release disabled at right

Each of the gas turbines for McClain's 2 × 1 combined cycle has three zones monitored/protected continuously for fire. Most maintenance performed within any zone is done when the unit/equipment is offline and under LOTO, thereby eliminating CO_2 or temperature exposure risk.

However, employees occasionally must enter the auxiliary lube-oil and gas-compartment zones to perform operational checks and do minor maintenance with the engine in service. During normal operating conditions, high space temperatures do not exist within these two areas.

Nevertheless, if a fire monitoring/control failure occurred and released CO_2 while someone was inside a compartment the consequences could be dire. Most likely an employee would be able to exit the space given a 30-sec release delay and an audible/visual warning system—unless, of course, the person was incapacitated.

To assure personnel safety, key-activated maintenance switches were installed (photo). They enable employees to manually disable the CO_2 releasing capability, by individual zone, when performing assigned tasks. As a further safeguard, operating instructions were developed. They explain system operation and emphasize the importance of three-way communication for allowing employees to safely access CO_2-protected zones for a short time while the plant is in service.

Project participant: Benjamin Privett

Turbine-compartment safety platform

The OEM installed a ¼-in. metal baffle plate near the IGVs to help direct ventilation air to the turbine compartment, making it impossible to do maintenance in that area without stepping on the plate. However, the baffle plate was not designed to support weight. Plant staff redesigned it to serve both as a ventilation assist and safe work platform (Fig 1).

Project participant: Mike Carter

1. Redesigned baffle plate serves both as a ventilation assist and safe work platform

Current transformers on 89 SS/ND motor-operator circuits improves reliability

Calhoun had experienced multiple 89 static-start and neutral-disconnect motor-operator failures because of misaligned or slipped linkages. Weekly reliability cycling of the switches involved taking motor-operator current readings with a digital voltmeter. This procedure offered some indication of predictive failure, but only on a weekly basis, and was prone to operator-induced error.

Plant technicians installed current transformers on the 120-V ac motor operator supply with 4-20-mA feedback to the Mark VI control system (Fig 2). This permitted trending of current draw in the PI system and captured data from all switch cycles—not just that from the weekly reliability checks. Another benefit: Indication of potential issues with feedback switches when current draw is present and a switch indicates open/closed during cycling.

Result: Starting failures attributed to motor operators were eliminated and planned maintenance outages could be taken to repair issues arising from high current draw or over/under run indications.

Project participant: Steven Murray

2. Current transformers eliminated motor-operator starting failures

Rathdrum

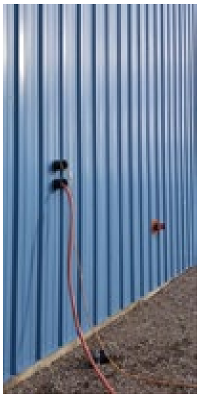
Rathdrum Power Plant

Owned by Tyr Energy
Operated by NAES Corp
275-MW, gas fired 1 × 1 combined cycle located in Rathdrum, Idaho
Plant manager: Gary Allard

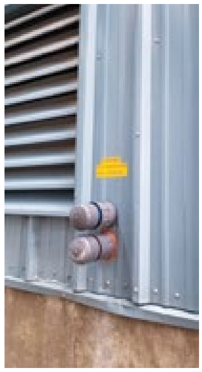
Bulkhead pass-through ports reduce safety hazards, extend equipment service life

During outages and other activities, plant and/or contractor personnel may have to pass hoses and electrical extension cords out of the enclosed power block to service containers, trailers, or auxiliary air compressors. When they are passed through doorways or rollup doors, a trip or overhead hazard is created; plus, electrical-cord insulation can be damaged.

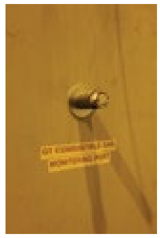
To mitigate these risks, staff came up with the idea of creating pass-through ports in the exterior bulkhead adjacent to high-use pedestrian and vehicular access doors. Simple enough. First step is to use a hole saw to "drill" holes. Next, insert lengths of PVC pipe through the holes (Fig 1) and plug the ends of the pipe with PVC caps (Fig 2). When ports are needed, merely remove the caps and pass the hose or cord through pipe.



1. Cut a hole in the bulkhead and insert PVC pipe



2. Cap the ends of the pipe when pass-through port is not in use



3. Combustion gas monitoring port eliminates employee exposure to a potentially explosive atmosphere

In addition to eliminating safety hazards and clutter, the pass-through pipe extends the service lives of hoses and chords.

Staff also cut ports into the gas-turbine combustion compartment, thereby allowing an explosion meter to run verification checks in the event a "high combustibles" alarm is received. The same pass-throughs (Fig 3) also can be used to verify compartment atmosphere is safe for employee access.

The two safety enhancements were inspired by Rathdrum's continuous improvement program and its efforts as a VPP Star plant to actively pursue safety improvement opportunities.

Project participants:
Don Kendall, maintenance mechanic
Richard Ihrig, operations manager

NAES fills reliability gap at the plant/grid interface

Last year, NAES Corp, well known to CCJ's audience as a leading third-party plant O&M services provider, acquired Gridforce Energy Management LLC, extending the company's services into the transmission and distribution arena.

Gridforce's genesis was at Duke Energy North America (DENA) back in the late 1990s when the industry was driving towards unbridled competition. For almost 20 years, Gridforce has occupied a unique space in the deregulated part of the industry—a provider of control, dispatch, and reliability services, including "balancing authority" functions for individual plants in bilateral markets, those *not* participating in an ISO, and plants located in organized markets such as CAISO, MISO, and PJM.

These services are most commonly provided by regulated investor-owned utilities, munis, and cooperatives but Gridforce's subject-matter expertise combined with a customer-service focus has enabled it to successfully compete and expand on these service offerings.

According to Gridforce President C J Ingersoll, the company runs an advanced energy management system from its control center in Houston, with custom code supporting reliability services throughout the US. Gridforce is not a trading entity and does not buy or sell power, enabling it to serve plants that are competitors in any market.

The company uses models supported with data-scan rates of less than six seconds to monitor discrete operations on the grid, along with highly trained NERC-certified system operators to staff the control center 24 × 7. The operators manage such functions as plant dispatch, remote generator operations, frequency regulation, contingency reserves, outage coordination, and other grid reliability services—including compliance with NERC reliability and cybersecurity standards.

Obviously, NAES manages a huge fleet of plants which can immediately benefit from Gridforce services. Going forward, Ingersoll sees decentralized management of reliability services that blend end-use customers, fossil fuels, solar, wind, and storage, as expanding Gridforce's role in the markets.

However, these reliability services will continue to require close coordination with traditional grid operators that manage, plan, and operate the interconnected transmission system that Gridforce works with every day. For its part, NAES sees the acquisition as an opening into additional transmission-related services.

Tina Lee, executive VP of commercial operations for Recurve Energy Asset Management (formerly Star West Asset Management), notes that Gridforce manages, as examples, Recurve's summer tolling power purchase agreements (PPAs) with several local utilities in real time and serves as its primary representative to the Southwest reserve-sharing group selling into the CAISO. The contracts with Gridforce date back to when the plants were under Star West before 2011.

Lee says Gridforce is very knowledgeable and responsive. "Recurve only has a dozen employees, and each plant only has around 25 staff, so we couldn't do this on our own," she says. With ever-changing policies and compliance rules in the various markets, Lee adds, "Gridforce handles the minutiae we couldn't even begin to understand." CCJ

Installing a jockey pump yields substantial potable-water saving

Bastrop Energy Center

Owned by Blackstone Energy Partners NQ LP

Operated by NAES Corp

550-MW, gas-fired, 2 × 1 combined cycle located in Cedar Creek, Tex

Plant manager: Jerome Svatek

Bastrop Energy Center was designed to receive potable water from the local utility for both domestic use and demin makeup. The system includes redundant potable-water booster pumps sized to provide adequate supply for the demineralizer.

The concern was that each pump requires a minimum flow rate of 27 gpm, and while the demineralizer is required to be in service only a few hours per day, a booster pump must remain in service 24/7 to provide adequate pressure for the restrooms, kitchen, eyewash stations, etc.

With average potable water usage well below the minimum flow rate, approximately 27 gpm of potable water was passed through a minimum flow valve and discharged to the cooling-tower makeup supply. From a water conservation perspective, this appeared to be a good initial system design; however, with the cost of potable water at $4.50/1000 gal, and the cost of river water used for cooling tower makeup at $0.50/1000 gal, an annual differential cost of approximately $52,000 was being incurred by using potable water for tower makeup.

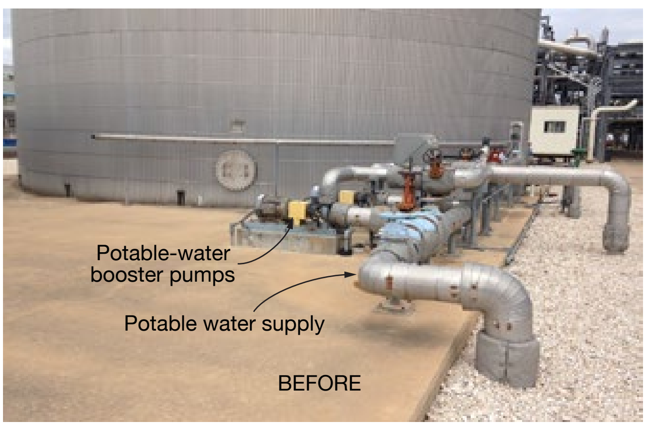
To resolve the issue, a small "jockey" pump was installed in parallel with the two existing booster pumps, along with a pneumatic pressure tank. This pump has its own local pressure switch, which cycles the jockey pump on and off to maintain adequate potable water pressure when the demineralizer is out of service and potable water requirements are small. This is similar to the type of system a homeowner would have with a private well.

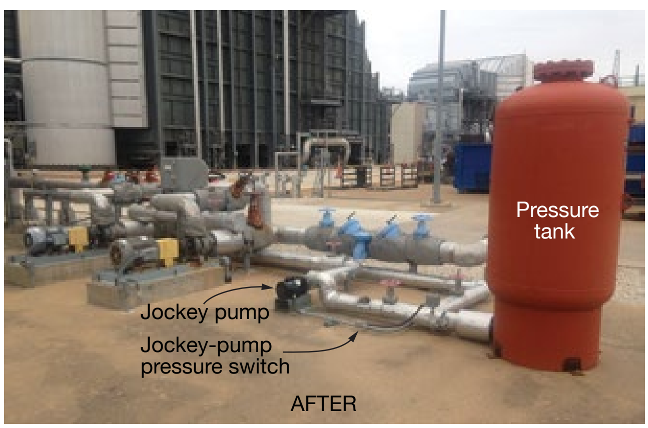
Staff changed the DCS logic for the booster pumps such that as pressure drops (as when the demineralizer is placed in service and the jockey pump cannot keep up with demand), a booster pump will start. Since its discharge pressure is higher than the jockey pump's "on" pressure, the jockey pump turns off. When the flow requirement for the demineralizer drops below the 27 gpm minimum flow level, the booster pump shuts down and the system returns to jockey-pump pressure control.

In the year prior to this modification, one booster ran continuously, logging 8760 hours. In the year following, a booster pump was in service for only 2520 hours. This difference calculates to 10.1 million gallons of potable water reduction for a saving of $40,435.

An additional saving of $3592 in the cost of power to operate the jockey pump versus the booster pump is offset by the added cost of chemically treating the river water of $3,380. This yields an approximate annual savings of $41,000. The total cost of installation, including materials and labor, was $39,836, which gives the project a one-year payback.

Project participants: Most of the design work for this project was performed by a team of four engineering interns from a local university working with several members of the plant staff. The installation was a staff effort.





Potable-water system as designed had no "jockey pump" (left); improved system at right reduced operating cost considerably

Nuevo Pemex

Mobile backup battery bank streamlines discharge testing

Nuevo Pemex Cogeneration

Operated by NAES Corp

277-MW, gas-fired cogeneration facility with two 7F/single-pressure HRSG trains located in Villahermosa, Tabasco, Mexico

Plant manager: Hugo Ordoñez Ruiz

Plant management wanted to identify a means for reliably performing battery discharge testing as stipulated by IEEE, as well as by NERC standard PRC-005-02, at the recommended intervals without jeopardizing the integrity of Nuevo Pemex Cogen's operations.

Nuevo Pemex currently has 10 battery banks:

- Two rated 125 V dc/1300 AH for dc distribution system A/B.
- One 125 V dc/1500 AH for main UPS.
- One 125 V dc/600 AH for secondary UPS.
- Two 125 V dc/600 AH for dc systems for the gas turbine controls.
- Three 125 V dc/300 AH for the electrical S/S.
- One 125 V dc/190 AH in the ERM (European Reference Materials) for fuel gas.

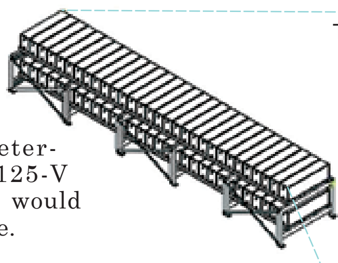
Battery banks provide the ultimate defense against a possible catastrophe. For example, backup dc power assures a continuous supply of lube oil to the turbine bearings in the unlikely event ac power is lost.

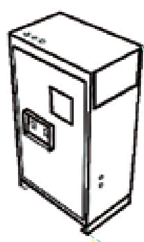
Recall that battery capacity can decrease significantly before reaching the storage device's design lifetime. High ambient temperature, dust, loose contacts, overload, and other conditions all take their toll. Periodic discharge testing is the only reliable way to measure capacity over time. However, if testing were conducted during routine operations, the battery bank would be disabled for a brief period, leaving the system unprotected by its backup power.

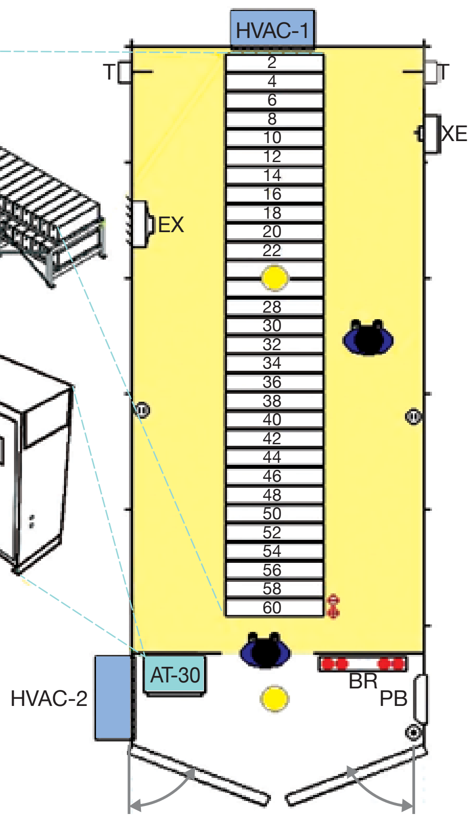
Battery banks typically are not designed with built-in redundant systems, and it would require a huge investment to retrofit each of the plant's 10 existing banks with its own backup unit.

Plant staff collaborated and came up with the idea of building a mobile backup battery bank that would provide redundant power while discharge-testing each battery bank—rather than taking the plant offline or waiting until the next planned outage.

Capacity of the mobile bank was based on the highest "real" consumers among all of the installed banks (allowing for the fact that some of the banks are oversized). Staff determined that a 125-V dc/600-AH bank would serve the purpose.







Metal container at left houses the mobile bank of batteries at right

A 19 × 7 × 8-ft metal container was selected to house the batteries (figures). The mobile bank is divided in two sections: one holds the rack of 60 SBS 900 batteries that make up the 125-V dc/600-AH bank, the other the charger.

The shaded zone in the drawing is equipped with lighting, accessories, HVAC, and instrumentation that meet Class 1, Division 2, explosion-proof requirements. HVAC-1 is a 24,000-Btu/hr heating/cooling unit; the Ts are local temperature gauges; XE is a stand-alone gas monitor with highly visible LED indicators, piezo horn, and strobe lamp. EX is a 12-in. vertical extractor activated automatically by the XE to extract explosive gases from the enclosure.

The unshaded zone at the bottom of the figure houses an AT-30 CPU-controlled battery charger; a distribution panel (PB) that feeds all of the installed equipment; and HVAC-2, a non-explosion-proof 12,000-Btu/hr heating/cooling unit.

Project participants:

Hugo Ordoñez Ruiz, plant manager
Henry Barrios García, plant engineer
Ernesto Hernández Peña, maintenance manager

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MEAG Wansley

MEAG Wansley Unit 9

Owned by Municipal Electric Authority of Georgia

Operated by NAES Corp

520-MW, gas-fired, 2 × 1 combined cycle located in Franklin, Ga

Plant manager: Timothy Williams

Corrective action, ergonomic improvement for GT offline water-wash drain valves

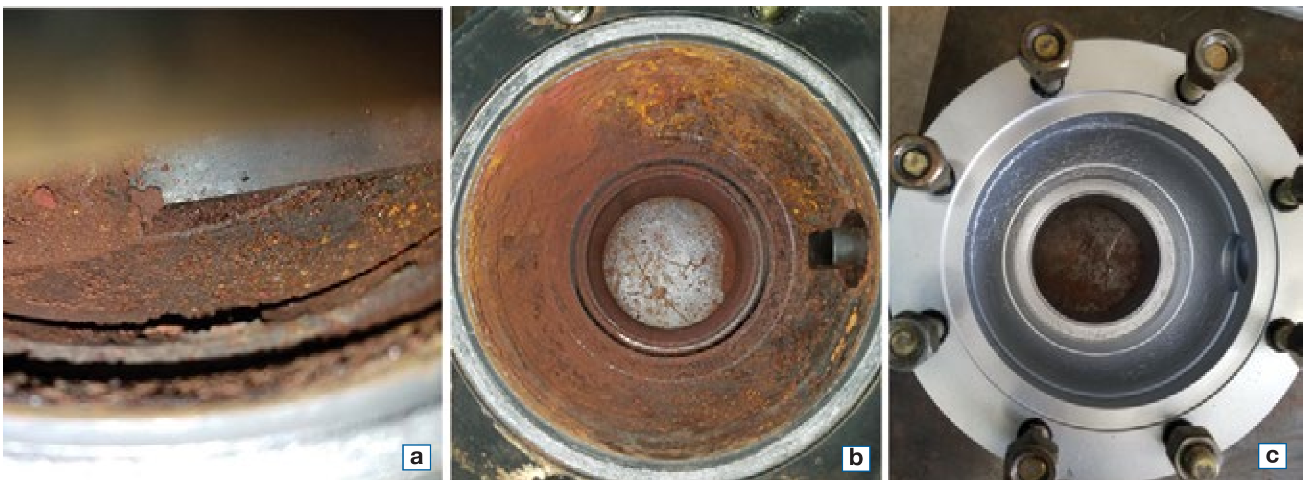
Some offline water-wash drain valves are difficult to operate when new and become nearly impossible to operate after a few months in service. This creates a significant ergonomic risk of muscle strain or sprain and fatigue for the operator tasked with aligning this valve for compressor cleaning.

If the valve is not fully closed, or is over-closed past the stops (which causes the same condition as a valve not being fully closed), there are possible safety and equipment risks as well. When the unit is placed back in operation, hot air from the compressor discharge case and combustion gases will pass through the carbon steel drain header, causing it to heat up enough to burn off paint. This is of particular concern with oil-fired units, where residual fuel oil also may be present.

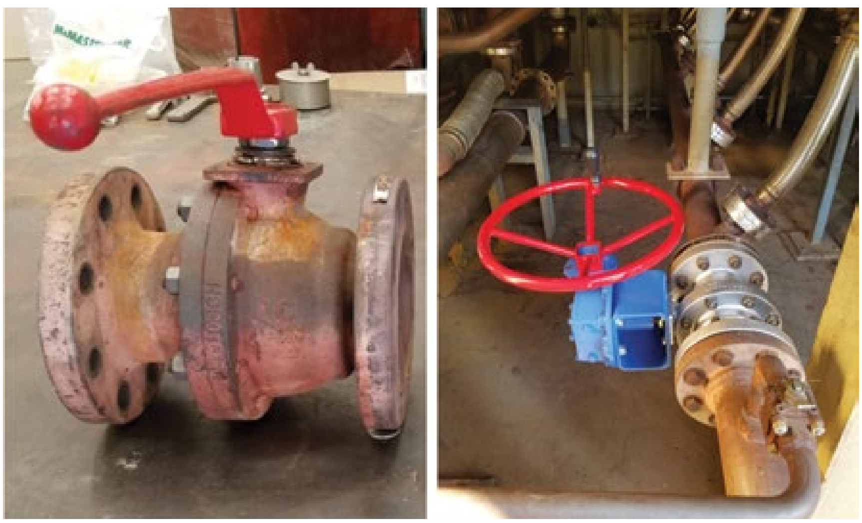
Plant staff conducted a root cause analysis that included the full disassembly of an existing stuck valve. (When the valve was removed from service, a blank flange was installed temporarily.) The RCA found severe rust accumulation inside the cast-carbon-steel valve body and a broken valve-closed stop.

The rust had accumulated between the ball (Type 316 stainless steel) and seat, and rust was compacted between the ball and body, under the seat rings and in the stem (also Type 316) packing area as well (Figs 1a and b).

The primary root cause: Corrosion of



1. Rust had compacted between the ball and body, under the seat rings, and in the stem packing area (a and b). After grit-blasting, plant personnel checked for pitting and then applied, both outside and inside the valve body, a high-heat-resistant spray paint coating that did not require oven curing (c)



2. As an added ergonomic benefit, staff replaced the original valve operator (left) with a gearbox operator and handwheel (right) specified by the valve manufacturer's representative

PAG favored over petroleum-based lubricants by an increasing number of turbine users

Sponsored by American Chemical Technologies Inc

Polyalkylene glycols (PAG) are no longer the "new guy on the block" in the power generation industry. American Chemical Technologies' (ACT) EcoSafe® line has remained unchanged, using PAG base stocks in its formulations since the early 1990s. PAG chemistry has provided lubricant solutions in many different turbine applications for over a decade.

These synthetics are a paradigm shift away from all the obstacles contended when using petroleum-based lubricants—including varnish, electrostatic discharge, failed demulsibility, and hydrolytic instability. The challenges with varnish and solids are here to stay, and might heighten because of the changes forced upon the petroleum industry by OSHA and the EPA.

With more and more turbine users suffering varnish-related issues, the power industry has turned to the non-varnishing PAG to rid their operations of unfavorable variables. In chemistry "likes dissolve likes."

Petroleum products are non-polar with only hydrogen and carbon in their make-up. As petroleum products oxidize, they produce polar decomposition products that will not solubilize in the base stock. By contrast, PAGs have 28% oxygen, and as they oxidize, produce low-molecular-weight polar byproducts that will always remain soluble in the base stock.

ACT offers the following synthetic non-varnishing PAG formulations in the EcoSafe line for power generators:

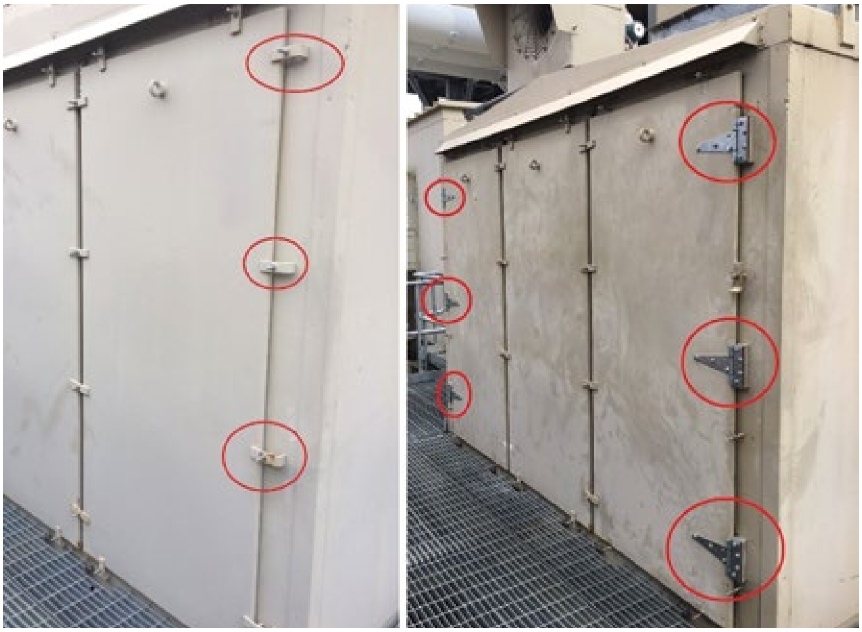
- EcoSafe EHC, a Factory Mutual-approved, fire-retardant hydraulic fluid, was developed for use in servo-operated electrohydraulic control systems. This product, in use since 2004, is now protecting over 220 units, including nine 501F gas turbines.
- Full-synthetic EcoSafe TF-25 was developed for lube-oil systems. The first user of this fluid just surpassed 11 years of non-varnishing performance with no lubrication-related trips, failed starts, or servo-valve failures. With an anti-oxidant loss of around 2.5% annually, the fluid in the oldest system is tracking to provide an approximate 30-year fluid service life. Today, more than 110 turbine lube systems rely on PAG chemistry.

Oftentimes an end-user plagued by varnish/solids doesn't have a budget for an oil change, or an outage planned to conduct the work. Some of the newer turbine-oil formulations are yielding reduced service life, with varnish potential lurking after only a few years of service.

Powerplants are having to proactively investigate alternatives to remove the soluble and insoluble varnish. To provide a chemical solution to the chemical varnish problem, ACT developed and patented an oil-soluble PAG base-oil modifier—EcoSafe Revive—that when added to a varnished petroleum product (patent calls for 2% to 20% treatments), shifts the polarity of the co-mingled lubricant, and solubilizes varnish/solids keeping the system liquid. All varnish in the system is "dissolved" back into solution with no need to remove it by way of mechanical filtration. EcoSafe Revive has provided varnish solutions in over 170 units, including 18 501F turbines.

Now with over a decade of use and data under its belt in the power generation industry, EcoSafe is one of the oldest formulations on the market. PAGs have proven that no matter the situation, they are a true solution to varnish.

3. Confined space (arrow) in GT accessory module inhibited the ability of technicians to escape quickly in the event of a fire or alarm fault



4. Bolted straps that secured the accessory module's access panels on all sides (left) were replaced with hinges (right) without compromising the compartment's integrity

the valve body over time and jamming the seats against the ball and the stem in the body. Investigators found that the corrosion was caused by water—from the wash activity and condensation from normal operation—contacting the valve's cast carbon steel body.

The "unidirectional" design of this particular ball valve uses system pressure to force it against the downstream seat, leaving the upstream seat lightly loaded. This may allow moist compressed air to condense in the header over time and infiltrate the valve body, aggravating the corrosion problem.

A special overhaul kit was ordered from the vendor of the non-standard valve, which was specified by the OEM. The valve was completely disassembled, grit-blasted to remove rust, and visually inspected for pitting and other damage (Fig 1c). Staff then applied a high-heat-resistant spray-paint coating (one that did not require an oven-curing process) on the inside and outside of the valve body—except for the stem packing seal area, which was masked for protection.

The valve was reassembled with new seat rings and gaskets and all fasteners were torqued according to the manufacturer's published procedure. As an added ergonomic benefit, the original brute-force valve operator (Fig 2 left) was replaced with a gearbox operator and handwheel (Fig 2 right).

After more than six months of operation, the valves were still easy to operate and showed no signs of leak-by. The new gearbox operator and handwheel mitigate any risk of strain or sprain for technicians.

Project participants:
Matt Engelbert, plant engineer
James Jensen, maintenance mechanic

Hinged access panels provide easier access to/escape from GT accessory module

Gaining access to some sections of the gas-turbine accessory module were difficult. Areas technicians had to enter to monitor vibration and perform other routine maintenance could be a tight squeeze—a safety concern if a fire were to start with someone inside or if the CO_2 system discharged accidentally.

Even with a mandated warning system and time delay, escaping in timely fashion could be difficult. The red arrow in Fig 3 shows one of these locations: clearly there's very little room to move freely, and the access panels would take time and effort to remove (Fig 4 left), making a quick exit challenging.

Plant personnel considered equipping technicians entering the module with breathing packs. But they were concerned that their size might restrict movement and vision, and might not provide team members what they needed where and when they needed it. After further review, staff decided to improve access by installing hinges on the existing accessory panels (Fig 4 right), thereby converting them to access doors. The panels were hinged in a manner that assured the integrity of the accessory module would be retained.

5. Safe escape. Arrow shows the same difficult-to-access confined space as before, but with hinged panel that now allows personnel quick and easy access, eliminating the risk of confined-space entry

The bottom line: At a tiny fraction of the cost of breathing packs, the solution described provides much easier and safer personnel access for regular maintenance. Plus, the doors eliminated concerns regarding escape from a confined space (Fig 5).

Project participant: Jason Land, I&E technician

Paved access makes moving CEMS gas cylinders safer

At virtually all powerplants, continuous emissions monitoring systems (CEMS) have been installed to ensure reliable, acceptable emissions monitoring results. The tests rely on calibrated gas cylinders for multiple facility verification and testing. For many units, these cylinders must be moved back and forth depending on the test conditions that day.

The large, heavy gas cylinders (typically 65-70 lb each) must be moved and positioned manually (Fig 6), putting technicians at risk of strain injuries. Some of the walkways that provide access to the CEMS shelters are graveled and uneven. Taken together, these conditions are a recipe for a serious accident or injury.

To protect staff against the potential hazards described, plant personnel poured a concrete pathway to enable cylinder transport to each shelter and smoothed the graveled area surrounding it. The pathway edges are highlighted with yellow paint for added safety.

Project participant: Jimmy Shehan, maintenance technician

6. Gas cylinders and hand truck used to move them to/from CEMS shelters

Squeezing more life, better performance from legacy assets

Frame 6 Users Group

2019 Conference and Vendor Fair

Hilton Orange County Costa Mesa
Costa Mesa, Calif • June 10 to 13

Steering Committee

Co-Chair: Jeff Gillis, *ExxonMobil Research & Engineering Co*

Co-Chair: Sam Moots, *Colorado Energy Management*

Robert B Chapman Sr, *Chevron Maintenance & Planning Execution*

James C Rawls, *BASF-Geismar Site*

Mike Wenschlag, *Chevron Global Power*

Zahi A Youwakim, *Huntsman Petrochemical*

www.frame-6-users-group.org

The Frame 6 Users Group switches its meeting location to the West Coast in 2019 (box at right) after conducting its annual meeting last year on the East Coast. Not much changes in this organization year over year—other than meeting location and the all-important technical content.

The steering committee remains the same except that Brian Walker, a major contributor to this forum for decades, has moved on because of new job responsibilities. His chair was filled by Robert B Chapman Sr, a turbine repair engineer for Chevron Maintenance & Planning Execution, who spent 18 years at GE before joining the petrochemical giant about five years ago.

For readers unfamiliar with this all-volunteer organization, be aware that its highly interactive conferences have five key elements:

- Training workshop.
- User-only subject-specific roundtables focusing on major engine components.
- GE Day.
- Invited presentations from vendors on topics of importance to 6B owner/operators.
- Vendor Fair.

Workshop. The need to do more with less should not surprise anyone in the electric power industry these days. Users groups are working diligently to make the next generation of engineers and technicians productive more quickly than, perhaps, ever before in peacetime. Mindful of the need for specialized training, the 6B steering committee integrated a frame-specific half-day workshop on engine design, operation, and maintenance into the 2018 meeting. It was an instant success with John F D Peterson as the instructor and discussion leader, one of the organization's founders with more than three decades of relevant engine experience.

Anyone who knows Peterson will tell you this session alone is worth the conference registration fee. Few know as much about this frame as he does.

The half-day course, Monday afternoon, June 10 (the day before the conference begins), will be fast-paced and conducted in four sessions of about 50 minutes each, with short breaks between them. Each attendee will receive a course workbook with descriptions of components, definitions of technical terms specific to the 6B, a listing of common operational and maintenance issues, etc. This document will be an invaluable aid for the meeting and at the plant afterwards.

Here's a summary of the subject matter included in the course:

- Brief history of gas-turbine technology and the Frame 6B.
- Theory of gas-turbine operation; engine performance basics.
- General description of the 6B gas turbine and the typical plant that it serves.
- Auxiliary equipment and system descriptions.
- Troubleshooting of critical systems—including lube oil, hydraulic oil, trip oil, fuel gas, rotor ratchet mechanism, etc.
- Control systems.
- Glossary of 6B terms and jargon.

Attendee profile. Frame 6B gas turbines are the heart of many cogeneration systems, and the O&M personnel responsible for them are a breed apart from most users the editors meet at industry meetings. The typical 6B user is a highly experienced "lifer" responsible for keeping steam flowing from his or her cogen facility to one or more process units.

The lives of 6B owner/operators rarely are controlled by a grid contract, by the need to "fill in" around must-take renewables, or by power prices. Electricity is simply a byproduct of steam production, a world where an empty steam pipe means you might well be looking for employment elsewhere tomorrow.

Such a challenging environment is conducive to a practical solutions-driven mindset. It's not news that some cogen-plant owners consider power production a "necessary evil" and keep O&M budgets lean, opting to spend on process facilities first. Their belief is that end-product investments will produce a better return—at least until a gas turbine is forced out of service.

Adding to the financial challenge is that many cogen facilities are not supported by a corporate engineering staff, and instead rely heavily on the talents of very-capable deck-plates personnel. The Frame 6 Users Group contributes to success by providing a "technical solutions lifeline" for its membership and the reason many of these people continue to attend meetings year after year—some since the group was founded more than three decades ago.

FRAME 6 USERS GROUP

User discussion sessions

Safety

The main technical program at Frame 6 meetings begins at 8 a.m. Tuesday morning (June 11 in 2019), following Monday's engine familiarization workshop and welcome reception and dinner. Roundtable discussions led by members of the steering committee and one of the two invited vendor presentations fill the first-day program until the vendor fair and reception at 5 p.m. The second vendor presentation and remaining discussion topics are on the Thursday morning program; adjournment is at noon, then lunch. Wednesday is GE Day.

Safety is the first discussion topic. That roundtable is led by Co-chair Jeff Gillis, whose position as gas-turbine technology lead for ExxonMobil's frame gas-turbine fleet worldwide gives him a global perspective on this subject of importance to all attendees. OSHA is not global and America does not have all the answers.

Gillis' first slide was designed to stimulate thinking aided by morning coffee. He put up a list of possible topics in three categories to get the discussion rolling, including:

General
- Life-saving rules.
- Compartment entry.

Safety systems
- Hazardous-gas detection.
- Fire suppression.

Maintenance
- Fall protection and PPE (Personal Protective Equipment).
- Scaffolding and access.
- Safety professionals and other personnel.
- Inlet filter house fire prevention and escape.
- Rescue considerations.
- Fuel-nozzle failures resulting in a casing breach.

One of the users in attendance thought "life-saving rules" at the top of the list was a good place to start, suggesting immediate removal from the site of anyone working without a LOTO (Lock Out/Tag Out) permit, engaging in horseplay, walking under a suspended load, not observing rules pertaining to electrical isolation, as well as other infractions. Others agreed.

Compartment entry when the unit is operating always generates discussion among users; opinions differ. On the one hand it's much easier to find leaks and troubleshoot when the unit is on; on the other, there are hazards in doing this.

European gas turbines trip if the compartment door is opened while the unit is operating. GE claims opening compartment doors violates the ventilation scheme. Some units trip on low ventilation airflow because air escapes from the door rather than exiting via the ventilation ductwork.

While the consensus view was that compartment entry protocol is site-specific, the discussion revealed many users are trying to minimize, if not eliminate, access with the GT in service. Ideas offered: Install hazardous-gas detectors in the compartment to warn of fuel-gas leaks. Retrofit armored windows in package doors and floodlights inside the compartment to allow visual checks from outside. Provide access to important operating data outside the package.

Another idea offered is to check for leaks when the unit is on crank. One user went beyond this, saying you can introduce enough air into the system to leak-check with the unit offline.

1. Filter houses should be designed with multiple exits to allow rapid escape from all floors and sides in the unlikely event of a fire

Trip reduction worked its way into the discussion because 6Bs are installed at many industrial plants to provide steam and loss of an engine might upset a process that must run continuously. It was said that the OEM now has a package to alarm rather than trip for some operating conditions. This enables operators to assess the situation and decide what to do. The number of trips related to a single event also has been reduced.

Attendees were warned about the hazards of standing directly in front of a door being opened. Also noted was the need to properly close the compartment door after exiting; there's not much protection from CO_2 if the door is ajar.

The possible dangers associated with tying-off when working on top of the turbine was another topic. Fall protection lines can get tangled and cause injuries—possibly ones more severe than an actual fall. Railings have been installed in some cases. A few users reported having tie-off exemptions during outages for work on top of the turbine.

Having a safety professional assigned during outages was suggested. Use of bump caps in place of hard hats was recommended for work inside the generator stator.

The possibility of a fire at the turbine inlet is a real concern to many because it can consume the filter house in a matter of minutes trapping anyone inside if there's no way to exit safely on both sides (Fig 1). Safety tip: Ban the use of halogen lights in the filter house, near evap media, etc. One user mentioned an incident involving the use of halogen lighting when an oil sump was being cleaned out. A lamp came into contact with oil-soaked rags, creating a large amount of smoke in a confined space.

There's a vast amount of safety-related information readily available to owner/operators wanting to improve their procedures to best-in-class. You might want to begin your research on the CCJ website (www.ccj-online.com) where you can find best practices submitted by colleagues over the years.

For the Frame 6 specifically, Gillis prepared a slide of 6B user-forum safety threads, several slides describing more than 30 Technical Information Letters focusing on 6B safety concerns issued by the OEM (TIL 1700, for example, "Potential Gas Leak Hazard During Offline Water Washes"), and content summaries of four GE Product Service Safety Bulletins issued by GE.

Some material pertinent to 6B owner/operators goes beyond the basic engine. One example, PSSB 20161220, "GT Upgrade Impact on HRSG," presents the experience of an owner that learned a GT upgrade had been implemented without sufficient evaluation of the safety impacts on the boiler. Specifically, the new steaming capacity was greater than the nameplate rating and the relieving capacity of the existing safety valve.

This is a serious concern, but don't expect to get a meaningful HRSG discussion going at a meeting focused on gas turbines. For that you need to attend the annual *HRSG Forum with Bob Anderson*. Next conference: July 22-25 in Orlando. Details at www.HRSGforum.com.

Auxiliaries, generators

There wasn't as much discussion as you might expect on auxiliaries but the allotted one-hour time slot was shared with generators and excitation. Best for users with concerns/questions on this equipment is to send an email to Co-chairs Gillis and Sam Moots a couple of weeks in advance of the coming meeting and get them on the agenda.

A user described a load-coupling failure on a 1990 unit. He said the OEM replaced the coupling in 1998 because of high vibration, but it failed on startup after 50,000 hours of service. GE wanted a year to deliver a replacement so the owner went to a third-party supplier and purchased a similar coupling. Shortly thereafter, it was said, the OEM issued an advisory to plant personnel saying that it had "lost faith" in its coupling.

Torque converters (Fig 2) and the ratchet mechanism (Fig 3) got some air time with one user saying that if the latter is not ratcheting, the torque converter likely is the main cause of the failed start. Another user reported binding of the ratchet shaft. Yet another was a problem with varnishing of the sequencing valve—severe enough to require disassembly and cleaning at every major.

Load-gear oil leaks were introduced by a user trying to determine just what is "acceptable leakage" is. He attributed the leakage to a design issue.

A stator rewind was the highlight of the generator session. The user described the removal of the stator frame which was then sent to the shop where the work was done. Project was considered a "great success" by the owner.

2, 3. Torque converters (above) and the ratchet mechanism (right) typically promote much discussion in the auxiliaries session

Compressor

The user-only compressor session at Marriott Sawgrass didn't include any new topics, at least while the editors were in the room. At most 6B meetings, discussions include filter experience (HEPA in particular in recent years), online and offline washing, corrosives and particulates in the air impacting compressor cleanliness (and how to remove them), inlet bleed heat, bearing damage, clashing experiences, coatings, etc.

Proven coatings, when applied correctly, can offer meaningful economic upside. A compressor that remains clean year-round without washing minimizes performance loss (a topic incorporated into the Monday workshop conducted by Peterson) for the entire run cycle, virtually eliminates the cost of demin water and soap for washing and any expense and permitting associated with wastewater disposal, and eliminates any operating penalty that might be associated with washing.

While the Frame 6 Users Group attracts some offshore attendees, the large majority of 6Bs is located outside North America and the experiences of those owner/operators generally are not shared at the US meeting. CCJ's international activities, which include participation in the best practices program organized by the European Turbine Network (ETN), brought to light coating experience at a Scandinavian industrial facility that might benefit others.

That plant was challenged to reduce fouling-related degradation of 6B performance caused by a harsh coastal refinery environment containing salt, dust, soot, etc. The airfoil shown in Fig 4 was not washed prior to a major inspection after 40k hours of service. Plant management was reluctant to perform online or offline compressor washing given the possibility of engine tripping and/or other problems during restart, as well as the possible negative environmental aspects of water use.

The stainless-steel compressor blades were cleaned and coated with the anti-fouling treatment AFT from United Services Sweden AB during a major overhaul in 2011. No fouling-related degradation was in evidence after 56k hours of operation (seven years) with annual washing only (Fig 5). The photo shown in Fig 6, taken after spraying water on the compressor blades, shows that the coating's hydrophobic properties remained intact.

4. Fouling of blades and the resulting performance loss were mitigated by coating airfoils and installing more efficient filters to deal with the industrial dusts and vapors, and carbon particles, present in ambient air supplied to the 6B

The DLN-equipped engine normally operates baseload, dialing back output only when steam demand is low. Inspection and water washing of the GT is done during the annual maintenance period for process equipment. An HGP inspection is scheduled for the engine every 24k hours; a major is done at 48k intervals.

Note that United Services is owned by Peter Asplund, previously affiliated with Florida-based Gas Turbine Efficiency, a compressor-cleaning solutions provider. United's stated mission is to permanently improve and maintain power-generation energy efficiency by minimizing fouling-related losses.

The editors communicated with the plant manager (PM) by email to get the details that follow. The plant learned about United Services' coating through discussions with other users in Scandinavia. One member of the collaborative group of owner/operators had used the coating on his IGVs with positive results. The PM said he reviewed that experience, as well as laboratory tests, before putting AFT on IGVs and first-stage rotating blades of his 6B about three years before the 2011 major. His trial showed that fouled airfoils were cleaned simply by washing with demin water.

United Services both cleaned and coated the compressor section in the plant shop without removing blades from the rotor. This work took four days and had no impact on the outage schedule.

The PM said he expected the coating would retain its dirt-repelling properties for the entire period between consecutive majors and that was confirmed by inspection. However, an additional coat of AFT was added to the IGVs and first-stage blades after a

FROM RELIABLE EFFICIENCY TO KEEPING THE LIGHTS ON

SHELL TURBO MAKES IT POSSIBLE

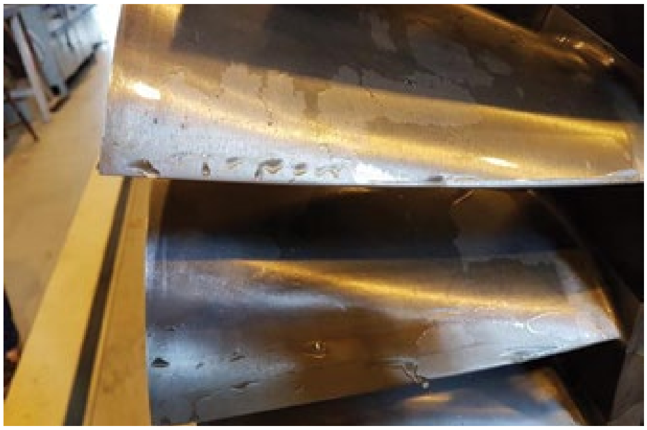
Power companies are under immense pressure to keep the lights on. As a result, modern turbine oils must be able to cope with increased stress and considerable design and operational challenges. Although selecting an underperforming lubricant rarely results in immediate failures, it can lead to long-term increases in maintenance costs and heavy power-outage penalties. In contrast, adopting a total-cost-of-ownership[1] approach with a high-performing lubricant from the Shell Turbo range can help to reduce costs by unlocking reliable efficiency. Ask us how we can work with you to make it possible.

Shell.us/power

SHELL LUBRICANTS
TOGETHER ANYTHING IS POSSIBLE

[1]Total cost of ownership is defined by Shell Lubricants as the total amount spent on industrial equipment, including the cost of acquisition and operation over its entire working life and the cost of lost production during equipment downtime.

5. **Compressor looks like new** after a 56,000-hr run between major inspections. Credit the AFT coating and HEPA filters



6. **Simple spray test** proved coating's hydrophobic properties remained intact for 56,000 hours of operation

couple of years of service. The recoated rows were viewed as easier to clean with demin water (no soap).

Compressor performance degradation was said to be "considerably less" after the coating was applied and air inlet filters were upgraded. The PM said the 4-MW loss experienced between annual shutdowns with uncoated blades dropped to 1 to 1.5 MW after coating and installing filters offering more efficient capture of fine particulates.

F7 filters allowed the fouling shown in Fig 4, so they were upgraded to HEPA, which are changed triennially. Both prefilters and fine filters are installed; G4 and E11 ratings, respectively.

The inlet plenum later was coated with AFT to smooth out air flow to the engine.

A new *uncoated* rotor recently was installed in the 6B; the original was retired after about 200k hours of service. The PM said he would use this opportunity to monitor performance degradation between annual outages to determine the impact of better filtration with uncoated blades.

Combustion

The combustion session encompasses discussion of fuel nozzles, liners, flow sleeves, transition pieces (TPs), crossfire tubes, igniters, flame eyes, and combustion cans and piping. One snippet of advice from an attendee: Never buy new flow sleeves (Fig 7). You can repair them many, many times. However, having a spare set on hand was viewed as prudent.

Discussion of combustion hardware was lively. It was said that the OEM only guarantees 15 ppm NO_x but that you'll probably see 9 ppm on 24k DLN hardware. A user said his unit comes in at around 5 ppm using third-party hardware. DLN1+ users reported 3.5-5 ppm.

TPs and first-stage nozzles were not fitting-up properly, one user said, despite flat and square picture frames. Another participant stressed putting TPs and nozzles on a flat surface before installing. Yet another user suggested sending the first-stage nozzles and TPs to the same vendor at the same shop. This enables set up in a proper fixture (Fig 8) to mitigate fit-up issues.

Recommendations from the floor:

- Strip, inspect, and recoat TBC on TPs and liners after a three-year run.
- Test igniters on the turbine deck to avoid reinstalling them and finding out they don't work.

Turbine

Discussion on the turbine section always is robust at Frame 6 Users Group meetings (Fig 9), likely because there are many "senior" machines in the fleet—those with well over 100k operating hours. Current thinking of the OEM and a few others is that an end-of-life inspection should be done at about 100,000 hours and that the rotor should be replaced at 200k.

One of the users said he thought there might be an economic benefit to simply replacing the rotor at 100k, at least for 6B engines, because vibration issues are common after an EOL inspection and machines generally run very well after installing a new rotor. Another attendee's experience added credibility to this suggestion. He said excessive wear was found in the dovetails of the third-stage wheel for one of his units during an EOL inspection and the heavy coating applied in the worn areas presented issues during restack.

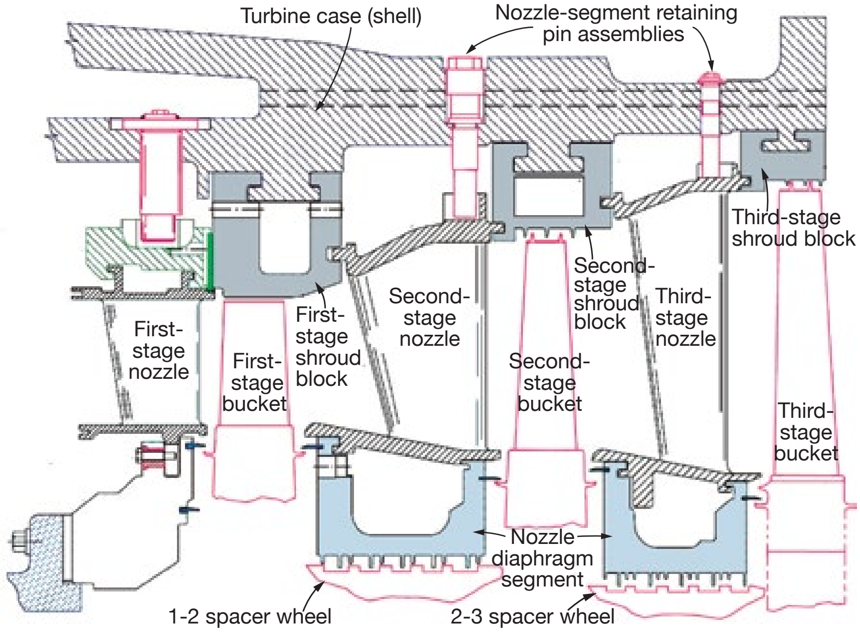
Frame 6 veterans had good advice on parts and coatings for attendees having limited experience this frame. When you're in the market for parts, know the specifics of what you need. Specifications are critical to the bid process. Attention to detail is important: "If you get it wrong," the group was told, "your machine will not operate as well as expected."

Consider visiting candidate vendors before making a buying decision and engage with them on coatings, design, alloy, casting, grain structure, airfoil shape, heat treatment, repairability, etc.

Regarding coatings, one user mentioned that the OEM offers an "optimized coating," enabling a choice based

7. **Repair flow sleeves,** don't buy new ones (left)

8. **Proper fit-up of TPs** and first-stage nozzles is confirmed in fixture (right)



9. Turbine-section diagram highlights important parts

10. First-stage bucket with 16 cooling holes in the tip

11. Spalling of TBC and trailing-edge damage can be expected on first-stage nozzles

on operating paradigm. It was said that some coatings are better suited for baseload operation, others for peaking service.

First-stage buckets generated significant give-and-take. One user said getting anything but the 16-hole airfoils was challenging (Fig 10). Another user, noting that new first-stage buckets don't have TBC, asked if other attendees were adding a coating to ensure a 24k interval and one more repair cycle. Adding a coating might not make sense, one colleague replied, it depends on your business goals. "Are you looking for reliability or performance?"

One user concern regarding new first-stage buckets is that cooling holes are so close to the squealer tips that a rub could block air flow. A suggestion was to always check cooling holes when you can to be sure they are open.

First-stage nozzles. TBC is optional; however, repairs can be very expensive if you don't specify a coating. But be careful: If you "go crazy" with TBC, you might restrict air flow and adversely impact performance. Specify TBC thickness and be sure the shop measures it. Remember, too, if you add TBC to a nozzle that didn't have it previously, some metal must be shaved off to accommodate the coating thickness.

An attendee troubled by TBC spallation and trailing-edge damage was told not to worry too much because they would not wreck his machine (Fig 11).

Shroud blocks. The group was told that casings like to ovalize over time. Remove shroud blocks until you get to one with the minimum clearance and shave down the ones removed. First-stage shroud blocks must be recoated, not those in the second and third stages; however, you can have challenges with the latter because of honeycomb seals. Be patient, ovaliation stops at some point.

Exhaust flex seal eventually will crack and fail because of the challenging operating environment. A telltale clue is over-amping of the exhaust fans, which can't get enough cooling air into the bearing tunnel. A quick visual inspection of the flex seal was recommended each time the shell is off. CCJ

GE Day

The Frame 6B OEM was responsible for the Wednesday technical program and split the day with the morning dedicated to fleet-wide topics suggested by the steering committee and the afternoon divided among three discussion-focused breakout sessions catering to specific user interests.

A "state of the frame" presentation launched the GE Day program with highlights of the 6B's 40 years of service to the industry. The first engine was commissioned in Montana in 1979 and advancements in the technology have been ongoing since that time, the group was told. To date, the 1150 6Bs installed globally have operated more than 65-million hours on a wide variety of fuels with a reported reliability of about 99%. Eleven 6Bs were installed in 2017-2018.

Perhaps the most significant announcement of the day was the startup of the first US 6B AGP (Advanced Gas Path) unit two days earlier. The highlighted benefits: 14% increase in output, HGP (Hot Gas Path) intervals of 32K FFH (Factored Fired Hours), heat-rate improvement of up to 5%, and an increase in exhaust energy of up to 8%. Eight units in Saudi Arabia were said to have the AGP upgrade

Beyond the advantages of the AGP offering, the speaker mentioned solutions for better performance, lower O&M costs, and life extension—including extended turndown, efficiency enhancements, and a flange-to-flange 6F.01 drop in module. Five 6F.01 modules were said to have been sold, but not shipped, at the time of the meeting. Three of these will be configured as hot-end drives.

TILs (Technical Information Letters) important to 6B owner/operators and issued between the 2017 and 2018 meetings were reviewed. A handy table indicating document number, title, date of issue, and degree of importance is available on the user group's website.

If you are not familiar with TILs 2041, 2044, 2046, 2051 2003-R1, 2060, 2064, 2066, 2076, or 1566-R2, it's a good idea to come up to speed quickly. Two of these documents are safety-related and five others require compliance, a couple at the first opportunity and one prior to next time the affected system is operated.

The compressor sections for 6Bs generally have been bullet-proof over the years. Problems experienced include IGV cracking attributed to corrosion pitting and rubs; root liberation at the leading edge of some R1 rotor blades believed caused by erosion and corrosion or, possibly, IGV miscalibration; S1 stator vane leading-edge cracking/clashing; and tip loss from some airfoils in Rows 2 and 3.

Mitigation actions were offered. One

example is replacement of carbon-steel vane rings with ones made of stainless steel to prevent the lock-up of vanes from rusting and minimize the potential for clashing. Blade health monitoring via sensor probes on the first three compressor stages is expected to help warn of possible clashing by monitoring changers in blade deflection and frequency.

Documents offering maintenance advice for the air inlet structure to improve compressor availability/reliability included PSIB20170428A, GEK 116269, PSIB20130813A, and GEK101944. Add missing documentation to your plant library. Need help? Ask your GE representative.

GER3620N, issued in October 2017 and accessible online with a simple Google search, provides inspection and maintenance advice for the engine proper.

A briefing on the OEM's new blade-health monitoring system, which relies on vibration signature (probes are installed on the compressor casing) to warn of an impending issue, was a highlight of the compressor presentation. Get details from your GE rep.

Parts interchangeability. Given the fleet's 40-year service life and the number of people who have had O&M responsibility for your 6Bs since COD, it's easy to believe you might not know the vintage of parts installed in the engines or those on a warehouse shelf. What parts fit where and how was the subject of a short presentation, "HGP considerations," that's worthwhile reviewing before the next outage—especially one involving parts replacement in a row of mixed airfoils. Visit the Frame 6 Users Group website.

Controls. When the first 6B went into operation, the control system offered by GE was the Mark II. Some machines in service today still are equipped with the Mark IV, offered from 1982 to 1991. Many have Mark Vs, manufactured from 1991 to 2004. During the user-only discussion session on controls the day before the OEM's presentations, by show of hands, four attendees said their units were equipped with the Mark IV; about half of the group's engines had Mark V. Another third had the Mark VI, the remainder Mark VIe.

The OEM urged attendees to upgrade their control systems to the Mark VIe. There are several reasons to do this, chief among them: availability of parts, cybersecurity issues (patching is not supported), technical support during outages, ability to allow new performance-enhancement options the owner/operator might find of value.

Two modernization options were discussed, full-panel retrofit and migration. A complete control system replacement was said to take about 25 days and possibly require more floor space than the existing system occupies. Migration translates to nondestructive key-component replacement through plug-and-play. All field wiring remains as is—no determination/retermination. Depending on scope and technician deployment, the migration option could take from about a week to 14 days. This option is less expensive than a full panel retrofit.

The speaker went on to describe stepwise conversions from the Mark IV, Mark V, and Mark VI to the Mark VIe—a good starting point for someone considering an upgrade.

Generators were the last topic on the OEM's 6B technology agenda. This was the longest presentation of the day and rightfully so: Most plant personnel are comfortable with mechanical work and I&C, and typically have little experience with high-voltage electrical equipment—generators in particular.

The speaker began with an examination of lifecycle considerations. Cyclic operation (starts/stops) taxes the rotor, he said, while operating hours impact stator maintenance intervals. Historically, the speaker continued, rewind risk increases for rotors between years 15 and 20 and 35 to 40, for stators between 25 and 30 years.

The value of GEK 103566 (ask your GE site rep for a copy) in planning an effective generator maintenance program was stressed. Rev L updates were discussed to bring users up to date. Key talking points included these:

- Updated rotor life-management recommendations.
- Addition of recommendations for when to remove the rotor—only for repairs, not inspections. Condition assessments can be made using a combination of online trending, in-site testing, and visual (borescope) inspection.
- Recommendation for a low-oxygen stator cooling-water system.
- Benefits of combined stator and rotor test and inspections.

Types of robotic inspections—in-situ air gap, in-situ retaining ring, and wedge tapping—and their applicability to the various generator models associated with the 6B, were explained along with their idiosyncrasies and the background information required to assist in condition assessment.

A case study describing the need for a generator rewind based on robotic findings was incorporated into the presentation. The robotic inspection for this unit included a partial stator-slot wedge-tightness check, an EL CID test, and visual inspection of field parts, stator core, and field/stator windings. Here were the findings:

- Slot wedges in good condition.
- Some FOD impact damage to the core.
- Minor dusting in the stator.
- Four broken leaves found on one main lead terminal stud.
- Several slots found with springs moved and nearly closed vent holes.

Generator monitoring to enable condition-based maintenance—partial discharge, rotor flux, rotor shaft voltage, endwinding vibration, stator temperature, collector health, and static leakage—was a major part of the presentation. Keep in mind that the benefits of early fault detection are considerable. For example, it enables plant personnel to control unit operation to limit deterioration and prevent a forced outage.

Each of the diagnostic tools noted above was reviewed in terms of the sensors used for detection, what was being monitored, and what it was capable of finding—for example, loose stator bars in the case of partial discharge.

To dig deeper into generator monitoring, inspection, and maintenance, access Clyde Maughan's course, available at no cost, on the CCJ website (www.ccj-online.com/onscreen). Maughan is well respected for his knowledge of generators, the focus of his 35-year GE career and more than three decades of consulting work after retiring from the OEM. The program is divided into the following manageable one-hour segments:

- Impact of design on reliability.
- Problems relating to operation.
- Failure modes and root causes.
- Monitoring capability and limitations.
- Basic principles of inspection.
- Test options and risks.
- Basic approaches to maintenance.

The three afternoon breakout sessions each featured three presentations, conducted in parallel, as outlined below. These were followed by a reception and special GE product fair.

Breakout No. 1:

- Exhaust and wheel-space thermocouple reliability.
- Rotor end of life.
- Combustion systems.

Breakout No. 2:

- Control system obsolescence, including generator excitation systems.
- Repair technology.
- Peakers.

Breakout No. 3:

- Instrumentation.
- FieldCore.
- Accessories.

Users talk back. Attendees expressed several concerns during the course of GE Day. Here are a few of them:

- Level of experience of FieldCore personnel.
- Amount of time it takes to respond to PAC (Power Answer Center) cases.
- Quotes for non-LTSA customers take too long.
- Repair improvement and lead-time expectation.
- Division of responsibility between the Power Services and Baker Hughes organizations.

Vendor presentations

With much of the time at Frame 6 meetings devoted to user presentations and deep discussion, there remains limited time for vendor presentations. Each year, the steering committee carefully selects two third-party vendor presentations in tune with what owner/operators are experiencing in the field. The two topics selected for the 2018 meeting dealt with combustion hardware and personnel safety and are both applicable to all gas-turbine makes and models.

Fuel nozzles

"Don't play musical chairs with your combustion parts," says EthosEnergy's Iain Maclean, the company's product sales manager for HIT fuel nozzles. In a gas turbine, flame temperature and distribution are a function of both fuel and air distribution. Optimization is achieved from flow testing the gas in the fuel circuit, flow testing the liner air circuits, and then marrying the two processes for enhanced performance. According to the speaker, with emissions limits perpetually tightening, the only way you can confidently repair is if you flow test.

The process of minimizing the range of variation in fuel flow to each can in a low-NO_x combustion system is called "wheeling." Its objective is to have each can operate with approximately the same flame temperature, thereby making it easier to tune the combustion system to obtain lower emissions and dynamics levels, reduce temperature spreads, and improve hardware life.

While wheeling fuel flow is helpful, the reality is that a variation in combustor flame temperature is caused by both fuel variation and air variation, not just the former. To truly minimize flame-temperature variation among the combustors, the variation in "fuel-to-air" ratio must be minimized. To do this, combustor air flow must be known.

Air flow is more difficult to determine than fuel flow because of the large effective area of the liner relative to the effective area of the fuel system. EthosEnergy has developed and offers a service to flow full liners for wheeling purposes to get the effective areas of various liner components, including:

- Venturi.
- Head end.
- Full liner.
- Dilution holes.

The test-stand configuration is "reverse-flow" as in a real machine and allows for investigation of a range of pressure ratios for standard, DLN1, and DLN1+ units. All testing is done at ISO conditions but EthosEnergy's ECOMAX® combustion-tuning system can be used to balance out the changing ambient conditions onsite.

By understanding the possible variations in fuel-to-air ratio, estimates of the range in combustor flame temperatures can be determined. Pairing the components properly results in temperature-difference reductions critical to obtain very low emissions levels and low temperature spreads. The low temperature spreads resulting from flow testing and wheeling can help buy time if any tuning issues arise during operation.

Other advantages include the following:

- Higher confidence level on startup

after an outage.

- For multi-engine fleets with limited spares, flow-tested components can be normalized for all units to improve flexibility and reduce capital expenditures on spare parts.

Fire suppression

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. The presentation by Chuck Hatfield of Orr Protection Systems is a good first step in the learning process.

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. The company also offers design/build, system modification, and decommissioning services.

Hatfield's presentation addressed CO_2, water-mist, and hybrid systems. Given the number of slides and the amount of material covered, this could have been divided into three presentations.

CO_2. The basis for Hatfield's CO_2 system coverage was NFPA 12, "Standard on Carbon Dioxide Extinguishing Systems," the latest version of which was published in 2018. CO_2 is an effective suppression agent, but there are safety concerns for personnel.

Hatfield discussed normally occupied, normally unoccupied (but occupiable), and un-occupiable areas, and things of general importance regarding CO_2 systems—such as safety-sign specs (type size, color, etc) and where they should be placed, supervision of automatic systems and manual lockout valves, rules for discharge pressure switches and pneumatic time delays, provisions for prohibiting entry into given spaces, etc.

Water mist. You hear more about high-pressure water mist systems today than only a few years ago because of concerns about the accidental release of CO_2 when personnel are in normally unoccupied spaces—such as the gas-turbine compartment. In fact, at least one OEM prohibits package entry when the GT is in operation.

Hatfield went on to describe high-pressure water mist systems, standards set forth in NFPA 750, importance of droplet size, and its advantages in comparison to other systems, including:

- Safe alternative to CO_2.
- Cost-effective alternative to inert gases.
- Clean alternative to foam and powder.
- Environmentally friendly alternative to halon.
- High-performance alternative to low-pressure water mist systems.

Hybrid. Hatfield ventured into the latest technology and developments in fire protection with an overview of hybrid systems that are becoming more prevalent in powerplant applications, especially the Victaulic Vortex™ system. It uses a supersonic emitter to create a multi-layer shock wave of nitrogen which atomizes the water to a sub-10-micron mist, thereby creating a homogeneous suspension of nitrogen gas and water.

To dig deeper, NFPA 770 provides the standards for hybrid fire extinguishing systems using water and inert gas. CCJ

TURBINE TIPS, No. 2 in a series

How manual controls help in troubleshooting legacy GE gas turbines

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

Turbine Tip No. 2, from the PAL O&M solutions library, applies to General Electric Frame 5 models K-LA and M-P, and early 6Bs, 7Bs, and 7Cs, equipped with Y&F fuel regulator and Speedtronic™ Mark I, II, and IV controls.

Overfiring a gas turbine during startup can be a serious condition, particularly when the engine is cold. As a GE gas turbine fires and warms up, fuel flow is controlled by the average exhaust temperature—called **Txa**. During the subsequent acceleration period, the starting means (diesel engine or electric motor), assists in bringing the turbine rotor up to rated operating speed.

On legacy units, as the coupled rotor passes through a mid-range zone, compressor air flow and pressure may be insufficient to maintain **Txa** under 950F, as recommended by the OEM. If your control system is incapable of limiting fuel flow to prevent the exhaust temperature from exceeding 950F, be advised that GE provided for manual control of its early gas turbines (years from 1960 to 1980).

In the decade of the 1960s, GE gas turbines used the Young & Franklin fuel regulator for engine control. In the early 1970s, Speedtronic became the electronic control and protection system of choice. In this 20-year span, the OEM provided methods for "overriding" the automatic controls with a *manual* feature on its gas turbines.

In Fig 1, an operator is shown "thumbing" General Electric Manufacturing Co's (GEMAC) **70TC** programmer to control exhaust temperature during acceleration of a Frame 5L gas turbine. This action limits **Txa** temporarily, by manually controlling fuel flow to the combustors. Once the temperature has "crested," at about 2200 to 2400 rpm, the operator can release his thumb, allowing the timer to run up to its 100% stop.

Several MS5001K-LA gas turbines installed in the mid-to-late 1960s have had their legacy temperature control and protection systems replaced/upgraded with a programmable logic controller (PLC), like the PAL GEMAC in Fig 2.

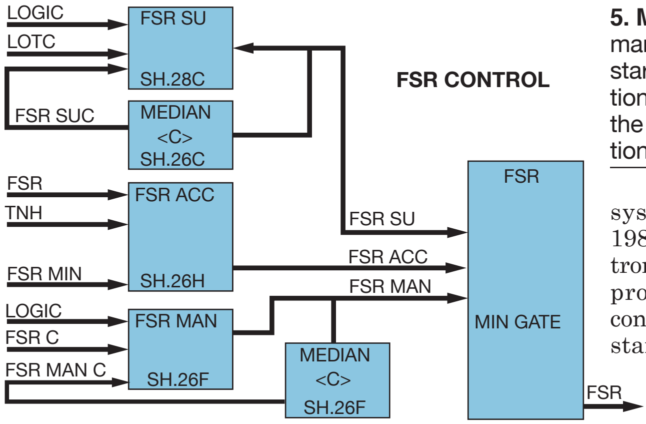
Recall that the technology of the day in the post Northeast Blackout era (November 1965) was early integrated circuitry. The operator-friendly PLC can perform many of the electronic functions from 50 years ago easier and faster. Example: Manual override with the PAL GEMAC is provided with the **F2** function key (arrow in Fig 2, right photo)—much simpler to use than the thumbwheel feature it replaced.

Beginning in the 1970s, Speedtronic Mark I controls had a *manual* resistor on the speed control circuit board called **SSZA** (Fig 3). It is the upper resistor knob in the photo—named **MAN VCE** for manual, variable control electronic, or minimum fuel command. Turning the knob to the right (clockwise)

1. Operator uses thumbwheel to control exhaust temperature during acceleration of a Frame 5L gas turbine

2. Modern programmable logic controller upgrades many of the rudimentary electronic functions that characterized temperature control and protection systems of the 1960s

3, 4. Speedtronic Mark I (left) had a resistor knob (top) to limit fuel flow and control exhaust temperature during startup. Mark II (right) relied on its SSKC card for this capability



5. Mark IV allowed manual control during startup and acceleration via FSR MAN in the MIN GATE function

decreases the fuel control voltage, thus fuel flow. An alarm will sound. Fig 4 shows the later version of Speedtronic, the Mark II. Its **MAN VCE** is located on the **SSKC** card. The audible sound can be silenced, but the annunciator flag remains until the knob is returned to normal.

Case study. A user recently had a problem starting his MS5001N, equipped with Speedtronic Mark I controls. When the turbine reached approximately 1900 rpm the unit tripped because the average exhaust temperature exceeded its allowed operating limit of 1000F. Subsequent trips made the problem particularly difficult to diagnose. The diagnostics team believed the turbine had to continue operating, so the system could be observed and analyzed.

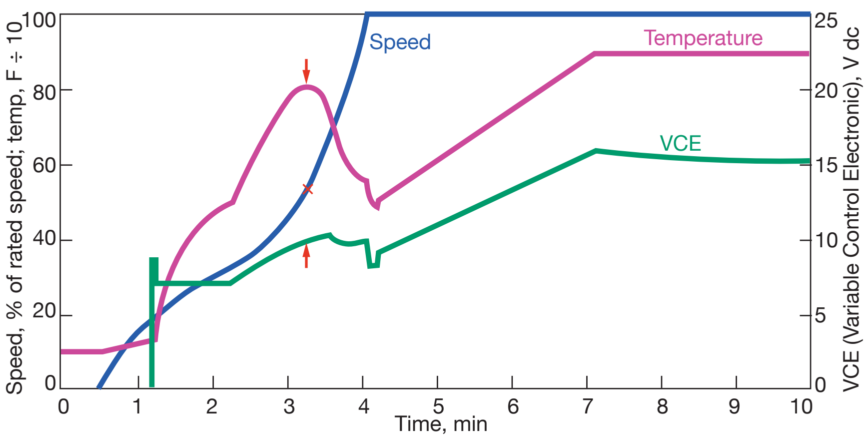
Plant personnel were unaware of the manual control option and the reasons why GE had installed it. The site engineer was advised to turn the **MAN VCE** knob clockwise during acceleration (at 1700-1800 rpm). Yes, the alarm sounded. **VCE** was limited temporarily, so troubleshooting could begin. In this case, it was desirable to run at a safe speed at an exhaust temperature less than 900F. I&C sleuths determined that a 240F comparator "oven" was defective and had to be replaced.

Even modern GE gas turbine control systems (circa 1980-1985), like the Speedtronic Mark IV (Fig 5), provided for manual control during turbine startup—should it be needed. Refer to **FSR MAN** in the **MIN GATE** function. During startup and acceleration, manual control is possible with this function, though on later-model gas turbines its use is less likely. The **MIN GATE** looks at all inputs and selects the one that "calls for" the lowest fuel flow. In this case, **MAN VCE** can be that one.

On a new Frame 5 gas turbine, the average exhaust temperature was expected to "crest" at about 810F approximately 3 minutes and 20 sections into the start cycle (red arrows in Fig 6), when the turbine was at about 80% speed (nominally 4000 rpm).

Bear in mind that if the temperature drifted too high, the turbine might trip on over-temperature. The operator could limit **VCE** manually (read 10 Vdc on the right vertical axis) to prevent a trip until the air flow and compressor discharge pressure increased to cool the exhaust. Perhaps a **MAN VCE** setting of 9.5 Vdc might work better in this case. Later, the **ACCE VCE** limit could be recalibrated lower to this same limit.

In conclusion, many legacy GE gas turbines have ways to temporarily control fuel flow (manually) to the combustors. During startup, it may be necessary to manually limit fuel flow until rotor speed passes through a critical zone (1800 to 2300 rpm). GE provided the controls to assist the operations team in troubleshooting. CCJ



6. Average exhaust temperature was expected to "crest" at about 810F and 3:20 min into startup on a new Frame 5

Resiliency, demand charges drive university to add microgrid to CHP

Superstorm Sandy was one of those events which changed most everyone's thinking on infrastructure reliability, especially in the NYC metropolitan area (CCJ 3Q/2016, p 52). But Sandy is only one element in the "perfect storm" which led Montclair (NJ) State Univ (MSU) to add a microgrid to its relatively modern combined heat and power (CHP) system (Fig 1).

Other elements include a unique state-level public/private partnership created in 2009 in the wake of the "Great Recession," recurring utility-side events responsible for several campus-wide outages annually, and ratcheting utility demand and T&D charges.

Today, MSU can operate 100% divorced from the grid and export up to 3 MW of power to it, thanks to an engine-based 5.2-MW microgrid (Fig 2) commissioned in May 2018 that works in tandem with a 5.6-MW gas-turbine/HRSG-based combined heat and power facility (CHP, Fig 3) commissioned in 2013 to replace and upgrade an antiquated CHP system installed in the 1950s. The gas-fired engines can also burn LNG, for yet another level of backup.

1. State-of-the-art microgrid and new CHP facilities (foreground) are housed in these buildings on the campus of Montclair State Univ in New Jersey

The two 2.6-MW Jenbacher engine/gen sets anchoring the microgrid have three functions, according to Plant Manager Andrew Morrissey: peak-demand shaving, backup capacity when the gas turbine is in an outage, and supplemental generation when utility power supply is lost. On a normal day outside of the peak season, however, MSU "sells a little power to the utility during nighttime, and buys a little power during the day," adds Morrissey.

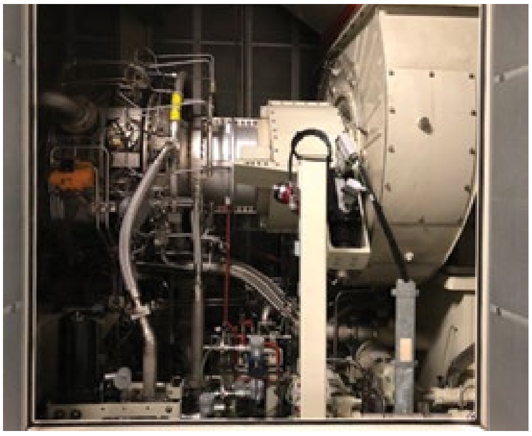
The CHP plant can deliver 100% of the campus steam and cooling needs and up to 86% of its electric demand. But recurring issues with utility-supplied power caused MSU to invest in further relief, the microgrid.

In a presentation to the Distributed Energy Conference, Denver, October 2018, Frank DiCola, CEO of DCO Energy, noted that, over its first summer, the new microgrid netted close to $400,000 in savings by shaving electric demand peaks. "Utility capacity charges were the main economic driver for the microgrid project," he said. Electricity costs to MSU are now 40% lower than before the new CHP.

Jonathan Wohl, DCO's senior VP of project development, noted during

2. Twin 2.6-MW engine/gen sets anchor the microgrid shaving peak demand, backing up the CHP gas turbine, and replacing utility-supplied power when necessary (left)

3. Air inlet to Solar Turbines' Taurus 60, generating up to 5.6 MW of electricity, is shown inside the casing in the CHP building (right)



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AGTSI Teams with Eaton on Global Product Distribution for Aeroderivative Market.
In a new agreement with power management company Eaton, Aeroderivative Gas Turbine Support, Inc. (AGTSI) of Boca Raton, Florida, has been selected as Eaton's official global distributor for aeroderivative, industrial and commercial marine engine components and services.
Eaton's products include dynamic and static seals, hoses and fittings, as well as specialty lube system sensors and components. Eaton's product reliability is proven across all gas turbine applications including aerospace, ground based industrial, power-generation and marine propulsion.
"AGTSI is well positioned to serve this highly specialized market and maintains a vast inventory of complex products and components manufactured by Eaton. AGTSI also provides operators and repair facilities that specialize in Eaton's marine gas turbines."

Aeroderivative Gas Turbine Support, Inc. (AGTSI) was established in 2004 and is a global stocking distributor of parts and assemblies for industrial and commercial marine gas turbines.
The company maintains an extensive inventory at its headquarters in Boca Raton, Florida in order to fulfill customers' "just in time" requirements.
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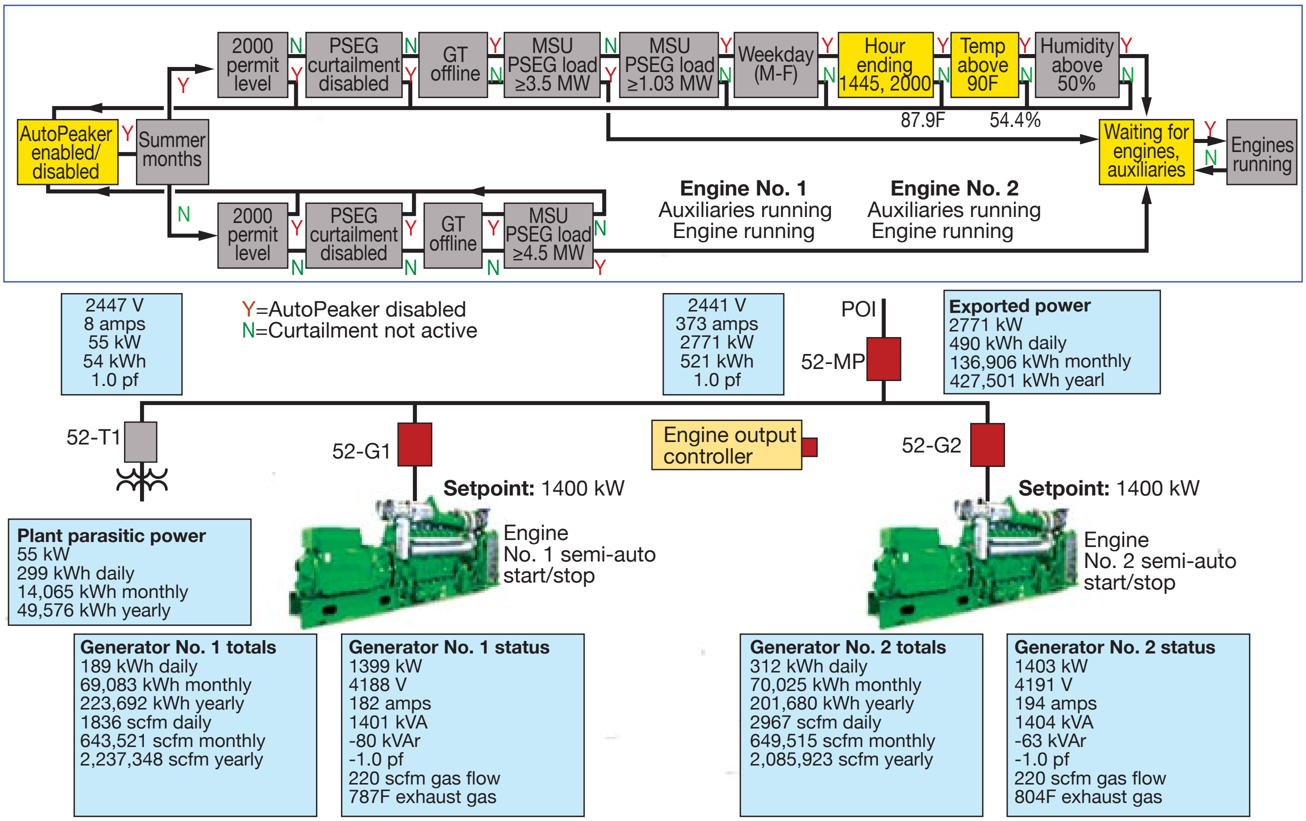
4. Fuel splitter valve, (left), located in the lighted area, has a 52-week lead time; plant manager keeps a spare in his office (right) "to keep an eye on it." It's an example of a "minor" component with a major impact on reliability and resiliency

5. Motor driven chiller (left) and steam-turbine-driven chiller (right) sit side-by-side below the turbine deck. Turbine, was down for maintenance at the time the picture was taken; shell is in the foreground protected by plastic sheet



6. Operation of MSU's microgrid is described in the logic diagram for both the summer (June-September) and winter (October-May) months. The figure illustrates how it operates in conjunction with utility-supplied power, gas turbine/generator, and seasonal, daily, and weekly ambient conditions

CCJ's visit to the facility, that the T&D cost component of MSU's utility bill is also rising significantly, as the utility adds T&D infrastructure to bring in more renewable energy. Of course, what will also happen is that as more customers like MSU divorce from the grid to the extent possible, costs for maintaining the "grid" have to be spread among fewer customers and/or customers buying fewer kilowatt-hours.

Another project driver was the reliability of grid-supplied electricity. MSU could experience as many as three blackouts a year, even though there are two 26-kV utility lines feeding the campus. Disturbances on the utility lines could also trip the turbine in the old CHP plant. Outages typically were from 30 minutes to several hours in duration. Superstorm Sandy in 2012 added to the concern about resiliency of campus utilities.

Risk mitigation and resiliency run deep in the psyche of the facility staff. DCO, which develops, designs, builds, operates, and maintains CHP systems across the country, has engine, turbine, and chiller expertise groups within the firm. The process performance group identifies cross-facility issues and addresses them. At MSU, spares are carried for any component with over a 10-week delivery time.

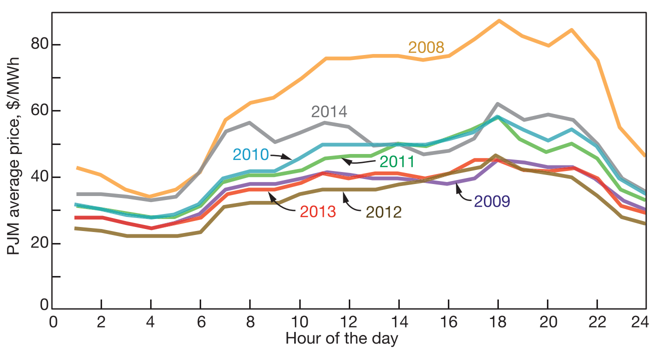
"We evaluate the N+1 risk for all major components across our fleet," said Fred Eckert, DCO's executive VP of facility operations. Morrissey referred to a fuel splitter valve for the gas turbine (Fig 4) with a 52-week lead time. "I keep one of these in my office," he said, pointing to it on the floor in the corner.

Since the gas turbine doesn't run

without it, the HRSG is a major risk component because it can take down the turbine. All of the campus steam normally is provided by the 28,000-lb/hr HRSG (at baseload), equipped with a duct burner capable of producing an additional 22,000 lb/hr. Two backup fired boilers, each rated 42,000 lb/hr of steam, also are available; one is kept in hot standby at all times.

Two large chillers (Fig 5) are used for cooling; one (2300 tons) is steam-turbine driven, which also adds a large "sink" for productive use of steam when electric demand is high and campus steam demand is low. This is important because the system does not include an HRSG bypass stack. The other chiller is a 2000-ton motor-driven unit. Both chillers were supplied by York®, a unit of Johnson Controls.

A big challenge for the CHP construction team was trenching through solid rock to add 8500 ft of condensate return lines. That caused a hit on the budget, although the overall project remained within anticipated costs. The antiquated CHP system was only returning 20% of the condensate. "It returned more rainwater than condensate," quipped Eckert. As the campus grew, chilled-water demand kept growing. MSU had resorted to renting chillers for individual buildings. Today, 90% of the condensate is returned; DCO has a contract guarantee at 80%.



7. Historical LMP data are incorporated into the dispatch model used to determine when and how much power to exchange (buy or sell) with the grid

A lesser challenge on the O&M side proved to be raw-water quality for the boilers. The campus buys water from the city, but it often has to be supplemented with well water. When that happens, "the hardness goes through the roof," said Morrissey. Adding deionizer resin bottles brought the issue under control.

Like most powerplants these days, the CHP + microgrid is controlled with a sophisticated SCADA system (Fig 6). MSU's includes a Rockwell automation system with Schweitzer Electric relays and load-management system (LMS), the last incorporating model-predictive control. The controller adjusts actual electrical, steam, and chilled-water loads versus what is expected based on ambient conditions (temperature and humidity) and historical demand data.

A dispatch model crunches real-time LMP pricing data from PJM (Fig 7) and electricity costs to MSU to determine whether to sell or buy and how much. Recall that LMP is the acronym for "locational marginal pricing." To establish the predictive model, DCO reviewed historical 15-min demand intervals to "predict" when and how much peak-shave electricity would be needed from the microgrid engines. The engines are only permitted to run 2000 hours per year.

There can be significant and unanticipated electric demand from the campus. For example, electric demand tends to spike during rainy days. Although classes are typically not in session during the summer, there are many special events and the CHP + microgrid facility operators may not get much notice about when they are occurring.

The LMS controls every major electrical breaker on the campus, and also is tied into a load-shedding strategy when necessary. Overriding objective is to avoid ratchets on the utility demand charges, which are calculated based on the five single hours of highest demand in the current year setting the rates for the following year. According to DiCola, historical data showed that the highest demand hours occur during the third weekday of heat waves characterized by 90F+ temperatures and high humidity. Black-start capability also is built into the LMS.

No money down. The state public/private partnership program allowed MSU to add the CHP facility with no capital investment. A 2009 Economic Stimulus Program encouraged universities and others to take advantage of public private/partnerships combining taxable and tax-exempt bonds to finance facilities over 30 years. DCO was awarded both the EPC contract and a 30-yr O&M contract.

As part of that, the major equipment, primarily the gas turbine/generator, engine/generators, and motor- and steam-turbine-driven chillers, had to be protected by long-term service agreements.

MSU decided to take advantage of the program and modernized the existing CHP—consisting of two legacy boilers, a 1950s-vintage steam-distribution and condensate-return piping network, a 1990s-vintage Solar Centaur 40 gas turbine/generator coupled to an HRSG from the same time period, a small black-start engine/gen set, and backup generators "past their prime" in several buildings.

The central plant was operating at an efficiency of less than 50%, reported DiCola. There was no chilled-water distribution network, only local rental chillers. The entire steam distribution system had to be replaced. These and other deficiencies were delineated in a 2009 Energy Master Plan issued by MSU.

MSU's facility was the first powerplant under the stimulus program. The CHP + microgrid is expected to save \$2-million annually, including debt service. The facility also received a clean energy grant from the state EPA. The GT emits only 9 ppm of NO_x, thanks to Solar's $SoLoNO_x$ emissions reduction technology, which requires no reagent and no water or steam injection. The plant was not required to include continuous emissions monitors.

CHP plant availability reported by DiCola in his presentation was 97.4%. "Most of our issues are with the utility, not the onsite equipment," Morrissey said during the site visit.

Capital, always scarcer than one wishes, could now be put to work towards MSU's primary mission, educating students and expanding campus facilities. The college campus is New Jersey's second largest, with 27,000 students, 8000 in the dormitories. Indeed, the campus continues to grow, adding buildings and refurbishing older ones.

As importantly, MSU is relieved of the responsibility for day-to-day deliveries of critical energy streams, and can focus on monitoring consumption to identify and address inefficiencies. DCO also manages fuel supply for the university, which can be dicey in the Northeast given harsh winters and bottlenecks in regional natural gas supply.

Certainly not a household name in the CCJ community, DCO Energy, headquartered in Mays Landing, NJ, employs close to 500 people and designs, builds, and operates CHP, cogeneration, small power, and non-utility powerplants across North America. According to DiCola, the firm is now in the process of evaluating the economics of battery storage at many of its facilities, which could be the final piece of the puzzle for sites wishing to divorce completely from the local utility. CCJ

HRSGs—a view from Down Under

So you switch hemispheres in both directions, west to east then north to south, and you discover that the pesky operational issues and concerns you are familiar with are much the same everywhere. Your colleagues are interested in what you have to say, and you are interested in their stories. Everyone wants to listen. For combined-cycle owner/operators, it is indeed a small world.

The 2018 Australasian HRSG Users Group (AHUG) Conference and Workshops took place November, in Brisbane, Queensland. Chairman Barry Dooley of Structural Integrity Associates Inc told the editors the meeting attracted 50 participants (half from plant owner/operators) from Australia, New Zealand, Thailand, UK, and the US.

AHUG is supported by the International Association for the Properties of Water and Steam (IAPWS) and held in association with the European HRSG Forum, the *HRSG Forum with Bob Anderson,* and the journal PowerPlant Chemistry.

The organization's 11th annual conference provided an interactive forum for new information and technology specific to HRSG challenges in combined-cycle plants. There were in-depth case studies on plant issues and possible solutions, and pointed discussions among equipment users, suppliers, and international industry experts.

The more universal interactions focused on:

- Cycle chemistry, instrumentation, and flow-accelerated corrosion.
- HRSG thermal transients.
- Oxide growth and exfoliation.
- Attemperators, condensate return, superheater (SH)/reheater (RH) drain management.
- Steam-turbine bypass operations.
- Experience and research into the evolving field of film-forming substances.
- Awareness and detection of air in-leakage.
- IAPWS activities and guidance documents. Dooley, who serves as executive secretary of IAPWS, referred attendees to that group's website (www.iapws.org), where the organization's Technical Guidance Documents of great value to powerplant owners and operators can be downloaded at no cost.

Highlights of the meeting are summarized below.

1. Failure location looking up. Note discoloration and wide gap between modules

2. OD and ID surfaces at failure zone

Steam-drum cracking

Presentations included several case histories of HRSG steam-drum cracking, occurring primarily at drum-to-downcomer and circumferential welds. Inspection methods included visual, phased array, magnetic particle, ultrasonic, replication, and hardness.

Poor control of rolling and heat treatment of the original materials were highlighted as culprits, followed by weldability concerns. A summary point on weldability: Parent-material properties are dependent on manufacturing parameters for high-strength low-alloy (HSLA) steels, and welding introduces heat that disrupts the parent-material microstructures. Proper microstructures cannot be regenerated by post-weld heat treatment. Repairs, when required, can be problematic.

The common root cause was summarized as reheat cracking propagated by corrosion fatigue. The use of HSLA steels (for reduced wall thickness and increased allowable stress) contributes to this problem because of a unit's higher operating stresses and material susceptibility to reheat cracking.

Fitness-for-service issues were reviewed that consider stresses caused by pressure, the simple weight of water and steam, and thermal effects of startup and shut down.

Reheater tube failures were examined for a 760-MW 2 × 1 combined cycle commissioned in 2002. The subject three-pressure, three-module HRSG does not have duct burners.

This presentation of a unique reheater-tube failure mechanism may be the precursor of many future mid-life failures in other HRSGs. The tube adjacent to the gap between modules, and entering the lower outlet header horizontally, had clearly overheated as shown by the large internal oxide growth and exfoliation data base (Figs 1 and 2).

Metallurgical reports showed multiple circumferential and transgranular cracks at the ID of the tube, beyond the heat-affected zone, progressing toward the outside.

Discussions and details led to observations of progressively more rapid

localized oxide growth and exfoliation (OGE). Various hypotheses and further analysis steps were reviewed. The key takeaway was the following proposed sequence of events:

1. Normal steam-side oxide growth during years of operation.
2. As oxide thickens and insulates the tube internal surface from the steam, tube metal temperature increases, as does the oxide growth rate.
3. Tubes adjacent to the mid-module and sidewall gap operate hotter, and grow oxides faster than other tubes.
4. Eventually the oxide buildup reaches a critical thickness and it exfoliates.
5. In the case described, exfoliated oxide plugged, or partially plugged, the horizontal section of tube resulting in severe overheating.
6. Severe overheating and thermal-transient-driven strain at the failure site further accelerated localized OGE, thinning the tube wall and resulting in failure.

Learn more about this failure and OGE from Dooley at the upcoming *HRSG Forum with Bob Anderson,* July 22-25, 2019, in the Hilton Orlando (details at www.HRSGforum.com).

Inspection after four years

A comprehensive presentation was given on pressure-vessel inspections at a combined-cycle plant after four years of operation, covering all major systems and components.

The unit's cycle chemistry includes all-ferrous feedwater metallurgy, AVT (O), solid alkalizing agent added to the HP and LP evaporators, no condensate polisher, and low iron level in the feedwater.

Inspection methods, including commissioning and beyond, were described.

First in-service inspections (2015) showed loss of wall thickness in the HP economizer headers (one unit) and cracking in HP and LP drums (second unit), two-phase FAC in the condenser, and liquid impingement erosion of L-0 turbine blade row and shroud.

Water-chemistry management was reviewed, revealing a lack of trained personnel, lack of water-chemistry documentation, insufficient sampling and testing, and insufficient instrumentation to meet IAPWS recommendations. Improvements began, and by 2018, water-chemistry management was considered "close to normal."

With chemistry management improved, the plant will concentrate on more active in-service inspections, and a proactive risk-based analysis approach.

3. New drum transported to Tallawarra site

4. Installation of riser spool pieces

HP drum replacement

The conference organizers called this "A great example of successful significant HRSG plant engineering projects—specifically, a total HP steam-drum replacement in a triple-pressure unit with key learnings outlined and shared."

The HP drum at Tallawarra in Australia was replaced in 2018, after cracks were discovered in 2013 (just four years after commissioning). Deep cracks were discovered in various parts of the drum (risers and downcomers).

The cracks aligned with the fusion line between the weld and the drum and were determined to be blunt and oxide-filled, most likely the result of original welding defects—for example, a lack of sidewall fusion in the weldment to parent material.

The repair option was considered, but would mean a long outage (112 days). Even then, there was risk of not fully resolving the issues. This option was declined. Tallawarra was determined safe to operate (with adjustments) in the short term, and drum replacement planning began.

The challenges An intensive two-year program was set that included factory visits and documentation reviews, stringent weld procedure and welder qualification checks, material certificates, reviews of heat treatment and hydrostatic test procedures, and clearly defined hold points.

Site preparation included risk-assessment workshops (including health and safety) and mitigation strategies based on workshop outcomes. Material handling challenges included a ground-to-height distance of 100 ft, anchor points with drone location reviews, and physical separation of multiple working levels (three above the drum floor, one below). Height restrictions from a nearby airport called for adjustments to the lift plan (Figs 3 and 4).

A key takeaway from this presentation was lessons learned. Engaging contractors in the work-assessment workshops was given high marks, as were real-time opportunities for safety strategies and improvements.

The drum was replaced within the scheduled period of 58 days.

An attendee with relevant experience told the editors afterwards that the drum-replacement plan presented certainly was one a similarly affected user might consider—provided his or her site could accommodate the cranes necessary to remove and replace the drum.

However, he said, he was not aware of a crack in a properly constructed drum-nozzle weld that has required replacement. While there are a lot of in-service cracks being found, the participant continued, he believes all have been successfully managed and/or repaired without removing/replacing the nozzle—thus far, anyway.

Workshop 1: Steam-turbine bypass

A workshop led by Bob Anderson, Competitive Power Resources Corp, on optimization of steam turbine bypass systems covered the arrangement, purpose, and optimum methods for operating and maintaining this equipment. Highlights follow.

In a conventional plant, the operator can:

- Limit furnace exit-gas temperature to protect SH and RH tubes.
- Limit the drum-pressure ramp rate to avoid humping and through-wall thermal stress.
- Limit the temperature of steam admitted to a cold turbine.

But in a combined-cycle system, the operator generally cannot limit gas-turbine startup exhaust temperature and, therefore, has limited control over exhaust temperature, the HP-drum-pressure ramp rate, and steam temperature.

HPSH and RH tubes need cooling steam; the steam turbine needs precise steam temperatures and pressures during startup.

Therefore, the bypass system's primary job during startup is:

- Control HP-drum-pressure ramp rate.
- Provide cooling steam to HPSH and RH.

5. Known CUI problem areas, drains and feedwater pipework

- Control RH pressure.
- Provide HP and IP pressure matching.
- Permit smooth blending of a lag unit into the main-steam and hot reheat (HRH) systems.

During shutdown, the primary job becomes:

- Permit smooth removal of lead unit from the main-steam and HRH systems.
- Permit control of HP pressure for bottling-up the unit.
- Permit steam cooling of HPSH during shutdown.
- Control HP-drum-pressure ramp rate if depressurizing during forced cooling.

Major bypass station components

6. Forgotten areas, include small-bore pipework

are the following:

- Pressure control valve. It provides backpressure control for HP, RH, and LP steam and is exposed to severe duty in the HP and HRH systems.
- Desuperheater. It controls steam temperature downstream of the bypass. Principal components include a spray-water control valve and block valves.

Some of the key points made during the workshop:

- Failure to coordinate HP and HRH bypass PCV positions can lead to large RH pressure transients, and severe attemperator overspray.
- Pressure control valve erosion is caused by water, wet steam, or debris passing through the valve. Seat/plug damage results in leaking steam (overheating downstream carbon-steel piping).
- The desuperheater must not be operated with the PCV closed. (The valve must be open to its minimum position for desuperheater operation.)

Although many OEMs are using more-erosion-resistant designs and materials, presenters representing leading valve manufacturers stressed that "no PCV design can tolerate wet steam." Newer materials and designs will only slow the wet-steam erosion process. Severe damage can result within one year in cycling units. Mechanisms of damage by wet steam were explained in detail, with visual examples and specific case studies (both existing and new units).

Operation of bypasses with no heat input to the HRSG were covered—including temperature transients in high-energy piping (HEP) and increased production of condensate in the superheater and reheater.

Interesting case studies were presented on a few F-Class units that experienced repeated leaking after only a few runs (and rapid erosion following modification).

Discussions followed on:

- When to open bypass.
- Depressurizing the HP system with the bypass during hot layup.
- Risks of water hammer.

Cyclic stress examples, resolutions, and maintenance recommendations were presented, concentrating on possible causes. Instrumentation and thermocouples also were reviewed.

Corrective action discussions included modifying the HP bypass desuperheater spray valve logic with a master block valve/martyr control valve arrangement, as well as various inspection and maintenance programs.

Dig into the design and O&M details of steam-turbine bypass systems closer to home at the upcoming *HRSG Forum with Bob Anderson,* July 22-25, 2019, in the Hilton Orlando (details at www.HRSGforum.com. The open discussion periods at this meeting afford users the opportunity to get answers to their specific questions and return to their plants with solutions in-hand.

Workshop 2: Corrosion under insulation

This workshop covered the types of corrosion found under insulation (CUI)—galvanic, chloride, acidic, and alkaline-induced—attributed to moisture buildup on the external surfaces of insulated equipment (piping and vessels). If untreated, CUI leads to corrosion and forced or extended outages.

Common temperature ranges for corrosion are covered in API 570, "Piping Inspection Code: In-service Inspection, Rating, Repair, and Alteration of Piping Systems."

- 25F to 250F for carbon-steel pipes, particularly where operating temperatures cause frequent or continuous condensation and re-evaporation of atmospheric moisture.
- Above 250F for carbon-steel piping systems in intermittent service (flexible operation).

A primer. The key influence is water ingress by capillary attraction to the metal substrate. Moisture may be external, or may be inherently present in the insulation material. Resulting corrosion may attack the cladding, the insulation hardware, or the underlying equipment.

For high-temperature horizontal piping, water entering an insulation system diffuses through the insulation towards the hot pipe surface where it evaporates. Insulation adjacent to the hot surface may remain wet (both moisture and salts).

When a unit trips or comes offline for an outage, the pipe metal temperature falls, and the zone of saturated salts solution moves towards the metal OD surface. Upon return to service temperatures, heat will evaporate the moisture in the saturated salts solution, leaving salts on the pipe surface.

If this process is repeated, then the concentration of salts (for example, magnesium or sodium chlorides) will cycle up to a level that initiates corrosion (pitting or stress corrosion cracking).

Therefore, the root cause of CUI is prolonged wetness of steel, occurring with use of water-absorbent insulation. Essential elements are available oxygen, elevated temperature, concentrated dissolved species, and a closed environment.

Where to look. Known problem areas are drains and feedwater pipework. Small-bore pipework was covered as a lesser-known but important area (Figs 5 and 6). Common prevention strategies include these:

1. Painting the pipe surface with boiling-water-resistant coatings.
2. Waterproofing to prevent the ingress of water from outside.
3. Use of corrosion inhibitors.
4. Insulation material selection.
5. Self-draining insulation systems.

Histories and track records of insulating materials were reviewed in detail, traced back to the 1940s when the only available insulation was water-absorbent. The first hydrophobic insulation (expanded perlite) was introduced in the mid-1970s.

But even rigid hydrophobic insulation can allow water to exist behind the insulation. Design flaws can prevent drainage, and sealant applied at the bottom of terminations may trap water. Many examples were presented.

Insulation system design is therefore critical, and self-draining systems are preferred. Thermal conductivities and insulation bulk densities and required amounts were also reviewed and compared. Plus, compressive strengths and differential thermal expansions of surface, insulating materials, and cladding were examined in discussions, illustrating the complexity of the subject.

Fire and other hazards. Insulation system adhesives, vapor barriers, and sealants determine fire performance. These variables must be considered when selecting materials for applications and code compliance. Discussion on this subject covered related issues of combustibility, ignition susceptibility, surface spread of flame, and emissions of smoke and toxic gas. Note that fire performance of non-combustible insulation materials can be changed by the absorption of oil or other flammable liquids that can spontaneously ignite.

Another topic was resistance to molds, health hazards (including adhesives and solvents), removal/replacement risks, and objectionable odors.

Summary: "CUI is difficult to find because of the insulation that masks the problem until it is too late."

An insulation system should have removable modules to allow maintenance or inspection. A common method of inspection is to cut plugs in the insulation that can be removed to allow ultrasonic testing. However, these plugs can become a pathway for moisture ingress.

Also, if the plug is not in the right location, CUI can be missed. Various detection methods were incorporated into the open discussion, including the following:

- Neutron backscatter.
- Thermographic scanning.
- Long-range guided wave.
- Digital and real-time radiography.
- Pulsed eddy current.
- Electrical impedance spectroscopy (emerging).

Finally, case studies were reviewed, followed by fitness-for-service assessment (API, ASME) of corrosion and erosion.

Other meeting highlights in brief:

- International updates were provided on the HRSG thermal-transient aspects of attemperators, condensate return and superheater/reheater drain management, and bypass operation.
- Experiences on return to service of an F-class combined cycle unit after three years of layup and early operating experience in a new Flexible Operations market provided insight into what good layup practices look like.
- Representatives from four power stations supplied by the same OEM were able to network with peers on the subject of flexible operation with AHUG support. CCJ

there can be room for improvement." Some minor leaks are in evidence and dissolved oxygen (15-30 ppb) remains slightly elevated.

This odyssey continues with helium testing scheduled in 2019.

Not all plants created equal

Some segments of the next discussion thread highlighted as-built errors.

Doga Enerji owns a 180-MW combined-cycle cogeneration plant on the outskirts of Istanbul, Turkey. The plant features three GE-designed/Thomassen-built Frame 6 gas turbines, three HRSGs of European design, one GE/Thomassen steam turbine, an air-cooled condenser, and related equipment including onsite diesel storage. The site was commissioned in 2010 to supply both electricity and district heating.

At this facility, a demin plant feeds high-purity water to all systems. An amine blend for condensate/feedwater chemical treatment is injected into the condensate pump discharge; boiler water treatment is by a coordinated phosphate formulation. Nitrite and biocide chemicals are used for the closed cooling water, and corrosion inhibitors and oxygen scavenger are injected into the district heating system.

The ACC has three streets with five fans each. Air removal is by hogging (startup) and two main ejectors.

Deniz Celikkantar described the ACC's shortcomings:

- The original design had only two streets. A third (elevated) was added after two years of operation to improve summer operations (Fig 7).
- The original ACC intake area was blocked by containers, removed in 2013.
- A neutralization pit (Fig 8) under the ACC led to blade corrosion in one of the fans. The pit cannot be relocated and must remain open to cool plant wastewater.
- Local statutes required conversion to low-noise fans.
- Safety guard material under the fans is weak wire mesh, making maintenance both difficult and dangerous.
- Dissolved-oxygen measurement is incorrect, influenced by oxygen in the makeup water. A separate sampling line is needed.
- The original ACC tube-cleaning systems were not properly designed by the plant's maintenance team and are not safety-compliant.

The speaker then listed other common failures with the system:

- Motor coupling abrasion.
- Oil leakage from seals.
- Foiling of strainer filters.
- Particles in the oil pumps under the gearboxes.
- Motor bearing breakage.
- Gear abrasion.

A panel discussion on air in-leakage followed. It encompassed measurement data points and testing locations and methods. Helium versus SF_6 was reviewed, noting that the latter is both difficult to transport and prohibited in many locations.

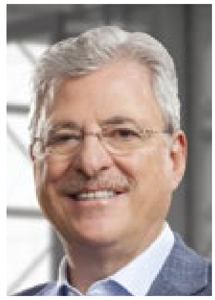
During the exchange, Dooley mentioned that the ACC Users Group is planning to publish guidelines on air in-leakage; its starting point will be a new IAPWS Technical Guidance Document currently in technical review. Dooley is the executive secretary of that global organization.

The goal of both documents will be specific guidance for detecting and addressing air in-leakage at the plant level. Ultimately, this information should make its way into project specifications and offer specific best practices for detection.

Windscreen verification

The Apex Power Project, located about 35 miles north of Las Vegas, recently installed windscreens on its six-street by five-fan ACC, anticipating a full return on its investment and improved long-term performance. The 2 × 1 F-class combined cycle, now owned

Gas-turbine operating metrics in an uncertain energy market



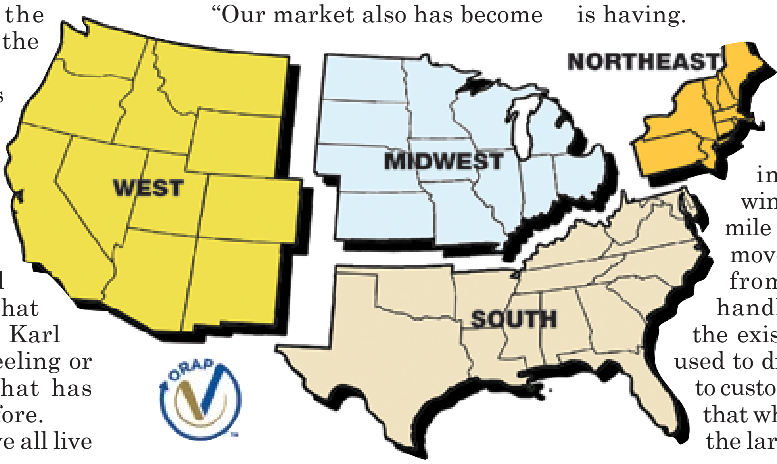
DellaVilla

Salvatore A DellaVilla Jr, CEO, Strategic Power Systems (Sidebar 1), typically begins preparing for annual meetings of the Western Turbine Users Inc and frame users groups during holiday quiet time when he can reflect in solitude on the highlights of the year winding down and how they might impact the electric-power business in the year ahead.

DellaVilla called CCJ's offices in early January 2019 to tell the editors that the déjá vu he normally experiences when reflecting on the industry he has served for more than two-score years was replaced this year with a feeling of what the organizational theorist Karl Weick calls vu jádé—the feeling or sense this is something that has never been experienced before.

"The global market that we all live and work in today, he said, is dynamic and very challenging. The global disruption is palpable, whether from the influx and growth of renewables or from the technical and policy changes that influence investment in conventional generating assets. The bottom line: We now work in an 'uncertain market.'

"Our market also has become an industry of headlines," he continued. "In this competitive and uncertain time we are reading and talking about the survival issues of the largest suppliers to the electric-power industry, GE and Siemens. We hear about the massive financial investment Elon Musk has made in batteries, for cars and industry, and the problems he is having.



"We hear about AEP's proposed $4.5-billion Wind Catcher Energy Connection project incorporating 2000 wind turbines and 360-mile transmission line to move renewable energy from the Texas panhandle to Tulsa where the existing grid would be used to distribute the power to customers. Next we learn that what would have been the largest wind project in

1. Who is SPS®?

Strategic Power Systems® Inc, Charlotte, NC, is the industry's leading analytics consultancy specializing in the collection, analysis, and dissemination of O&M data for owners and operators of generating plants—in particular those powered by gas turbines. The firm, formed by CEO Sal DellaVilla more than three decades ago, gained recognition quickly because of its work in support of the Western Turbine Users, which began in fall 1990—a few months before the group incorporated.

Recall that Western Turbine serves owner/operators of GE aeroderivative gas turbines, today focusing on the LM2500, LM5000, LM6000, and LMS100. The popularity of the LM2500 and LM5000 grew rapidly as the power block of choice for many of the cogeneration systems installed to take advantage of the Public Utility Regulatory Policies Act, enacted in 1978. Purpa opened up the generation market to non-utility entities as long as their facilities met certain size, fuel, and efficiency criteria. California was fertile territory for cogen systems.

WTUI offered users, some of whom already were meeting at various plants on an ad hoc basis, a formal structure to support the expanding base of operators. The organization's leadership understood new users would require operating knowledge and experience, and would share their desire for continuous product improvement.

They also understood the need to establish and follow a uniform process that WTUI, as an organization, could use to track and report the availability and reliability performance of the LM5000 and LM2500 fleets.

The objective was to have unbiased and accurate data to document the performance of gas turbines and other plant equipment. Users wanted data and metrics they could share among themselves, and with GE. These goals were enabled by SPS's Operational Reliability Analysis Program (ORAP®) and use of this data engine was supported by WTUI and GE.

DellaVilla and company went to work and issued their first ORAP report in June 1991, just three months after the incorporated user group's first meeting. It included data from 24 operating plants representing 19 LM2500s and 14 LM5000s and provided an overview of the reliability metrics that the user desired—including component causes of downtime and engine removal rates.

SPS's service to WTUI members and owner/operators of other engines, including today's largest and most sophisticated frames, has grown dramatically over the years in terms of number of participants, extent of equipment coverage, depth of data analysis, and speed of information delivery.

Table 1: Key performance indicators for aero engines developed from ORAP® simple-cycle RAM metrics

Parameter	2018 Aero	2017 Aero	2012-2016 Aero
Peaking units:			
Annual service hrs	346	411	446
Annual starts	95	112	113
Service hrs/start	3.6	3.7	3.9
Service factor, %	4.0	4.7	5.1
Capacity factor, %	2.9	3.3	3.9
Output factor, %	67.6	64.8	70.1
Availability, %	90.7	87.2	92.6
Reliability, %	96.3	95.4	97.4
Cycling units:			
Annual service hrs	1798	2026	1930
Annual starts	198	191	193
Service hrs/start	9.1	10.6	10.0
Service factor, %	20.5	23.1	22.0
Capacity factor, %	15.0	17.8	14.6
Output factor, %	74.2	80.6	69.2
Availability, %	89.3	91.6	92.1
Reliability, %	95.8	96.0	96.4
Baseload units:			
Annual service hrs	6718	6801	6603
Annual starts	55	52	63
Service hrs/start	121.8	130.0	104.6
Service factor, %	76.7	77.6	75.4
Capacity factor, %	55.1	69.4	59.5
Output factor, %	72.4	89.1	79.8
Availability, %	91.9	91.7	92.4
Reliability, %	96.3	96.4	96.9

Note: LMS100 included with Aeros

Table 2: Comparing capacity (CF), output (OF), and reserve standby (RSF) factors regionally

Parameter	2018 Aero	2017 Aero	2012-2016 Aero
West:			
CF, %	15.4	14.6	17.3
OF, %	73.0	73.8	80.2
RSF, %	66.4	67.5	69.9
Midwest:			
CF, %	15.0	13.2	13.3
OF, %	71.9	74.1	75.5
RSF, %	70.1	70.4	73.2
Northeast:			
CF, %	22.9	21.2	13.2
OF, %	93.5	93.2	59.7
RSF, %	67.3	70.9	69.4
South:			
CF, %	13.0	10.6	12.1
OF, %	80.3	77.7	78.8
RSF, %	77.6	72.8	77.7

Notes: West includes Alaska and Hawaii; LMS100 included with Aeros

the US was canceled because utility regulators concluded the project didn't offer sufficient benefits to ratepayers and rejected it.

"All this uncertainty begs the question, 'What is happening in the gas-turbine market?'

"Fundamentally," DellaVilla says, "the question we have to answer is this: 'What role will gas turbines (both heavy-duty frame engines and aeroderivatives) play in this changing market (or set of regional markets) and what will be the fuel of choice or necessity?'

"Perhaps," he added, "we should rephrase the question and ask, 'What are the opportunities for gas turbines as technology and fuel challenges evolve?'"

Looking for answers, DellaVilla reviewed data from a variety of sources, including that published in the "BP Statistical Review of World Energy 2018." Summarizing, he said it shows that conventional powerplants continue to play a significant role in meeting the world's base-capacity needs. Renewables have found a place in the market, and while there is recognition of their potential long-term benefit and value, they are intermittent power at this time—not baseload capacity.

Here are some important points DellaVilla gleaned from the BP report:

- Worldwide generating capacity totals about 6300 GW. Nearly 60% of that capability is installed in six countries: China, the US, India, Russia, Japan, and Germany—in that order.
- Over 86% of the primary energy consumed in these six nations comes from fossil fuels—with coal (for electric production) and oil (for transportation) continuing to play a very significant role.

  Unfamiliar with the term "primary energy"? It is defined as an energy form found in nature that has not been subjected to any human-engineered conversion process. Fossil fuels (coal, oil, and gas), biofuels, wind, solar, and nuclear fuels are all primary sources of energy.
- China (60.4%), India (56.3%), Japan (26.4%), and Germany (21.3%) are major users of coal for power generation.
- Russia (52.3%), the US (28.4%), Germany (23.1%), and Japan (22.1%) are major users of natural gas.
- For the top six energy-consuming nations combined, renewables contribute only 3.8% of the electricity produced, with Germany leading at 13.4%.
- France, No. 7 on the list of largest consumers, relies on fossil fuels for 53.5% of its primary energy—mostly oil (33.5%) and natural gas (16.2%). Interesting to note is that 37.9% of France's electricity is produced by nuclear energy, only 4% by renewables.

Setting aside the BP report, DellaVilla focused on the interrelationship between energy and the environment. "We live in a world that values a clean environment," he said, "and using advanced generation technologies—including gas turbines—is important to help us achieve that goal. There is almost a universal acknowledgement that carbon emissions, in the form of CO_2, must be contained. This puts us

Table 3: Gas-turbine models arranged by peer group and OEM

Frame gas turbines							Aeroderivative gas turbines	
Vintage Tech	E-Class		F-Class		Adv Class	Next Gen	<40 MW	>40 MW
GE	**Ansaldo**	**Hitachi**	**Ansaldo**	**MHPS**	**GE**	**Ansaldo**	**GE**	**GE**
MS5001	AE 94.2	H-25	AE 6	M501F	MS9001H	AE 36	LM1600	LM5000
MS5002	**GE**	H-80	4.3A	M701F	MS7001H	**GE**	LM2500	LM6000
MS6001B	MS7001E/EA	**MHPS**	AE 94.3A	**Siemens**	**MHPS**	MS7001HA	**MHPS**	**MHPS**
MS7001ABC	MS9001B	M501D	AE 26	V84.3	M501G	MS9001HA	FT4	FT4000
GT8/8B	MS9001E	M701D	**GE**	SGT-1000F	M701G	**MHPS**	FT8	**Siemens**
GT9	GT8C	**Siemens**	MS6001F/FA	SGT5-4000F	M501GAC	M501J	**Siemens**	SGT-A65
GT11D	GT11N/N1	W501D	MS7001F/FA	SGT6-4000F	M701GAC	M701J	SGT-A05	
GT13D	GT11NM/N1M	SGT-800	MS9001F/FA	SGT6-5000F	**Siemens**	M501JAC	SGT-A20	
Siemens	GT11N2	SGT5-2000E	MS7001FB		SGT6-6000G	M701JAC	Industrial Olympus	
W251	GT13E/E1	SGT6-2000E	MS9001FB		SGT5-8000H	**Siemens**	SGT-A35	
W501A/B	GT13E2	SGT6-3000E	GT24		SGT6-8000H	SGT5-9000HL		
SGT-700		W701D	GT26			SGT6-9000HL		
V64.3								

Table 4: General characteristics of frame gas turbines by class

Market segment	Base rating, MW	Efficiency, %	Firing temperature	Pressure ratio	State-of-the-art technology	Year introduced
Vintage Tech	<100 (50 Hz) <70 (60 Hz)	SC: <34 CC: <55	<1093C <2000F	<12	None	<1985
E-Class	≥100 (50 Hz) ≥70 (60 Hz)	SC: <34 CC: <55	>1093C >2000F	<15	Air-cooled turbine blades	<1995
F-Class	>200 (50 Hz) >150 (60 Hz)	SC: >34 CC: >55	>1260C >2300F	>15	Aeroderivative compressor design Dry low-emissions combustor DS or single-crystal turbine blades Sequential combustion	>1995
Adv Class	>300 (50 Hz) >200 (60 Hz)	SC: >37 CC: >58	>1370C >2500F	>18	Advanced HGP cooling Active clearance control	>2005
Next Gen	>450 (50 Hz) >300 (60 Hz)	SC: >39 CC: >60	>1600C >2900F	>25	Advanced combustor cooling Advanced thermal barrier coating	>2013

Notes: (1) The criteria described in the table are determining factors in the classification of individual designs and are listed in priority order from left to right. (2) State-of-the-art technology refers only to the technology introduced in a design/model at the date of introduction; it does not refer to retrofits made to enhance existing technology. (3) Efficiency is stated for both simple-cycle (SC) and combined-cycle (CC) applications using the lower heating value of fuel. (4) Base rating represents the simple-cycle equipment only.

Table 5: Key performance indicators for E-Class engines developed from ORAP® simple-cycle RAM metrics

Parameter	2018 E-Class	2017 E-Class	2012-2016 E-Class
Peaking units:			
Annual service hrs	306	280	322
Annual starts	54	44	51
Service hrs/start	5.7	6.4	6.4
Service factor, %	3.5	3.2	3.7
Capacity factor, %	2.5	2.0	2.4
Output factor, %	79.6	72.8	63.0
Availability, %	92.8	93.0	92.9
Reliability, %	97.5	98.4	97.9
Cycling units:			
Annual service hrs	2275	2254	2343
Annual starts	122	124	125
Service hrs/start	18.7	18.2	18.8
Service factor, %	26.0	25.7	26.8
Capacity factor, %	20.9	22.7	19.6
Output factor, %	83.9	88.4	72.6
Availability, %	90.5	91.9	93.8
Reliability, %	96.8	97.5	98.5
Baseload units:			
Annual service hrs	6488	6323	6644
Annual starts	54	51	56
Service hrs/start	120.4	123.1	119.5
Service factor, %	74.1	72.2	75.8
Capacity factor, %	66.2	65.7	70.2
Output factor, %	88.3	88.9	91.1
Availability, %	91.1	89.1	91.3
Reliability, %	98.1	97.9	98.3

Table 6: Key performance indicators for F-Class engines developed from ORAP® simple-cycle RAM metrics

Parameter	2018 F-Class	2017 F-Class	2012-2016 F-Class
Peaking units:			
Annual service hrs	291	309	462
Annual starts	28	33	45
Service hrs/start	10.3	9.5	10.2
Service factor, %	3.5	3.5	5.3
Capacity factor, %	2.5	2.3	3.7
Output factor, %	70.8	72.7	69.8
Availability, %	94.0	89.7	92.6
Reliability, %	97.9	95.5	98.0
Cycling units:			
Annual service hrs	2435	2438	2532
Annual starts	130	120	107
Service hrs/start	18.7	20.4	23.7
Service factor, %	27.8	27.8	28.9
Capacity factor, %	22.1	22.2	19.0
Output factor, %	79.9	78.3	66.7
Availability, %	90.6	89.7	91.6
Reliability, %	97.7	97.2	97.8
Baseload units:			
Annual service hrs	6683	6487	6644
Annual starts	52	54	54
Service hrs/start	127.4	120.5	122.1
Service factor, %	76.3	74.1	75.8
Capacity factor, %	63.8	62.7	53.4
Output factor, %	84.3	84.9	70.2
Availability, %	90.1	89.3	90.6
Reliability, %	97.7	97.2	97.7

in a place where we have never been before—vu jádé.

"Whether you believe in the need to curtail greenhouse emissions or not," the SPS CEO added, "policy and regulations influence the market, and the market acts through technology selection and 'buy decisions.' Just follow the investment money.

"Yet there is little press or recognition that the 27% reduction in greenhouse-gas emissions in North America has satisfied the desired reduction in CO_2 called for by the Paris Agreement on climate change. This positive reduction was accomplished by a shift to natural gas, a reduction in the use of coal, and the growth in renewables. No other geopolitical region can make the same claim.

2. Definition of terms

Service hours is the number of hours equipment is in service—that is, generating either electricity or motive force. In-service is generally measured from a commercial perspective, from the time when the equipment is fulfilling its intended service until it is shut down and that service has ceased.

Start. A successful start is achieved when the breaker is closed and synchronized to the grid (power generation) or the driven equipment has reached stable operation (mechanical drive).

Service hours per start is a measure of a piece of equipment's average mission time, or the average number of hours the equipment operates each time it is started.

Service factor is the percentage of time a unit is in service.

Capacity factor is the percentage of maximum possible generation achieved over a given period, using the stated unit capacity.

Output factor is the percentage of megawatt production over a specified time period as a function of the total megawatts that could have been produced had the unit been operated at its nameplate rating for the actual operating hours. This statistic can be calculated in either gross or net terms. Net megawatts accounts for in-plant usage of a portion of the electrical output.

Availability is the percentage of time the equipment is capable of operating.

Reliability is the percentage of time in a given period that the equipment was not forced out of service.

"Also, it is valuable to know how gas turbines are performing. ORAP® operating data compiled by SPS offers asset reliability and availability numbers for the recent past, and the present, offering perspective for the selection of future generation resources. Plus, it shows us how the installed base (or a segment of it) is operating regionally, and what changes we have experienced over time."

ORAP data. DellaVilla then walked the editors through the ORAP Simple Cycle Plant RAM metrics (Sidebar 2) for various classes of gas turbines—aeroderivatives, E-Class, F-Class, and Advanced-Class. When reviewing the information presented in Tables 1, 5, 6, and 7, keep in mind that "simple-cycle plant," a term typically used in the reporting of reliability statistics, represents the basic gas-turbine plant arrangement, including the following equipment: GT, controls and accessories, generator, and balance-of-plant equipment to support the gas turbine and generator.

Table 7: Key performance indicators for Advanced-Class engines developed from ORAP® simple-cycle RAM metrics

Parameter	2018 Adv-Class	2017 Adv-Class	2012-2016 Adv-Class
Peaking units: Not a duty cycle for this asset class at this time.			
Cycling units:			
Annual service hrs	1708	1445	3486
Annual starts	18	8	22
Service hrs/start	93.3	180.7	161.6
Service factor, %	19.5	16.5	39.8
Capacity factor, %	5.5	12.3	24.7
Output factor, %	26.2	74.6	62.9
Availability, %	89.8	96.1	92.1
Reliability, %	92.6	100	98.0
Baseload units:			
Annual service hrs	7052	7148	7162
Annual starts	36	23	29
Service hrs/start	197.4	312.1	246.0
Service factor, %	80.5	81.6	81.8
Capacity factor, %	68.3	74.0	69.5
Output factor, %	85.5	86.1	86.2
Availability, %	88.0	89.3	91.9
Reliability, %	98.3	97.3	99.0

The information compiled in Table 1 comes from 621 aero units for 2018, 657 for 2017, and 834 for the 2012-2016 period. Aeros in the sample include engines from GE, MHPS (formerly P&W), and Siemens AGT (formerly Rolls-Royce), and represent units operating worldwide. A regional analysis of aeroderivative data for the US is presented in Table 2.

Table 3 is important for clarification purposes. Mergers and acquisitions and renaming of gas-turbine models in the last five years or so might allow misinterpretation of the ORAP data if you have not kept up on industry changes. To illustrate: Engines formerly associated with Alstom now appear with traditional GE and Ansaldo assets.

You also may be unfamiliar with Siemens' current naming convention, particularly after the company's purchase of Rolls-Royce aero engines. Plus, as noted above, what formerly were Pratt & Whitney aero engines are now part of Mitsubishi Hitachi Power Systems' offerings.

Table 4 categorizes gas turbines by firing temperature and pressure ratio to differentiate among Tables 5, 6, and 7 for E-, F-, and Advanced-Class models. Of interest, too, is that SPS engineers are in the process of updating the technology characteristics presented in Table 4 as they evolve over time. Follow these developments in CCJ ONsite.

Information compiled in Table 5 comes from 427 E-Class units for 2018, 473 for 2017, and 470 for the 2012-2016 period. The gas turbines in the sample include engines identified in Table 3 from Ansaldo, GE, MHPS, and Siemens operating worldwide.

Table 6 data come from 549 F-Class units for 2018, 557 for 2017, and 646 for the 2012-2016 period. Again, refer back to Table 3 to identify the specific engines included in the global sample.

Information compiled in Table 7 comes from 25 Advanced-Class units for 2018, 27 for 2017, and 31 for the 2012-2016 period.

DellaVilla concluded the interview with the following observation, "From a review of the data presented, and the operational levels gas turbines are achieving, perhaps there is a bit of déjá vu after all. Natural gas and gas turbines have played a major role in our nation's energy mix for more than two decades—and they will continue to do so for the foreseeable future." CCJ

V-ENGINE BEST PRACTICE

Walton

New gasket helps keep transformer moisture-free

Challenge. During a scheduled maintenance outage, power-factor testing for one of the GSU transformers produced abnormal readings. To further investigate the problem, a dielectric frequency response (DFR) test was performed and concluded that the GSU's H0 bushing had high moisture content.

Visual inspection of the bushing found that the gasket on the oil-fill plug was cracked (Figs 1, 2). Over time, moisture seeped through the gasket, saturated the cellulose insulation, and caused the bushing to fail the test, requiring its replacement (Fig 3).

Solution. The cost of the bushing replacement and conditioning of the GSU oil was approximately $30,000. To avoid further bushing failures, two things have been added to the plant's transformer test procedure.

The first is a more extensive visual inspection of moisture-vulnerable areas. Gaskets will degrade over time and are very inexpensive to change. The second addition is DFR testing. It is used to check for moisture in the cellulose insulation of transformers through multiple simultaneous low-frequency tests.

According to Megger (the company), typically 99% of the moisture in a transformer resides in the cellulose insulation, not in the oil. The DFR testing provides a way to trend cellulose insulation moisture content in the plant's bushings and transformers.

Results. Visual inspections during testing on other transformers since the bushing replacement has resulted in finding more cracked gaskets on bushing oil-fill plugs. By replacing gaskets that cost pennies, staff has helped extend the life of the bushings and avoid costly, unplanned repairs.

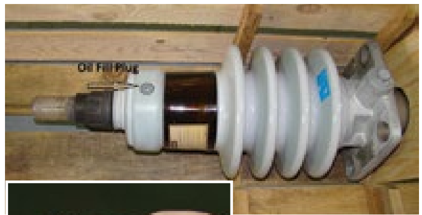
Walton County Power LLC

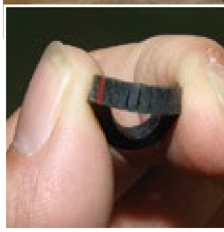
Owned by Mackinaw Power

Operated by Cogentrix Energy Power Management

440-MW, gas fired, three-unit, simple-cycle peaking facility located in Monroe, Ga

Plant manager: Mike Spranger





1, 2. Cracked gasket (left) for oil-fill plug shown above allowed moisture to seep into H0 bushing

3. New replacement gasket help to protect against moisture intrusion

Project participants:
James Goins, O&M manager
Bly Crane, plant administrator
Norman Jones, compliance manager
Chaz Gibson, lead technician
Scott Hobbs, lead technician
Frank Phipps, lead technician
Chris Harris, lead technician
Nick Sanz, technician II

FT8 BEST PRACTICE

Wolf Hills

Improved oil-drum handling practice mitigates safety, health risks

Challenge. Oil-drum receiving and distribution in the plant required lifting and transport of heavy drums, which presented an ergonomic risk, as well as a safety risk, to plant personnel. To move a drum into the storage/containment area, staff would place the drum dolly on the lip of the containment area, then lift the drum into place (Fig 1).

To remove drums from the area, they would roll the dolly off the grating and, if wheels were not perfectly aligned when the dolly left the edge, it would destabilize the drum, forcing the handler to twist in order to correct the weight imbalance, possibly incurring

Wolf Hills Energy LLC

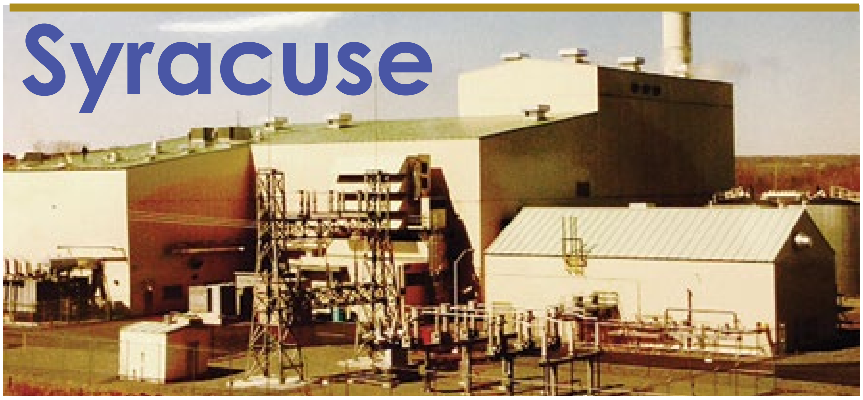
Owned by MPR Genco

Operated by NAES Corp

280-MW, gas-fired, five-unit simple-cycle plant located in Bristol, Va

Plant manager: Michael Beverley

1. Even with use of a dolly, lifting and lowering oil drums presented serious ergonomic and safety risks to employees



Syracuse LLC

Owned by Starwood Energy Group Global

Operated by NAES Corp

102-MW, duel-fuel, 1 × 1 combined-cycle cogeneration facility located in Solvay, NY

Plant manager: Steve Reinhart

HRSG, HEP improvements dramatically reduce EFORd

Challenge. The Syracuse V64-powered combined cycle typically has had an annual net capacity factor of less than 10% since COD in 1993; thus, it's important for the plant to start when dispatched.

Over the years, HP superheater 1 has experienced three tube failures at the outlet of the upper distribution header, the last one in June 2016. The latest forced outage required 70.5 hours of downtime, which pushed the plant's EFORd, or effective forced downtime rate, to over 10% for the year. To mitigate the potential for future forced outages, contractors were hired to inspect both the HRSG and high-energy piping (HEP).

Inspection of HP superheater 1 revealed that three adjacent tubes in the Deltak unit—Nos. 15, 16, and 17—had suffered similar failures, indicating there was a recurring problem (Fig 1). Inspection of the HP attemperator found one of the nozzles, and the attemperator pipe weld, had failed at the flange. The HEP inspection identified some pipe hangers and supports were not properly supporting the steam lines.

1. Superheater tube leaks were traced to failures in three adjacent tubes

Solution. The inspections were thorough, enabling staff to identify the root causes of the problems identified, thereby avoiding quick fixes that might not address the underlying issues.

The HRSG inspection pointed to undrained water in the lower header as the cause of superheater tube failures. This was attributed to a flow restriction at the point where the three ¾-in. drain lines from the A, B, and C sec-

2. Flow restriction was mitigated by replacing the ¾-in. drains collection pipe with a 1-in.-diam line

---

a strain or sprain.

Solution. After studying the situation, the team came up with a design for a hinged ramp, which was then fabricated. It allows offloading and loading of the drums into the storage area without ergonomic or safety risk (Fig 2).

2. Constructed of aluminum channel and plate, the ramp has side rails to prevent dolly from veering off one side or the other

3. Hinged ramp can be lifted out of the way and locked in the "up" position to avoid obstructing the high-traffic area

4. Simple locking mechanism keeps ramp in "up" position when not in use

It was constructed of aluminum channel and plate, making the ramp light enough to raise when not in use and avoid obstructing the high traffic area (Fig 3). The Wolf Hills team also designed a locking mechanism to hold the ramp "up" (Fig 4) and side rails to prevent the dolly from rolling off one side or the other.

Results. The team's solution answered all of the plant's needs:

- It reduces the ergonomic and safety risks associated with transporting the heavy, unwieldy drums yet allows free flow of traffic when not in use.
- It is strong enough to serve the purpose, yet light enough to be easily lifted; the locking mechanism prevents accidental lowering.

Project participants:

Wolf Hills Safety Committee members James Emmert, Charles Harris, Lloyd Montgomery, Russ Pope, and Wendy Tirado.

3. Thermocouples enable control room operator to monitor drain-line temperatures

4. Additional support was installed on main steam pipe

tions of HP superheater 1 combine into a single ¾-in. pipe. The downstream ¾-in. pipe was replaced with a 1-in. pipe to facilitate drainage (Fig 2).

In addition, thermocouples were installed on the HP superheater drain pipes inside the HRSG (Fig 3). Now, when the control room operator notices a step-change increase in the drain-pipe temperature, he alerts the outside operator to begin closing the drains. The plant modified its startup procedure to capture this process.

To address the HP attemperator problem, new nozzles were installed and an additional collar was added on the attemperator pipe as specified in the new design drawings. Staff also set up a recurring PM work order to inspect the attemperators semiannually.

The HEP support issues required a simple, straightforward improvement. Plant installed new hangers and clips and added an additional support for the main HP steam pipe (Fig 4). Hangers also were replaced on the NO_x steam header, which raised it 1¾ in.

Results. To sum up, Syracuse made several improvements based on findings of the HRSG and HEP inspections:

- Modified the HP superheater drains collection piping from ¾ in. to 1 in. based on engineering analysis.
- Added thermocouples to HP superheater drain piping and modified the startup procedure to ensure that water does not remain in the superheater when the drains are closed.
- Repaired and modified the HP steam attemperator to ensure spray water is properly atomized when in service.
- Repaired and modified the hangers and clips for the HEP system to ensure the steam piping is properly supported.

As a result of these improvements, the plant did not have a single forced outage attributable to a superheater tube leak in 2017, and then EFORd dropped to less than 4%.

Project participants:
Steve Reinhart, plant manager
Jesse McEwen, control room operator

Amman East

Reduce iron content of wastewater to allow unrestricted discharge

Amman East Power Plant
AES Jordan PSC
420-MW, dual-fuel, 2 × 1 combined cycle located in Al Manakher, Jordan
Plant manager:
Peter Kuijs

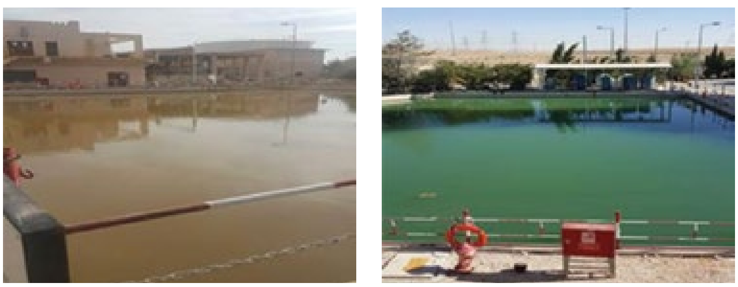
Challenge. Iron in plant wastewater, attributed to HRSG tube leaks, exceeded permit limits. Unable to discharge water as is, the only viable solution appeared to be use of so-called authorized discharge tankers. But given the large volume of water, the cost of disposal would be prohibitive. Plant personnel dug into the literature and found a technique for precipitating the iron to the bottom of the evaporation pond.

Solution. The precipitation reaction requires addition of trisodium phosphate and sodium hydroxide, plus lime to raise pond water pH to 8 to speed coagulation. The chemistry is relatively simple: Ferric ions combine with phosphate to form ferric phosphate which can be mucked from the pond.

Equipment required for the chemical reaction is standard and relatively inexpensive: dissolving tank, electrical agitator, chemical transfer pump, and associated piping and mixing nozzles. Treating in the evap pond the equivalent of a tanker batch of wastewater costs about 10% of what transportation and offsite disposal would have been.

Results. The precipitation process has met expectations at affordable cost (photos). No water has been discharged from the plant with iron above the permit level.

Project participants:
Khaled Qasem, project leader
Team members: Hashem Battat, Anas Hayajneh, Tarek Quronfuleh, and Mohmmad Dahe



Color of pond water tells the story: At left is the pond before treatment, at right after precipitating iron

Water-treatment solutions team (l to r): Battat, Hayajneh, Qasem, Quronfuleh, and Daher

Mulberry

Starting-motor trolley rail increases outage efficiency, safety

Mulberry Cogeneration

Owned by Northern Star Generation Services

Operated by CAMS

115-MW, duel-fuel, 1 × 1 combined-cycle cogeneration facility located in Bartow, Fla

Plant manager: Allen Czerkiewicz

Challenge. Mulberry Cogeneration produces both electrical and thermal energy, using steam from its extraction turbine to make distilled water for sale to local businesses.

The facility operates daily on a contractual peaking basis and provides service during the peak daytime hours for the seven-month summer period, and during the morning and evening peaks for the five-month winter schedule. This equates to nearly 500 starts annually. The demanding operational profile requires absolute dependability of the starting motor. Staff has found that having a spare motor and rotating it out every year for maintenance ensures reliability.

The site is located on a relatively small footprint, with access to the starting motor prevented on one side and limited on the other side by the water-injection skid. Top access is prevented by inlet air ductwork. To replace the starting motor, the auxiliary compartment roof must be unbolted in two sections, lifted, and walked back. After fire detection and other conduit is removed, the side walls of the compartment are then unbolted, and a crane lifts them out of the way.

The motor then is lifted by chain hoist and rolled out of the compartment on the installed trolley beam which mounts to the underside of the inlet frame.

When outside the compartment, the motor is lowered to the ground and a crane flies it out of the area to an awaiting truck. This entire evolution takes four to six people (not including crane services) an entire day.

1. Trolley rail attaches to upper beam and extends from the starting motor to outside of the compartment

2. Trolley rail with chain hoist mounted

Solution. The Mulberry team looked at several possible solutions to make this job faster and safer, settling on the installation of a lower trolley rail that attaches to the existing upper trolley rail (Fig 1). The new trolley rail extends down into the auxiliary compartment (Fig 2) and follows the existing beam out through the side of the compartment. The roof penetrations are sealed to retain CO_2 fire system integrity.

The new configuration allows the motor to be lifted without removing the roof, the side walls, or the conduit. Personnel simply lift the motor (Fig 3), roll it outside the compartment, and lower it to the concrete pad, where a forklift retrieves the motor and moves it to the warehouse. Only a small sealing panel must be unbolted to open the side wall doors for easy access (Fig 4). The beam sizing and attachment weld schedule were engineered by a local firm. The system was load tested after installation.

Results. First use of the modified system was as easy as had been foreseen and resulted in a huge man-hour saving. Plus, a safety improvement, by eliminating the need to handle large roof and wall sections by crane. The removal process for the motor now takes two men only two hours, saving cost and freeing-up plant personnel for other outage tasks.

Project participants:

Allen Czerkiewicz, plant manager
Lee Bland, maintenance manager
Jason Wolfe, operations manager
David Joiner, maintenance mechanic
Dean Buchanan, materials specialist

3. Chain hoist hooked to starting motor

4. Panel removed and doors open for motor removal

Ferndale

Step challenge generates health, occupational benefits

Challenge. Many people think of health only in terms of illness, but it is actually a positive concept that covers your physical, mental, and social well-being. Physical activity improves every aspect of your health: Adults typically start to see tangible health benefits if they engage in at least 150 minutes of moderate physical activity weekly—such as a brisk 30-min walk five days a week.

Such a fitness program helps reduce the risk of a heart attack, make it easier to manage your weight, lower your cholesterol and blood pressure, reduce your risk of Type 2 diabetes, and speed your recovery from injuries and illnesses. Further, it generally increases your energy, elevates your mood, and improves your sleep.

Ferndale Generating Station

Owned by Puget Sound Energy
Operated by NAES Corp

270-MW, gas-fired, 2 × 1 combined cycle located in Ferndale, Wash

Plant manager: Tim Miller

Solution. As one of the initiatives in the plant's 2017 Safety Improvement Plan, the safety committee developed a wellness program that included a plant-wide step challenge. To foster a positive attitude toward it, participation in the program was encouraged on a strictly voluntary basis.

Employee teams were created with a view to ensuring competitive equality. Personnel were categorized into four disciplines—administrative/management, control room operator, plant operator, and maintenance—then randomly selected to create four teams with one person from each discipline.

Each participant was provided with a Fitbit activity tracker to log the number of steps performed on a daily basis. All were encouraged to "friend" each other on the Fitbit app. The overall goal was to encourage more activity both at work and at home (photos).

As part of the challenge, a recognition plan was established. Participants' steps were tallied weekly and posted. At the end of each quarter, members of the team who recorded the most average steps received gift cards and recognition during the monthly safety meeting.

To ensure continued participation of those who were not leading the group on step counts, weekly challenges, pitched to different levels of difficulty, were established: flights of stairs, difficult-to-achieve step goals, and even bracketed step challenges to keep people engaged. Raffle tickets also were issued to participants based on personal challenge results, which made them eligible to win one of five prizes at an annual celebration.

Results. The entire staff accepted the challenge, which helped create camaraderie as well as a spirit of friendly competition. All participants finished with positive results, some of them in multiple parameters. For example, some lost weight and increased their flexibility, alleviating long-term aches. Some experienced an improvement in family morale or relationships because of their increased outdoor activities.

To tally up more steps, participants would opt to walk from work site to work site rather than use carts or bikes. They would take the stairs instead of using elevators. Many became more conscious of their diet and began eating more nutritious foods to augment their increased physical activity.

Over the nine-month challenge, 17 employees logged 55,308,557 steps—or 27,654 miles. This is equivalent to walking around the globe at the equator plus taking an additional trek across America.

Project participants:
Terry Grumbles, maintenance manager/safety director
Kris Thorpe, I&E technician
Ferndale Safety Committee

Walking up steps at work

Hiking for the fun of it

Holland

CHP generates electricity, melts snow for muni

Challenge. Holland's 60-MW coal-fired generating station, built in 1939 along the city's waterfront, was not able to meet the municipality's growing demand for electrical energy and for the thermal energy required by its expanding snowmelt system.

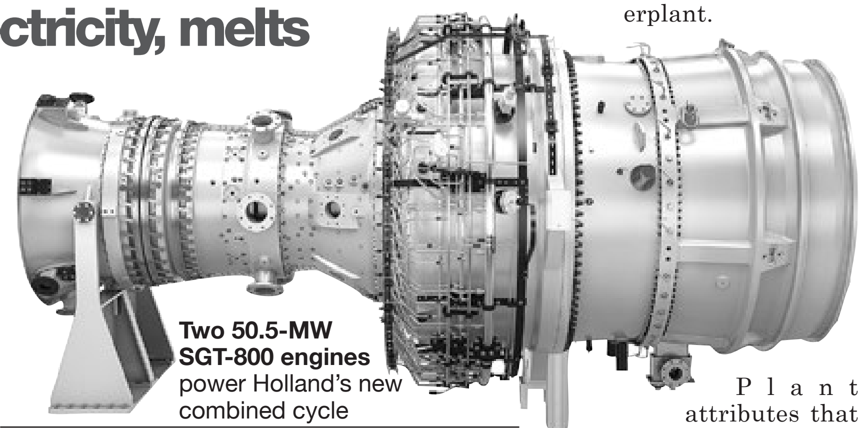
The Holland Board of Public Works (HPW) initially considered modernizing the facility, but there was no support for more coal power at the state level. However, it was important to maintain the underground snowmelt system, which serves about 13 acres of downtown sidewalks and roads.

The region experiences an average annual snowfall accumulation of over 70 inches. Use of snowplows, trucks, and salt for snow and ice removal is a considerable expense with some undesirable side effects—including pavement wear and tear and the negative impact of salt runoff on water quality.

Solution. In 2011 Holland conceived an innovative Community Energy Plan to provide a guideline for securing a reliable and independent power supply far into the future. Consequently, when planning for a new power station, HPW took into account environmental, health, and social implications as part of its Sustainable Return on Investment analysis.

The city, Siemens, and several design/engineering firms teamed up to develop a sustainable, fuel-efficient powerplant that uses natural-gas-fired combined-cycle technology. The result was a cost-effective and efficient solution considering investments in wind power and landfill-gas generation.

Two Siemens SGT-800 gas turbines power the combined cycle. A side stream of circulating water exiting the condenser serving the SST-400 steam turbine is pumped into the city's snowmelt system. The water leaves the plant at approximately 95F and returns at about 75F—enough thermal energy to drive a heat pump at the plant for building heat.



Two 50.5-MW SGT-800 engines power Holland's new combined cycle

Results. The new combined cycle produces 125 MW of electricity in summer and 145 MW in winter while reducing CO_2 emissions by 50% and virtually eliminating emissions of solid-particle pollutants.

Holland has the largest snowmelt system in the US. It is capable of melting one inch of snow per hour in ambient temperatures of 15F to 20F.

Holland Energy Park

Holland Board of Public Works

145-MW, gas-fired, 2 × 1 combined-cycle cogeneration facility located in Holland, Mich

Plant manager: Dave Koster

Holland Energy Park is a world-class power generating plant with its stunning architecture, a visitor center, and walking trails—a landmark for residents and tourists. It received the first ever Envision® Platinum designation from the Institute for Sustainable Infrastructure for a powerplant.

Plant attributes that helped city officials drive the migration to the cogeneration system included the following:

- Reduced fuel costs using less expensive (than coal) gas supplies.
- Increased revenue from the expanding industrial consumer base.
- A revitalized downtown district that is accessible throughout the winter months.
- Holland expects the new plant will maintain the city's 30% rate advantage to residential customers compared to competitor power producers.

Project participant: Chris Van Dokkumburg, planning analyst

LM2500 BEST PRACTICE

Nevada Cogen

In-house operator rounds tracking

Challenge. Plant had used a fee-based third-party software and hardware solution for years to capture and store operator rounds data. It worked well until support was necessary. Issues with this platform included the following:

Nevada Cogeneration Associates No. 1

Owned by Northern Star Generation Services

Operated by CAMS

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

Plant manager: Howard Forepaugh

- If a handheld device had to be replaced, the cost was substantial (more than $1500).
- If there were backend database or program issues, vendor support essentially was non-existent.
- Retrieving data was cumbersome and frustrating.

Solution was to use 7-in. Android tablets on rounds and Excel for data storage. Most tablets have Excel or a compatible program pre-installed, and the unit cost (around $250) is significantly less expensive than the third-party device.

On the company server, Excel rounds were created with macros to automatically retrieve data from the tablets. The simplicity of using this solution allows for greater customization and doesn't require outside contractor support if issues arrive. Using the data for trending is simple and the information readily accessible.

Results. The tablets have been used for more than three years with positive results. There have been no problems with data corruption or loss, and the tablets are much more user-friendly than the earlier handheld device.

Project participant: Mike Sweeney

RECIP BEST PRACTICES

Fuel-flexible burner reduces aux-boiler O&M cost

AES Levant Power Plant
AES Levant Holdings BV Jordan
250-MW, tri-fuel, peaking facility consisting of 16 diesel/generators located in Al Manakher, Jordan
Plant manager: Peter Kuijs

Challenge. AES Levant, a 250-MW generating station powered by 16 reciprocating engines (Fig 1), was designed to run at peak load on natural gas, light fuel oil (LFO), or heavy fuel oil (HFO). The plant's purchase power agreement requires the facility to be available to operate on any of these fuels at any time. This means heat always must be maintained on HFO tanks and pipes.

Two LFO-fired auxiliary boilers were provided to supply the heat required to maintain the HFO system ready to operate when the plant was not producing power. Plant staff was challenged to reduce the cost of using expensive LFO as a boiler fuel.

Solution. Project personnel identified and evaluated three possible solutions:

1. Insulating some lines and tanks.
2. Burning HFO in the boilers rather than LFO.
3. Replacing the burners with dual-fuel burners capable of firing natural gas or LFO. At the plant location, gas was less than half the cost of LFO on a heating-value basis.

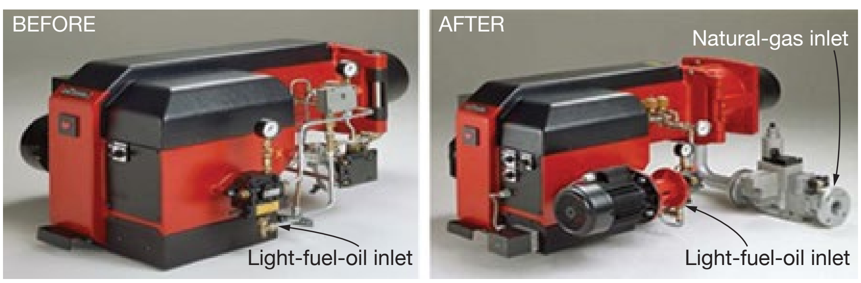
A standard four-box matrix was established with "effort" along the horizontal axis and "impact" on the vertical axis. The engineering team found the third option as requiring the least effort and having the greatest impact.

Equipment specs were developed in-house and a burner that met the plant's requirements in terms of compatibility and cost was identified (photos). The project was completed two weeks after contract signing; performance tests were completed successfully.

Results. This was an extremely worthwhile project from a financial and operations perspective. The cost of the burners was $72K and the fuel saving was $93K from August (when the burners were installed) to year-end 2017—a payback of less than five months. A saving of $170K was forecast for 2018.

Project participants:
Anas Diab and Laith Jaraabeh

1. Engine-room layout at AES Levant



2. Original burner at left was designed for LFO only, new burner at right is capable of firing either LFO or natural gas

Come up to speed on turbine fluids and their care at the 7F conference

The 2019 annual conference of the 7F Users Group, May 20-24, at the Renaissance Schaumburg (Ill), provides an opportunity to update your knowledge on turbine lube and hydraulic fluids—both their selection and maintenance. By the end of March, three lubricant suppliers had committed to participating in the vendor fair along with six aftermarket services providers offering fluid inspection, analysis, and reconditioning services.

In this issue of CCJ you'll find messages from Shell (p 39; 7F Booth 46 Tues, Booth 67 Wed) and American Chemical Technologies (ACT, p 31; 7F Booth 16 Tues/Wed), the former offering the latest mineral-oil formulations, the latter promoting the value of polyalkylene glycol (PAG), an alternative fluid. Aftermarket solutions from C C Jensen (p 9; 7F Booth 2 Tues), EPT (p 25; 7F Booth 18 Tues), Hilliard Corp/Hilco (p 19; 7F Booth 56 Tues, Booth 51 Wed), and Hy-Pro (7F Booth 9 Tues) will help you hold varnish in check and reduce fluid degradation from sparking with filter elements that eliminate static discharge. Consider visiting with

2. How Laborelec evaluates alternative turbine fluids

The first step for assuring top performance from your turbine fluid is to choose the optimal product for your engine based on OEM recommendations and the plant's operating profile. Your experience, and that of industry colleagues, should be factored into the selection process, of course.

It also is necessary to implement a proper maintenance program to maintain your turbine fluid in good condition throughout its operating lifetime. However, it's important to re-evaluate this program regularly—annually, perhaps—and factor in operational changes that can influence fluid condition—such as a shift from baseload to peaking service.

Laborelec's experts point out that once a turbine fluid enters service, it starts oxidizing, a process that promotes the formation of degradation products. The solubility of degradation products, in the case of mineral oils, is temperature-dependent: the lower the lube-oil temperature the more likely the degradation products are to plate out on turbine parts and impede operation of servos, inlet guide vanes, etc.

Backgrounder. *The stress experienced by a turbine lubricant contributes significantly to the ageing of petroleum oil, causing the* non-polar *fluid to oxidize. However, the resulting byproducts of decomposition are* polar *and insoluble in the base oil; they come out of solution as "varnish." By contrast, leading alternative turbine fluids—such as polyalkylene glycol (PAG)—are* polar *in nature and their byproducts of decomposition are infinitely soluble in the base stock. The bottom line: No varnish is produced.*

Fluid	New oil	One cycle	Two cycles	Three cycles	Tour cycles	Five cycles	Six cycles
PAG	100	77	50	44	35	25	25
MO	100	<23	<10	<10	<10		
TSMO	100	86	86	81	43	<10	<10
HPMO	100	91	59	32	25	17	15

Performance of PAG in the Ruler test bested that of all mineral oils included in the Laborelec study. The lab test results in this table and those referenced in the text were provided by ENGIE Laborlec. For more information, contact ENGIE Laborelec through koen.balman@engie.com

Laborelec engineers and chemists were of the opinion that information important to decision-making on the selection of an appropriate turbine fluid for a given plant was not provided on the manufacturer's technical data sheets. For example, a prospective customer might not know the service conditions considered in the development phase of turbine fluids of interest. All users had, basically, were some results of various ASTM tests.

In 2012, the research organization began work on the design of a test protocol to compare different turbine oils/fluids on a level playing field. First step was to meet with lube-oil suppliers, maintenance companies, and turbine OEMs to discuss their test specs.

This effort was the foundation for the development, in early 2014, of the "Laborelec Cyclic Turbine Oxidation Test." The LCTO test protocol combines the "Standard Test Method for Oxidation Characteristics of Inhibited Mineral Oils (ASTM D943)—a/k/a/ Turbine Oxidation Stability Test (TOST)—and the dry TOST developed by Mitsubishi Heavy Industries.

Test program

The results below obtained from the testing of 20 turbine fluids were interpreted based on the standard practice used for in-service monitoring of mineral turbine oils for steam and gas turbines (ASTM D4378-13 and VGB-S-416-00-2014-08-EN).

The fluids were grouped into four categories for comparison purposes by turbine owner/operators and test participants—this to keep information on specific products anonymous. The all of them at the 7F conference.

A suggestion: Take a few minutes to think about what you need to know about turbine fluids and their care to help avoid operational hiccups at your plant. Arrive in Schaumburg prepared to maximize the benefits of participating in the world's largest independent user group serving frame owners.

In turbine lubrication, like most areas of power-generation technology, there are no panaceas, no one-size-fits-all solutions. You have to do your homework to determine the best lubricant for your situation and the best way to manage its condition to assure maximum life. Talk to colleagues and subject-matter experts, read articles from back issues of CCJ (the search function at www.ccj-online.com is convenient for this purpose), scour user-group websites for back presentations, etc.

There may be no better way to learn about what works and what doesn't, in given situations, than from colleagues. Consider the following, shared by the operations manager (formerly the maintenance manager) at a plant with two 2 × 1 7FA-powered combined cycles. This user has been at the facility since before it began commercial operation in 2002, making his perspective and experience particularly valuable in an industry challenged by retirements of its most skilled personnel and high turnover rates in plant staffing.

The lubricant selected for all four gas turbines at the subject plant, which today start about 100 times during a typical year and run about 5000 hours, was a popular mineral-based product provided by a leading oil company that was said to meet or exceed the requirements of all turbine OEMs. "Exceptional" thermal/oxidation resis-

1. Who is Laborelec?

Laborelec, today officially known as ENGIE Laborelec, is one of the world's leading centers for research on electric-power technologies. Its objectives are similar to those of EPRI, familiar to most CCJ subscribers. Laborelec was founded in France in 1962, a decade earlier than the Electric Power Research Institute launched in the US.

ENGIE is a French multinational electricity provider claimed to be the world's leading independent power generator with more than 115 GW installed and another 10 GW under construction. The company, formed as GDF Suez in 2008 with the merger of Gaz de France and Suez, was renamed ENGIE in 2015. It has more than 150,000 employees and business interests in more than 50 countries.

Laborelec, one of nearly a dozen R&D centers under the ENGIE umbrella, has 240 highly specialized engineers and technicians working across the electricity value chain. It is organized as a cooperative with ENGIE and independent grid operators as shareholders.

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categories: mineral oil (MO), thermally stable mineral oil (TSMO), high-performance mineral oil (HPMO), and PAG.

Lube-oil suppliers, of course, have access to their data, enabling a comparison of their fluids to the group performance of competitive products regarding speed of degradation and the formation of degradation products.

An important aspect of the test protocol is that each fluid was stressed to simulate real-world operating conditions. This was done by thermally cycling the test samples. For the purposes of the LCTO test, samples were heated to a nominal 250F and held at that temperature for four days. Sample temperature then was reduced to 77F and held there for three days. This cycle was repeated six times. Data were taken for the fluid when new and after each cycle.

Results illustrating fluid condition were divided into three zones as illustrated in the figure:

- Normal (white field), no specific actions are recommended and the fluid can remain in service.
- Follow-up (yellow field), beyond the normal acceptable value. At this stage, the first indicators of oil oxidation become visible. Corrective actions are necessary, but oil generally can remain in service provided monitoring is increased.
- Out of spec (red field), indicates an on-going severe oxidation process. Immediate response typically includes specific maintenance actions to protect equipment from mechanical problems. Fluid replacement should be considered.

More detail is provided in the thumbnails below for each parameter included in the evaluation:

Color, ASTM D1500. Sample color darkens as the fluid degrades.

Fluid density at 20C, ASTM D4052, increases significantly.

Viscosity at 40C, ASTM D7072, exceeds ±10% ISO-VG class.

Acid number, ASTM D-664. Most rust inhibitors used in the formulation of new turbine oils are acidic and contribute to the acid number of the fluid. As mineral oils age, they form solids that precipitate out the amines, making the acid number rise. A maximum increase of 0.2 to 0.4 mg KOH/g of initial value is tolerable. Above 0.4, known as the condemning limit, is detrimental.

The best performers regarding acid number are the TSMOs which had acceptable acid numbers through six cycles. Mineral oils jumped out of spec after two cycles, while PAG received a caution flag after two cycles; HPMO went yellow in the first cycle but road through six cycles without hitting the condemning limit.

Note that ASTM D4378 refers to condition monitoring of in-service mineral oils and can create false-positive results or require modification for non-petroleum chemistries. For example, the Total Acid Number for PAGs starts at approximately 0.11 with a condemning limit of 2.0. The result after the sixth cycle on TF-25 of <0.40 represents a favorable result well within specification.

RPVOT, ASTM D2272, is a controlled, accelerated oxidation test to measure the remaining level of anti-oxidants in lube oil. When the RPVOT value (units are minutes) of the oil drops below 25% of its initial value, fluid replacement should be considered.

PAG was one of the two best performers in this category. After six cycles, its RPVOT was still 75% of the new-fluid value; HPMO stole the show, retaining 95% of its anti-oxidant package at the end of the test period. Mineral oils "failed" after the second cycle, TSMOs after the fourth.

Ruler, ASTM D6971. Like RPVOT, oil change is recommended when 25% of the initial ruler value is reached. PAG got the yellow flag after two cycles when its Ruler value hit 50%. However, it continued on under the caution flag until testing was complete. Mineral oil was out of spec before the first cycle was completed; TSMO and HPMO each lasted four cycles.

MPC a/k/a Membrane Patch Colorimetry, ASTM D7843, is a varnish potential test that identifies the propensity of a lubricant to form solid deposits, thereby helping maintenance professionals avoid catastrophic failures. MPC values greater than 30 require immediate attention.

Other tests included filtration (0.8 μm), as specified in ASTM D4055, and deposition (on glass tubing and catalyst coil), both with "dangerous zones" beginning at 100 ppm.

7F sump after more than 10 years of engine operation on TF-25

tance was another claim.

IGV issues surfaced in 2004 with varnish inhibiting proper operation of the inlet guide vanes during cold-weather starts. First "fix" was to install heat tracing on all oil lines to keep the varnish in solution.

In 2007, the plant took a more aggressive approach to resolving the problem: Sump was pumped and flushed. All "sorts" of gunk was removed, the user recalled. Refill was with ACT's EcoSafe®-TF-25. This was the second commercial use of the TF-25 product, the first being at a nearby plant a couple of weeks earlier. Budgetary considerations militated against converting the site's other gas turbines to TF-25.

Bear in mind that while heat tracing is not necessary on fluid-system components handling TF-25, it continues in service at this plant for mineral oils.

During a major inspection in fall 2018, the TF-25 sump was revisited and found in near-pristine condition after a service run of more than 47,000 hours and more than 1600 starts (photo). Turbine bearings and seals also were inspected during the outage and found clean.

What makes this plant a particularly good one for gaining objective experience on lubrication practices is that the sister unit of the gas turbine running with TF-25 continues to operate on the original oil supplied with both engines. Varnish issues have been mitigated by use of a commercial skid-mounted system that relies on resin technology to remove dissolved varnish precursors.

The two turbines serving the second combined cycle at the site were switched about 10 years ago to an alternative mineral oil (different brand than the original oil) as part of a beta test. The units have operated since without a varnish removal system.

However, varnish recently has been viewed as a possible concern and plant personnel are considering treatment with EcoSafe®-Revive™ to extend the productive lifetime of the oil. In the ops manager's view, "it does as advertised" based on his research.

How long does it last? One question on the minds of many users evaluating lubricants: "What's the long-term performance?" To get that answer for TF-25, a 10-year-old PAG sample was entered into an industry-wide study conducted by Laborelec (Sidebar 1), which developed a test protocol involving six thermal cycles to simulate turbine operation (Sidebar 2). Twenty turbine fluids were evaluated on a level playing field to help turbine owner/operators make better decisions regarding lubricant selection and treatment.

Key takeaways from the tests included the following:

- Ten-year-old PAG bested *new* conventional and thermally stable mineral oils in RPVOT tests.
- Ruler results showed "used" PAG was at least as good as all *new* fluids evaluated.
- Acid number for TF-25 was relatively constant across the six thermal cycles and below the maximum recommended limit.
- Membrane Patch Colorimetry results were 8 or less.
- Fluid density remained relatively constant across the six test cycles.

Test results thus far indicate TF-25 may last 30 years, or more. This means some plants might not have to change their turbine oils before decommissioning. CCJ

Questions on 7F inspections? Get answers in Schaumburg

The ability of gas turbines to meet expectations depends to a large degree on regular inspections by experienced technicians equipped with the diagnostic tools capable of finding and evaluating potential problems before they adversely impact engine operation. Equally important is guidance on what to inspect and how often, and exactly what to look for "under the hood."

Users rely heavily on the OEM for timely alerts and advice on issues as they are experienced in the fleet. One way this is done is by release of a Technical Information Letter (TIL, GE terminology) describing a specific concern, how to inspect for it (when and how often thereafter), how to correct findings, etc.

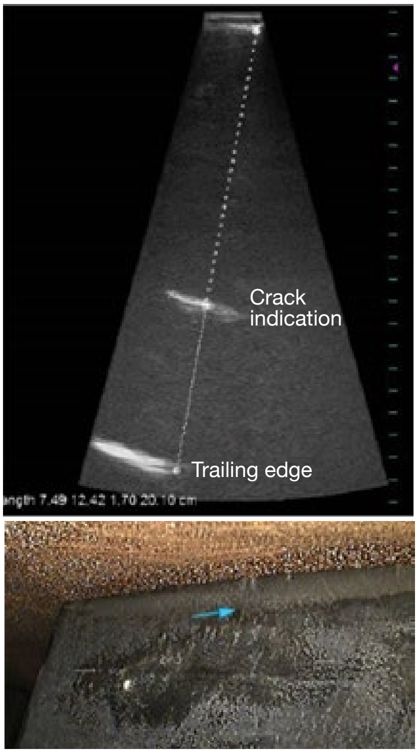
User group meetings like the 2019 7F annual conference, May 20-24, at the Renaissance Schaumburg, a few miles from Chicago, provide valuable perspective on the development of an optimal inspection plan for your plant. Formal presentations and open discussions allow the opportunity to relive the experiences of plant colleagues and listen to what the leading inspection companies are finding in their field work.

Snippets of valuable inspection-related information are sprinkled throughout every 7F program. At the 2018 meeting, the steering committee tried to aggregate some of this information in an "NDE Roundtable" with participation by the OEM, Veracity Technology Solutions, and Advanced Turbine Support. Team 7F didn't want to restrict the dialog and suggested the following as possible discussion topics:

- Compressor findings—clashing, cracking rocking, twisting, etc.
- NDE inspections on enhanced compressors.
- Combustion findings—fuel-nozzle leaks, transition seals, etc.
- Turbine findings—cracks, clogged cooling holes in buckets and vanes, etc.
- AGP hardware findings.
- Which NDE techniques to use and why.
- New NDE techniques.

In addition, inspection experience was sought on the following TILs: 2069 (1-2 spacer rim inspection), 2006-R2 (airfoil distress on third-stage bucket), 1972-R2 (conical flat-slot bottom compressor wheel), 1937-R1 (turbine-wheel inspection), 1907-R1 (forward shaft dovetail crack), and 1769 (aft-stator rocking).

Obviously an ambitious program for the hour allocated for the NDE Roundtable. The session could have filled a productive half-day workshop—in the opinion of the editors. A few of the topics addressed follow:



UTPA capabilities are illustrated by the 0.67-in. crack on the back (pressure) side of this R1 blade 3 in. from the trailing edge

Flat slot-bottom findings. The OEM reported that inspections have revealed indications requiring part replacement at around 2400 to 5000 actual starts on FA.02, .03, and upgraded .04 machines. The GER 3620 recommendation was said to take precedent at 5000 factored starts. Recommendation: Inspect at 1700-2200 starts to obtain indication size and determine operational safety.

Inspections completed to date have confirmed TIL 1972-R2 inspection recommendations and that they are necessary to determine true rotor capability.

Third-stage bucket distress. The 7F users were told that five third-stage bucket (S3B) liberations had occurred since mid-2013, each within 8000 hours of operation following repair and creep rejuvenation heat treatment. The affected units were 7F.01-.03 machines, plus a few Dot 04s running with second-tour buckets.

The liberation events initiated either at the leading edge of the airfoil at 40% to 50% of radial span, or at the trailing edge at 20% to 30% of radial span. Total hours on the failed buckets ranged from 25,000 to 55,000 hours. TIL 2006-R2, dated January 2018, provides corrective actions identified during the OEM's RCA.

Note that TIL 2006 was first released in July 2016 to provide mitigation during the RCA process. Eddy-current inspection was added to the OEM's repair process the following January and its creep rejuvenation cycle was updated in May 2017 to improve ductility and the tolerance of buckets to damage.

1-2 spacer wheel rim inspection. TIL 2069 applies to both 7F and 9F-class turbines. It was issued following the inspection of a 9FA that had tripped on high vibration. Technicians found a section of the spacer rim had liberated and caused significant collateral damage. Operating data provided no early warning of the incident: Vibration levels, wheelspace and exhaust temperatures, etc, all were normal.

Multiple initiation locations were observed on the inner surface of the spacer rim which then propagated radially and circumferentially outward through the spacer rim. The RCA identified the propagation mechanism as hold-time fatigue, an hours-based phenomenon.

Recommendation is that the inspection prescribed by TIL 2069 be performed along with the wheel inspection suggested in TIL 1937, during the first HGP or major after the spacer wheel completes 80,000 hours of operation. At a minimum, the turbine casing must be removed to provide the necessary access.

Tulsa-based Veracity discussed its experience fulfilling the requirements of TIL 1509, "F-Class Front-End (R0, S0, and R1) Compressor Inspections." The company reported being called to a 7FA site for a routine TIL 1509 inspection in mid-2018. The document's recommendations are important, and "required" by the OEM. One reason: Engine availability and reliability can be compromised by front-end compressor rubs, which are conducive to metal liberation and downstream damage.

TIL 1509 was said to be a good example of an inspection that benefits from using multiple NDE techniques to deliver very reliable results. Veracity relies on both the eddy-current method and its proprietary ultrasonic phased-array (UTPA) technology, which was originally designed for the Dept of Defense. Use of these two methods, the company says, yields the highest probability of detection over alternatives because it can detect cracks on both the pressure and suction sides of R0 and R1 blades in-situ.

Case in point: A tip crack on an R1 blade was detected. On its own, this does not sound like news of any sort, but it's where the crack was located that may lend credence to the use of UPTA technology for this type of inspection. The 0.67-in. crack was found on the back (pressure) side of the blade, 3 in. from the trailing edge (photos).

Those familiar with the R1 blade's anatomy know this area is a "meatier" part of the airfoil and this indication could not be seen from the suction (front) side. It also is an area not typically inspected because of limited access.

According to Veracity's Scott Kennedy, the crack would not have been located using the typical penetrant (PT) or eddy-current (EC) techniques employed in the field. UTPA allows for simultaneous capturing of both sides of the blade, thereby providing a full-coverage inspection.

Summing up the advantages of UTPA for a TIL 1509 inspection:

- Timely compared to PT.
- Very sensitive to small flaws.
- Can inspect both sides of the airfoil from either side.
- Not necessary to scan the entire length.
- Provides a permanent record.
- Can size flaws.

Eddy current's advantages include the following:

- Extremely timely compared to PT.
- Very sensitive to small flaws.
- Can detect material flaws and hardness changes that are precursors to stress risers.

- Known minimal detectable calibration.

For the case history described, after technicians discovered the indication with UTPA, they validated the indication with a near-field borescope and with a borescope-assisted EC inspection.

Advanced Turbine Support's Mike Hoogsteden opened his brief presentation by reviewing the leading-edge inspection tools used by the company's technicians—including phased-array ultrasonic, eddy-current array, and specialized surface inspection methods. While advanced NDE equipment allows the company to go above and beyond what the OEM typically asks for in its TILs, he mentioned there are instances where tried-and-true legacy methods may provide optimal results. He put visible dye penetrant in this group.

Hoogsteden stressed the company's ability to provide 100% NDE coverage of all R0 and R1 airfoils. He added that Advanced Turbine Support has never missed an indication or crack in its R0 and R1 inspections. On the turbine end of the machine, Hoogsteden said the company's eddy current array gear proved itself in a qualification run for a major utility to meet the requirements of TIL 2006 (see above) in evaluating the condition of third-stage buckets. Inspectors identified all of the surface and subsurface indications in the validation block.

Referring to TIL 1972-R2, he showed photos to illustrate the detection and crack-sizing information achieved for flat-slot-bottom compressor wheels when the surface condition allows.

Still more photos confirmed the considerable capabilities of advanced NDE in finding dovetail cracking in the forward shaft (TIL 1907), plus confirmation with liquid penetrant.

Wrap-up. There will be plenty of opportunity to get your inspection-related questions answered at the Schaumburg conference—at user-only sessions on the compressor (Tuesday) and turbine (Wednesday) sections, during GE Day on Thursday, at meals, in the hallways, and at the vendor fair. Regarding the exhibit hall, inspection experts from Advanced Turbine Support will be on hand in the exhibit hall Tuesday and Wednesday evening at Booth 57; Team Veracity will be at the vendor fair on Tuesday in Booth 73.

Plus, don't forget to sit in on the first series of vendor presentations Wednesday afternoon to see what Veracity President Kevin McKinley has to say about "Advanced NDT Protocols Needed for End-of-Life Assessments of Gas Turbines."

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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.

Federal Steel Supply Inc

Distributor of seamless HRSG high-energy pipe and power piping. Scheduled and heavier than scheduled walls in stock for headers, steam lines, etc. SA106 B/C and SA335 P11/P22/P91. Fittings to complement all pipe. Offering cut-to-length, custom fittings, specialty end preparation, supplemental testing, and emergency same-day shipments.

Frenzelit North America

Specializes in providing long-term expansion-joint solutions for gas-turbine exhaust applications. In addition to manufacturing superior quality expansion joints, Frenzelit also makes HRSG penetration seals, insulating materials, and acoustic pillows for silencers.

Gas Turbine Controls

World's largest stock of GE Speedtronic circuit boards and components for the OEM's gas and steam turbines. GTC stocks thousands of genuine GE-manufactured cards for the MKI, MKII, MKIII, MKIV, MKV, MKVI, and LCI controls, as well as EX2000, Alterrex and Generrex excitation.

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.

GTC Services

Field engineering company offers gas-turbine owners and operators worldwide "Total Speedtronic Support." Engineers have decades of experience servicing and troubleshooting all GE Speedtronic systems.

Haldor Topsoe

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.

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.

HRST

Specializes in technical services and product designs for HRSGs, waste heat boilers, and smaller gas or oil fired power boilers globally. Experience on over 200 boilers annually and able to provide quality inspections, analysis work, design upgrades, professional training, and more.

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.

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. This saves the O&M tech time and avoids additional downtime.

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.

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.

Multifab Inc (MFI)

Over 40 years of experience in design and manufacturing of products used for high-temp equipment along with air and flue gas applications. Offers a wide variety of services for all types of expansion joints, dampers, and high-temp products including installation, removal, repair, and splicing.

NAES

One of the world's largest independent providers of operations, construction, and maintenance services, provided through a tightly integrated family of subsidiaries and operating divisions. NAES services include O&M; construction, retrofit, and maintenance under dedicated long-term maintenance or individual project contracts; and customized services designed to improve plant and personnel effectiveness.

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.

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 Service Consultants

Boutique consulting group focusing on LTSA contract negotiation support for owner/operators of gas turbines, steam turbines, and generators. With over 30 years of experience in power systems service, our focus is to drive down avoidable maintenance costs.

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.

Precision Iceblast

World leader in HRSG tube cleaning. PIC cleans more HRSGs than any other ice blasting company in the world. It ensures that HRSGs operate efficiently by providing the cleanest boiler tubes possible.

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.

PW Power Systems

Provides competitive, efficient, and flexible gas-turbine packages rated from 25 to 120 MW. PWPS offers a full range of maintenance, overhaul, repair and spare parts for other manufacturers' GTs with specific concentration on the high-temperature F-class industrial machines.

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.

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.

Strategic Power Systems

Provides products and services focused on capturing powerplant operational and maintenance data to develop reliability metrics and benchmarks for end users—including some of the most recognized organizations in the global energy market.

Sulzer

Provides cutting-edge maintenance and service solutions for rotating equipment dedicated to improving customers' processes and business performances. When pumps, turbines, compressors, generators, and motors are essential to operations, Sulzer offers technically advanced and innovative solutions.

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.

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

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