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GRID TODAY

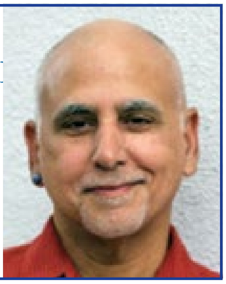
Features

INDEPENDENT VOICE OF THE GAS-TURBINE-BASED GENERATION SECTOR

LOOKING AHEAD

From congrats to catastrophe: 10 days across the grid-scale storage sector

Special to COMBINED CYCLE Journal
Jason Makansi, chairman, Editorial Advisory Board
GRID TODAY



All of us can point to truly memorable events and periods in our careers. A 10-day period that began with a tour and deep dive of Los Angeles Department of Water & Power's (Ladwp) Beacon storage facility in the Mojave desert (see following article) and ended with the catastrophic fire and explosion at Arizona Public Service Co's (APS) McMicken storage facility, Surprise, Ariz, certainly qualifies.

Within those two endpoints was attendance at Electric Power Research Institute's (EPRI) Energy Storage Integration Council (ESIC) meeting and the Energy Storage Association's (ESA) Annual Conference, both in Phoenix.

The week was a technology-development roller coaster. First, on Thursday (Mar 11, 2019), was the "high" of the 20-MW/10-MWh Ladwp facility essentially meeting all of its performance expectations in the first six months of operation. The ESIC meeting the following Monday tempered things, as one might expect, as utility engineers and vendors vigorously investigated technical challenges, standards, performance definitions, reliability goals, and life-cycle aspects of grid-scale storage.

This was followed by the unbridled optimism of the ESA conference and expo, where one rep of a prominent storage system vendor noted privately, "We're now responding to quality grid-scale RFPs and RFQs every day." At the opening keynote session, ESA representatives proclaimed their vision as 35,000 MW of storage by 2025, certainly a "stretch" goal based on the reported 770 MWh of grid-connected storage installed in 2018.

Inadvertently well-timed was ESA's announcement of its Industry Corporate Responsibility Initiative (CRI) to establish best practices in lifecycle, safety, and end-of-life decisions.

By Friday, the first accounts of the 2-MW/2-MWh battery facility catastrophic event at APS' McMicken substation were in the papers.

The path to commercializing and scaling-up a wholesale new electricity grid asset class is never linear. Another memorable career period was when advanced F-class gas turbines were being air-lifted from around the world in the early to mid 1990s to repair catastrophic failures and address design flaws. In the history books, you'll find the painful and deadly period of boiler explosions in the early part of the last century.

Challenges abound. While there's always healthy tension between the marketing and promotion in a sector and the more sobering engineering, operations, and maintenance activities, the ESIC and the ESA meetings were back-to-back days of contrast. The following broad challenge areas below discussed at ESIC make the stretch goal of 35 GW by 2025 ambitious, especially considering the APS event and other incidents which have come to light since then.

Parasitic power. Long-time residents of the desert Southwest are fond of saying air conditioning (a/c) isn't just a necessity, it's life support. Apparently, that's true of battery enclosures, too. The backup engine generators at the Beacon facility, for example, are sized based on cooling the battery enclosures for up to seven days if site power is lost. One attendee at the ESIC noted that the a/c has to be running whether the batteries are operating or not.

Parasitic power consumption can be a hit on projects planned for a low total operating hours.

Other sub-topics which arose were electricity rates for charging batteries (wholesale, retail), how charging power is metered (separate circuit?), and what the impacts will be on the Investment Tax Credit.

State of charge (SOC). This essential battery performance parameter continues to be a source of much confusion. SOC is a measure of the battery's available capacity, reported as a percentage of the battery's rated capacity. Overcharging or over-discharging a battery affects the internal cell structure.

Improperly managing the SOC impacts performance, especially degradation of the cells over time and safety. One owner/operator noted that the definition of SOC is not consistent across vendors. Also, it's not an open standard, and the battery control schemes to manage SOC, critical to overall performance, are proprietary.

Every charge/discharge cycle imposes a cost on the system, another stated, who then asked, "Do you restore the

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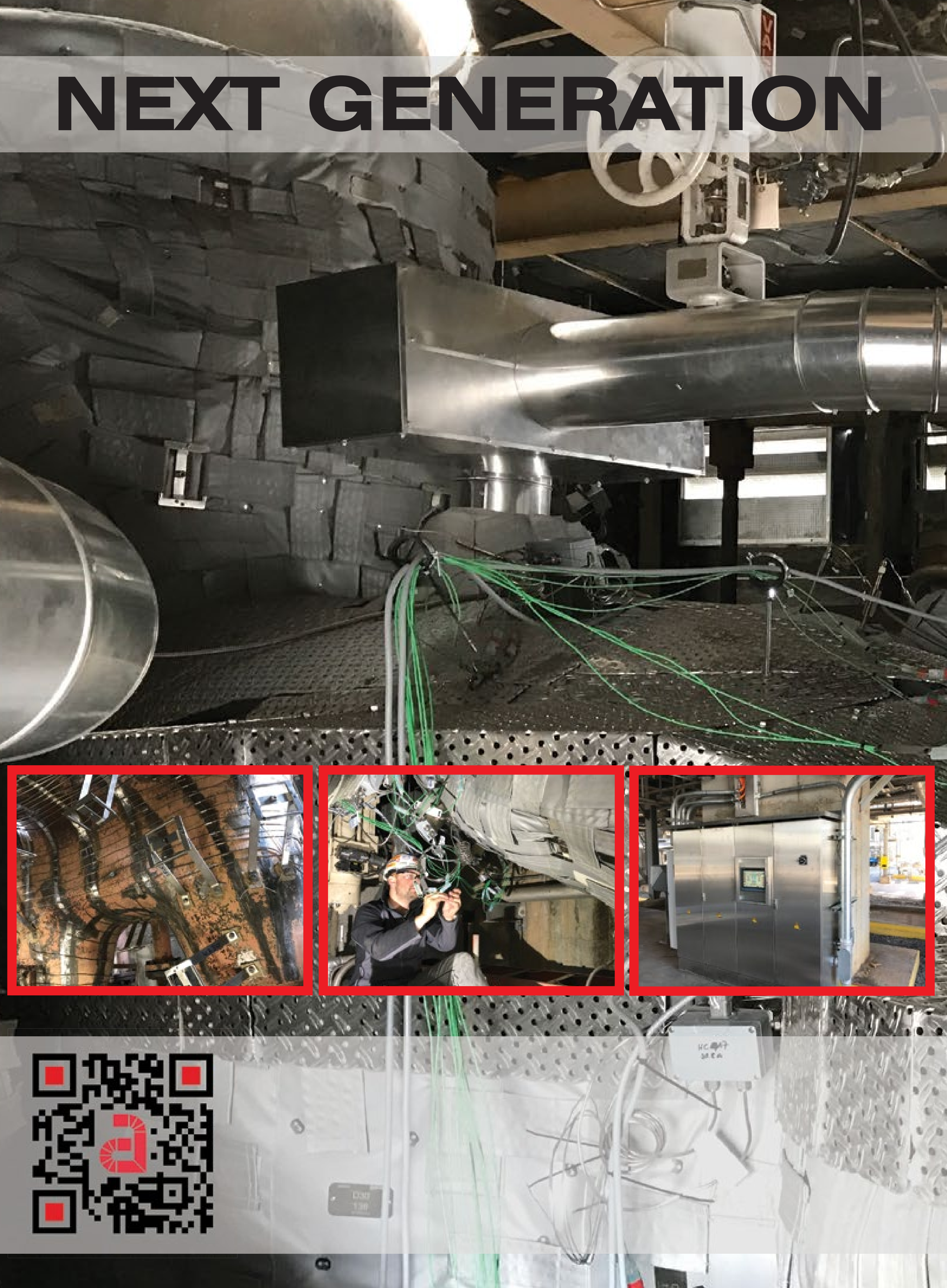
NEXT GENERATION



SOC quickly or slowly, and when, at night when electric rates are low?" There was a high degree of consensus that ESIC should focus on degradation rates for warranty claims. The degradation sub-model in the performance model EPRI is building has to be robust, because "vendors say you have to run the battery in exactly the mode specified for the degradation warranty to be valid." An attendee observed, "SOC is not a measured data point, but instead a vendor estimate."

Degradation test methods, models, and metrics received the highest rating and endorsements for ESIC's work product deliverables.

Safety. Codes and standards were the subject of some controversy. "Safety Test Method for Evaluation Thermal Runaway Fire Propagation in Battery Energy Storage Systems" (UL 9540A), derived from work in New York City and being adopted by California, is the applicable code for fire protection, but still a work in progress, according to attendees.

Another standard discussed was NFPA 855, "Standard for the Installation of Stationary Energy Storage Systems." At least one vendor claimed that meeting UL 9540A and NFPA 855 is "expensive and logistically difficult" because to get the right data, you have to deliberately induce a thermal runaway to see what happens.

When considering safety, one has to think in terms of four levels—battery cell, module, unit, and complete installation. At the module level, one design recommendation is that there be 3 ft between the enclosure wall and each 250-kW module, unless the battery is confirmed to pass the safety test.

Little information on cause has been reported out of APS on McMicken, but one source at the meeting noted that power electronics were the source of at least two high profile battery fires. Improper grounding has also led to fires.

Performance. Basic definitions, like efficiency, are not well defined. Storage advocates key in on "benefits stacking" for economic evaluations, essentially monetizing the various functions a battery facility can accommodate—such as transmission-line voltage stability, frequency control, peaking-power supply, taking power out of the grid (charging), short-term discharge, long-term discharge, black start, and other ancillary services.

Unfortunately, designing the control system to handle all of these functions is complicated, impacts on warranties can be severe, performance metrics for each function are ambiguous, and accurate forecasting of such things as weather and loads is required. The fact is, performance and reliability standards for grid-scale storage are just now being formulated.

ESIC is now incorporating reliability into the generic storage model (called StorageVET) it is developing for the industry. Plus, users note the model needs to be adjusted to reflect the constraints in different ISO regions. Currently, it is described as "very California-centric."

Other issues which came up include the following:

- Vendor difficulties with utility interconnection requirements and compatibility with utility SCADA systems.
- Commercial inverter products designed for solar PV, not batteries.
- Clear upfront costs of facilities, unclear lifecycle and O&M costs (failure rates, battery degradation, end-of-life recycling).
- Compliance with cybersecurity rules, division of responsibilities, and enforcement mechanisms (a white paper is available), especially when vendors need regular access for maintenance and control-related activities. Incorporating firmware upgrades in cybersecurity compliance was identified as a key issue.
- Defining availability, a big factor in procurement, especially when a utility needs to standardize across 20-30 projects (according to one attendee).

To learn more about industry efforts to standardize on some of these performance issues, consider reviewing IEEE 1547-2018, "Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power System Interfaces," which includes energy storage as a DER.

ESA activities. Being DC-based, ESA officials discussed in the keynote session FERC Order 841, which removes barriers to storage (in wholesale markets, which FERC has jurisdiction over); House of Representatives Bill 2096 (Energy Storage Tax Incentive and Deployment Act) which offers to stand-alone storage projects the same investment tax credit (ITC) benefits (30% tax credit) enjoyed by solar; storage procurement targets now issued in several states; the "clean peak" standard in Massachusetts, and expanding state integrated resource plans (IRP) to include storage.

In light of McMicken, the Corporate Responsibility Initiative undoubtedly has risen in priority. According to info at the ESA website, signatories to the initiative pledge to "engage in a good faith effort to optimize performance, minimize risk, and serve as an exemplary corporate citizen in the manufacturing, deployment, implementation, and operation of energy-storage projects across the US."

Best practices are being established by an inaugural task force in the areas of potential operational hazards, end of life and recycling, and responsible supply-chain practices.

Catastrophic events. According to press accounts, eight firefighters were injured, four hospitalized, by the explosion which occurred at McMicken after they had arrived and begun to fight the fire. All APS has said about the event, pending the results of an investigation, is that the facility experienced an equipment failure. It is important to acknowledge that the equipment could have been the battery, inverter/power electronics, or balance-of-plant components.

Press accounts have also noted that Korea has experienced 21 fires at lithium-ion battery facilities; incidents in China with electric busses, and in this country with Tesla electric vehicles, have gone unreported, or underreported.

APS also experienced a fire with an earlier, smaller storage demonstration project in 2013. Based on public statements, the utility's executives are undeterred in their pursuit of 850 MW of grid-scale storage by 2025.

Fluence, the joint venture between AES Energy Storage LLC and Siemens AG, is the supplier of record for the McMicken facility. It is responsible for close to 800 MW of storage around the world; this is reported to be its first major safety incident, according to an article in *Greentech Media,* Apr 23,2019.

About the author

Jason Makansi's experience in grid-scale storage spans more than three decades. As principal of Pearl Street, an independent consulting firm, he was executive director for two separate DC-based policy organizations (2001-2004, 2009-2013) focused on grid-scale storage; was principal investigator for two private-label storage executive reports issued by other consulting firms (2015, 2013); led a reverse trade mission on grid-scale storage for the US Trade & Development Association (2016); assessed market and economic potential for two advanced storage technology concepts, one for a Fortune 500 firm (2007, 2010), one for a fuel cell supplier (2011); acted as advisor of record for a $5-million venture capital raise for an ultra-capacitor firm (2011); and evaluated US markets and applications for a Japanese Fortune 50 energy-systems supplier seeking entry for its lithium-ion battery technology (2010).

He evaluated and reported on all leading grid-scale storage technology RD&D, applications, and demonstration facilities during his 18-year tenure at Power Magazine (1981-2000). Since CCJ's founding in 2003, his articles on storage have appeared exclusively in the COMBINED CYCLE Journal and its sister publication, GRiD*Today*, and CCJ On*site*.

Latest grid-scale battery tackles T-line stability

Large-scale battery energy storage systems (BESS) continue to demonstrate their ability to meet specific functional requirements of grid operations and management under a variety of business models and ambient conditions. Los Angeles Department of Water and Power (Ladwp) is the latest to add a BESS, primarily for transmission-line stability. It follows several recent projects with distinctly different primary functions.

Two years ago, Southern California Edison added a large BESS to its Center Peaker Facility (CCJ 2Q/2017, p 68). Its primary function is to capitalize on pricing for spinning-reserve capacity in the CAISO market. While the gas turbine/generator proceeds through its start sequence, the BESS delivers power immediately. The BESS also takes load swings while the turbine operates at maximum output, its most efficient and lowest emissions operating point.

SCE is credited with pioneering the first application of a fully integrated, hybrid BESS/LM6000 peaking facility. Just before that project began operating, the Village of Minster (Ohio) brought a 4.2-MW solar PV facility online paired with a 7-MW/3-MHh BESS primarily for power-factor control, peak-load management, and Reg D frequency regulation in the PJM market (CCJ 1Q/2017, p 30). Minster purchases all of these "services" and owns none of the equipment.

T-line stability. Last October, Ladwp brought a 20-MW/10-MWh BESS online down the road from a substation which takes 34.5-kV power, collected from 570 MW of solar PV in the area, and converts it to 230 kV for a long transmission line that takes the power to LA (Fig 1).

The Beacon Solar + BESS earned recognition from the American Society of Civil Engineers (ASCE) as an Outstanding Energy Project.

Unlike Center and Minster, the primary function of the Beacon BESS is T-line frequency control and voltage regulation, with a secondary purpose of load following during the daily transition late in the day from sunlight to dusk as the utility's afternoon peak demand begins to ramp up.

According to Ladwp's Tom Honles, power engineering manager, in its first six months of operation, the BESS has successfully demonstrated its daily load-following function from 6 pm to 8 pm, discharging from a full state of charge to minimum state of charge at a programmed ramp rate of 5 MWh per hour. If necessary, the utility's control center can dispatch the full 10 MWh of energy in a half hour or less.

Perhaps as importantly, the BESS has been shown to accommodate the extreme weather variations in the area, having operated through both sub-freezing and 120F ambient temperatures. The Mojave is among the harshest climates, in terms of extremes, in the continental US.

Utility grade. Experienced utility engineers will recognize a "utility mentality" in the design of this BESS. For example, there are redundant battery stacks to allow for scheduled maintenance outages and lifecycle cell degradation. While the plant requires 12 containerized battery units to meet rated load, a thirteenth was added for reliability and redundancy. Each container also includes redundant air conditioning systems; two HVAC fans are visible on each end (Fig 2). Each cooling system is "alarmed" as well.

Battery thermal management is always critical for a BESS but in the desert, even more so. To ensure that those a/c systems operate in the event of a complete loss of grid power in the area, a Cummins 180-kW (200-kW standby) turbocharged diesel/generator was incorporated into facility design. Seven days of fuel onsite is

1. Ladwp's new BESS facility serves a huge solar PV area (with numerous wind turbines nearby) that will soon top 1 GW of capacity in California's Mojave desert

2. Redundant cooling systems are installed in each container to provide thermal management in the harsh desert environment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3. Thirteen battery/PCS containers make up LADWP's Beacon Solar BESS facility, one serving as a "spare." Backup engine/gen set in foreground (green structure) ensures cooling to the containers in the event of loss of grid power available to keep the containers cool (Fig 3). The engine was sized based on the a/c load, which gives you an idea of the parasitic load taken for thermal management.

The battery control system is integrated into the complex of battery enclosures, with redundant failover intelligent controllers, while the operator console and system protection reside at the substation control house about a half mile down the road. The ac substation also has seven-day backup engine/generator capability to support both the solar array and energy storage.

On top of the physical design margin, Ladwp has a contractual performance guarantee with Doosan Gridtech and KTY Engineering, the BESS supplier and facility engineer, respectively. The utility performed site acquisition and development, grading, electrical interconnection, structural foundations, site security, and control integration into the Scada network and Ladwp's Energy Control Center (ECC).

Samsung SDI supplied the lithium-ion batteries/inverters. Fire protection is integrated into each box. The inverters are designed to meet PRC24 code for low-voltage ride-through.

Temperature has such a huge impact on batteries that, according to Honles, the components had to be sequenced and shipped to the site to minimize ground storage time. Otherwise, it could affect lifecycle performance.

As another precaution, the entire site is electrically grounded, since Li-ion batteries are "always hot," says Honles.

A thousand words. A picture of the area offers a glimpse into what Ladwp has to manage but a visit puts it in stark terms. One sees on the drive up to the facility endless wind turbine/generators as you get within 10-15 miles of Beacon. Then when you take the turn off the main highway into the Ladwp grounds, it's nothing but endless solar PV arrays. Honles notes that in a few years, more than a gigawatt of solar PV will be operating in the vicinity of the BESS.

Clearly, it is a remote location, but the BESS isn't expected to need much attention. O&M procedures include maintenance of the critical cooling systems for the containers; replacement of a/c filters, something most homeowners can relate to; and semi-annual battery inspections.

Startup issues focused mostly on the power converter systems (PCS) and the battery controllers, but were of the typical mean-time-between-failures (MTBF) bathtub curve variety, notes Honles, and were experienced in the first three weeks of contractually stipulated performance testing, prior to declaring acceptance into commercial operation.

The BESS went through extensive testing in all three performance modes (frequency control, voltage control, peak-power delivery) prior to acceptance. Each battery rack had to do one full charge/discharge cycle each day for 90 days and do this 95% of the time (95% reliability guarantee, 99% availability).

Software allows three selectable operating modes. Frequency control has priority most of the day. At 6 pm, the software automatically switches into discharge cycle, and empties 100% each day from maximum state of charge (SOC) to minimum SOC. The final mode is to soften the solar ramp out at the end of the day as the sun goes down. The BESS was exercised in all of these modes during the performance tests.

The controls and communications architecture is often the greatest challenge with a large-scale BESS. Each battery cell has to be monitored and managed with tens of thousands of others, a task relegated to the battery supplier and its optimized battery controller electronics.

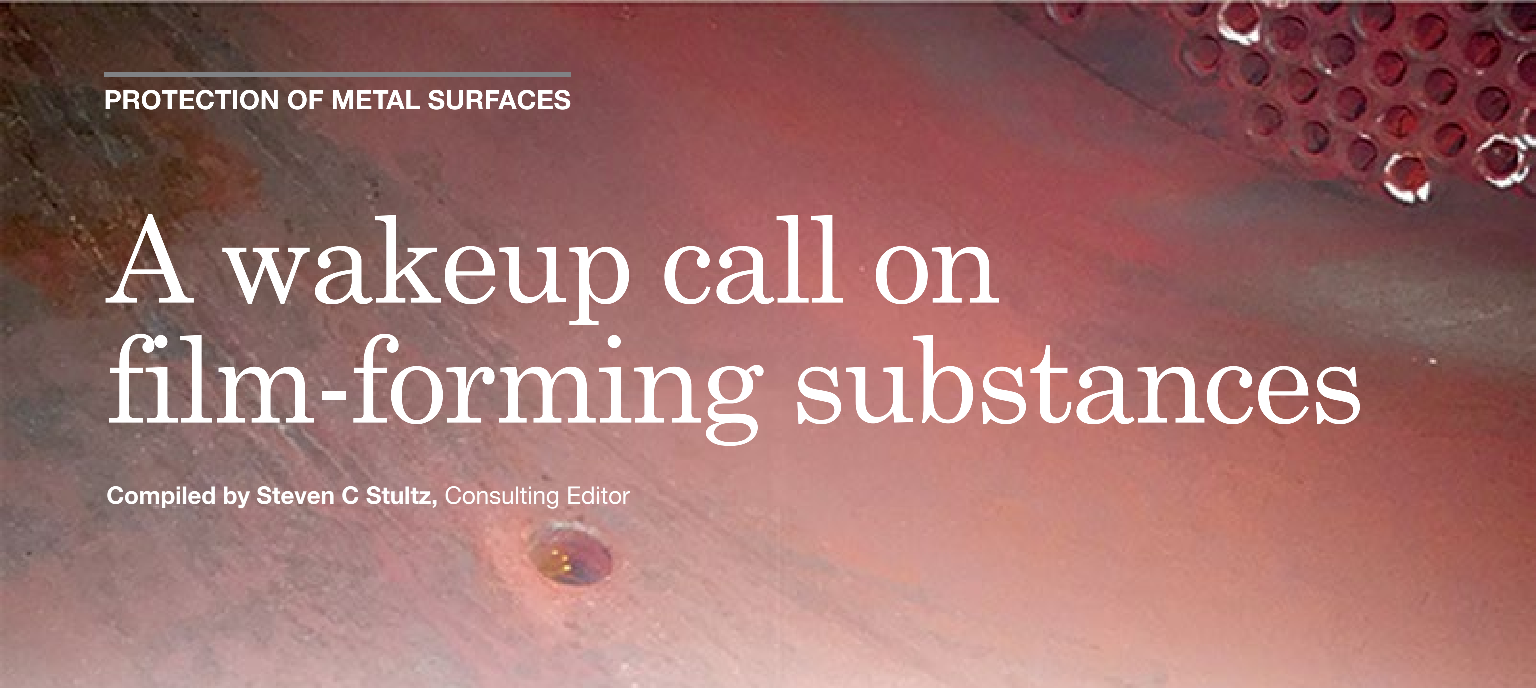
Then the battery system has to be integrated with the dc/ac PCS and inverters. The PCS's ac connection is matched with corresponding harmonic-rated ac step-up transformers to match the medium voltage of the plant. The BESS may be integrated with a solar PV plant, such as that at Beacon, and through a utility substation, stepped up to a high voltage and interconnected to the transmission system. Entire facility requires control and communication with the utility Scada system.

To handle all this, Ladwp specified an open standard, and accepted in the system integrator's proposal, the Modular Energy Storage Architecture (MESA), a communications protocol which, says Honles, includes a wide set of available data points, and flexibility with other storage configurations. While MESA was developed primarily for distributed energy resources, Ladwp adapted it to its needs by adopting a reduced set of data points necessary for the utility-type operations of their ECC.

Commercial terms. The BESS and balance of plant cost $17.5-million, almost $2-million less than the not-to-exceed authorization from the Ladwp Board. Total cost, including site development and interconnection, was around $23-million. However, it is important to note that the project was driven by the state's AB2514 storage mandate, not an investment-grade payback, and to demonstrate the ability to serve as a reliability-enhancement asset.

Regarding the latter, Honles notes, the other options would have been (1) a static VAR compensator or (2) load shedding and curtailment of solar capacity on the transmission line. Neither would have provided a peak demand solution, however.

Storage in context Finally, while this facility is large in the scheme of evolving grid-scale storage, it is worth noting that it is minuscule compared to the "big daddy" of storage in Ladwp's system, the nominal 1300-MW Castaic pumped-storage hydroelectric plant. In this context, BESS has a ways to go. In fact, some power-system engineers estimate that 250 MW of variable generation ultimately needs to be coupled to 100 MW of 4-hr-capable storage to truly provide grid stability. CCJ



PROTECTION OF METAL SURFACES

A wakeup call on film-forming substances

Compiled by Steven C Stultz, Consulting Editor

Film-forming substances (FFS), intended primarily for the protection of metal surfaces, are not new. The earliest patent (known to the editors) for one such substance, octadecylamine (ODA), was issued in 1954, with first powerplant applications in the former Soviet Union and East Germany. Earlier still, FFS were used to protect shipments of military equipment during WWII.

What is more recent is focused research and trial into applications for combined-cycle plants. Hoped-for benefits include corrosion protection in heat-recovery steam generators (HRSGs), condensers, and the phase transition zone (PTZ) of steam turbines. Other benefits could be better pH control, and less chance of both single- and two-phase flow-accelerated corrosion (FAC).

But also new is an increasing risk of system and equipment damage caused by misapplication, misinformation, and failure to accurately prepare and monitor—in other words, jumping in too quickly.

Although the expected results sound great, potential damage—the industry is learning—can be great as well.

Is the use of film-forming substances worth considering? Absolutely, especially given more cycling, low-load operation, and periods offline. Is this worth implementing, within an already complex water-chemistry program? It could be, depending on the system and equipment, and if you're both knowledgeable and careful.

Neutralizing, filming amines

About three years ago, the CCJ-Online Team posted the following session review notes for the Combined Cycle Users Group, perhaps the only organization that covers water chemistry for the entire combined-cycle plant:

> "The jury is still out on the use of amines," but "addition of an amine with a low volatility at the pressure of concern may provide benefit: It will hang along the tube wall to protect against loss of oxygen and ammonia from that space. Absent amine, oxygen and ammonia can migrate into the bulk water, leaving the tube-wall area unprotected. Amine volatilizes later, but after protecting the tube wall.
>
> "Bear in mind that amine blends are known to increase cation conductivity and possibly mask more corrosive anions. Their use is influenced by the severity of two-phase FAC and turbine corrosion. Monitoring of iron transport is highly recommended before introducing amine blends."

Then in Issue No. 51, 4Q/2016, p 70, CCJ issued a detailed primer on this fast-approaching frontier, by EPRI's Steve Shulder and Mike Caravaggio, entitled "Protect equipment against corrosion with neutralizing amines, filming products." This detailed review covered the latest EPRI research into amines and filming products, monitoring of these substances in action, corrosion control in the steam-turbine PTZ, the need for new tools to quantify corrosion improvement, and a glance at ongoing research.

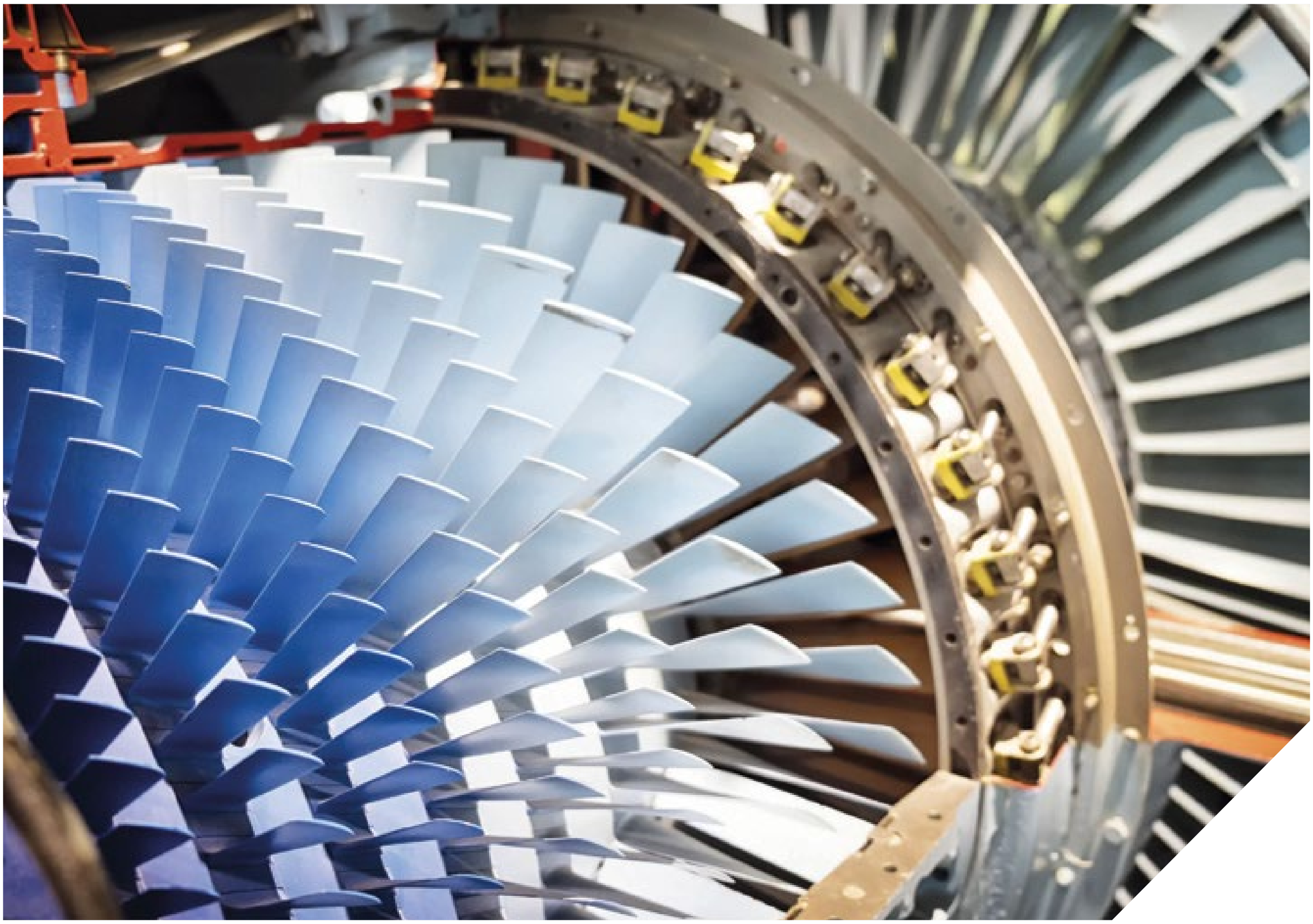
Since that time, the subject has been included, in some form, at all user-group meetings for combined-cycle systems and components—including turbines, HRSGs, and air-cooled condensers. Something has been happening.

A case study was noted in the inaugural (2017) *HRSG Forum with Bob Anderson* (CCJ No. 52, 1Q/2017, p 34), concluding with the importance (for all aspects of plant water chemistry) of "understanding the damage mechanisms and chemistry control options, performance monitoring, and the critical importance of acting on the measured results." Measurement, it has been determined, is a difficult part of the overall equation.

IAPWS. The spearheading organization for both FFS research and

IAPWS TGD8-16 Section 8 provides guidance for addition of FFS

8.1 Evaluating the potential benefits and side effects of adopting a plant chemistry program using FFS.
8.1.1 Are FFS treatments compatible with other treatment programs?
8.1.2 What effects do FFS have on plant equipment and processes (including ion-exchange resins and reverse-osmosis membranes)?
8.1.3 Are there special safety and environmental issues?
8.1.4 Impact on functionality of sensors.
8.1.5 Complete and comprehensive documentation (from the chemical vendor).
8.2 What does the operator need to do before applying FFS?
8.3 Determining product dosage levels and initial usage.
8.4 How and where to dose.
8.5 How to analyze the content of FFS within the cycle: Where and how to sample (container material and storage), method of analysis, analysis of decomposition products.
8.6 Determining optimum usage.



implementation is the International Association for the Properties of Water and Steam. A key participant is Dr Barry Dooley, senior associate, Structural Integrity Associates Inc, and the executive secretary of IAPWS.

CCJ has been following Dooley (and others) on this for quite some time.

Amines, products, substances

The First International Conference on Film-Forming Amines and Products was held in Lucerne, Switzerland, in 2017. Before the second conference in 2018, organizers had issued a formal and much-needed change in nomenclature.

The term *film-forming substances* was introduced by IAPWS last year. It was reported in detail in CCJ No. 56, 1Q/2018, p 6, "Film-forming substances: the next frontier in cycle chemistry."

Feedback from the first two conferences had indicated confusion about the various terminologies used within this relatively new field of chemistry, or what Dooley calls "a narrow topic in cycle chemistry control of powerplants." In response, IAPWS introduced the more general term *film-forming substances.* Two subsets describe these materials in terms of either being amine-based [film-forming amine (FFA) or film-forming amine product (FFAP)], or non-amine-based [film-forming products (FFP)]. FFS could now be the nomenclature for all of these substances worldwide.

FFS2019

The Third International Conference on Film-Forming Substances, chaired by Dooley, provided a highly interactive forum for the presentation of new information and technology related to FFS, research results, case studies of powerplant and industrial applications, and open discussion among users, equipment and chemical suppliers, researchers, and industry consultants.

The 2019 meeting attracted more than 70 participants from 22 countries to Heidelberg, Germany, March 19-21. Organizers were BHT GmbH and PPChem AG, publisher of *PowerPlant Chemistry.* Fineamine SA and Anodamine Inc provided financial support. All FFS conferences are supported by IAPWS.

At its first meeting in 2017, IAPWS issued Technical Guidance Document (TGD 8-16), "Application of film-forming amines in fossil, combined cycle, and biomass power plants." Access at www.iapws.org.

At FFS2019, there was global appreciation for and recognition of this unique document. Dooley announced that later this year, a new TGD will be issued on FFS for industrial plants, along with a White Paper on the application for nuclear plants.

It's important to note that experience in nuclear plants, primarily for layup and storage, continues to be good with ODA the substance of choice.

Nuclear plants have been a bright spot in discussion. There generally has been low impact on the chemistry control with complete observation of hydrophobic films in the feedwater and condensate systems. However, film formation in dry-steam areas remains a question.

But experience in fossil and combined-cycle plants continues to be variable in terms of corrosion-product transport and film formation in steam circuits. Suggestions are being made, repeatedly, to improve the verification process using tube samples and corrosion-product monitoring during startups.

At FFS2019, international updates were presented on recent experiences from powerplants of all types and from industrial plants. Bulleted items below provide some specifics. Participants indicated that problems experienced at fossil and combined-cycle plants after application of FFS most often relate to increased deposition on heat-transfer surfaces which result in under-deposit corrosion.

- Updates were provided on ongoing research activities from different international organizations dealing with decomposition of FFA, thermolysis and distribution of FFA, measuring/quantifying the concentration of FFS in the water, adsorption kinetics of film formation, and the effects of FAC.
- Many FFS mixtures contain undisclosed (proprietary) components including those commonly referred to as polycarboxylate dispersants. At high pressures these can break down and cause tube failures. Failures can also be caused by any free hydroxides that end up as sodium hydroxide during thermal breakdown. There was no understanding among participants on why a polyacrylate addition was being included in proprietary products.
- Another discussion thread was the open issues related to inspections following application of FFS to a plant, and the methods of determining hydrophobic films on surfaces, especially steam surfaces, and whether their presence can be related directly to corrosion protection.
- Little new work was presented on understanding the mechanism of the interaction of FFS with surface oxides and on how an FFS film might change the growth mechanism and morphology, and result in reduced levels of corrosion-product transfer. This relates to the interaction of the FFS film with existing oxide/deposit surfaces in condensate/feedwater and in boiler/evaporator water. Much discussion took place on the oxides which form in steam circuits, and on the chromia oxides which form in the phase transition zone of the steam turbine.
- One of the continuing conclusions from FFS2019 was the need to first optimize the current chemistry of a plant with verification, or through baseline monitoring, before application of any FFS. See *Section 8 guidance* discussion below.
- There were extensive discussions regarding gaps in knowledge and needs for further research work. Dooley noted that IAPWS will define, via one of the organization's Certified Research Need documents, the work needed on the interactions occurring under all plant conditions and temperature ranges.

To sum up, there is still much to learn and a lot of fundamental work that must be done to understand the mechanisms at play with FFS—including film-formation kinetics, equilibrium and stability, film structure (for example, thickness or number of layers), how the adsorption is affected by other amines, and the correspondence to the reduction in corrosion rate through understanding of the interactions with oxides and deposits.

1. **Testing** of filming-forming substances has been ongoing for decades

Cases in point

At the second annual *HRSG Forum with Bob Anderson* in 2018, EPRI's Shulder concentrated on FFS application for both corrosion resistance and layup protection. The summary review of his presentation is covered in CCJ No. 56, 1Q/2018, p 71.

He stated that amine/filming technology is increasingly considered for the following base benefits:

- Non-optimized corrosion product transport with recommended feedwater treatment program.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Better emissions compliance
Clean air is our business. The GTC-802 (NOx/CO-VOC) "Dual Function" catalyst will help your plant meet stricter emission standards while improving performance and profitability. GTC-802 combines two catalysts in one, delivering both superior NOx reduction and outstanding CO and VOC oxidation. Lowest pressure drop, near zero SO2 oxidation and reduced ammonia slip add up to improved heat rate, increased power output and fewer cold-end maintenance issues. GTC-802 is positioned downstream of the ammonia injection grid in the same location as the current SCR catalyst. As an added benefit, the catalyst allows direct injection of liquid ammonia or urea in place of the traditional vaporized ammonia.
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2. The entire sampling and analysis system at this plant had been out of service for eight years

3. Inappropriate cycle chemistry caused waterwall and superheater-tube failures

4. Steam turbine experienced deposits, pitting, and cracking

• Cyclical operation with a number of startups.
• Excessive ammonia may result in vapors within plant and short polisher runs.

- Two-phase FAC damage.

• Neutralizing amines may provide better dissociation and distribution than ammonia.
• Higher localized at-temperature pH.

- Better layup protection during outages of variable duration.

• Film-forming products place a hydrophobic barrier between metal surface and liquid.
• Limit on capital expenditures or labor (dehumidified air).

Ideally, FFS will place a hydrophobic barrier between the metal surface and the liquid (Fig 1).

This could be a great benefit, especially during outages.

One highlight of FFS2019 was a presentation entitled "Cycle chemistry issues due to the incorrect application of a film-forming substance," by David Addison, principal, Thermal Chemistry Ltd, Hamilton, New Zealand.

The case presented was a 600-MW (4 × 150 MW) coal-fired station in Australasia, commissioned in 2010. The plant features a reverse-osmosis/mixed-bed demineralizing plant and is seawater-cooled (no condensate polisher, copper condenser). The feedwater system is all-ferrous.

Although a coal-fired facility, the FFS issues presented are common considerations in both conventional and combined-cycle plants.

The site was commissioned on AVT(R) with phosphate treatment in the boilers, but converted to a film-forming product in 2011. Chemistry guidelines at the plant were described as "limited."

FFS details (contents) were listed as follows:

- Oleyl propylenediamine (OLDA).
- Cyclohexylamine.
- 2-aminoethanol.
- Polycarboxylate dispersants (details not known).

Treatment, co-dosed with ammonia, was manually applied and tested with a target concentration (as product) of 12 ppm.

A local agent supplied the product and used "consumption of product" as the basis for testing. Publicly available information from the vendor states the product was formulated "for steam and water systems with softened feedwater" (obviously not the case for this plant), and for plants without a steam turbine, also clearly not the case for this coal-fired facility.

Site steam/water analysis. At the time of the plant review by Addison, no online analyzers were functional and the majority of the sample points themselves were not functional. The entire analysis system had been out of service for eight years, and very little manual sampling and testing was being performed (Fig 2). According to the owner/operator, the site had been told by the FFS vendor that, thanks to the FFS program, there was little need for any online sampling and analysis.

Condenser tube leaks were occurring, undetected.

Major plant issues. Significant boiler waterwall and superheater tube failures were happening causing unplanned forced outages (Fig 3).

FAC was causing failures in the feedwater system (with high iron levels). The following observations were made:

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- There were multiple feedwater pipework/heater failures consistent with FAC attack.
- Multiple HP heaters had been removed from service because of excessive and repeated leaking.
- Significant amounts of iron oxides were observable in functioning manual sample points (economizer inlet and boiler).

Overdosing of the FFS (above 130 ppm) was at times causing blockages and so-called *gunk balls*.

No condition-assessment tube samples were taken at the plant during the time under review, and there was no tube failure reduction program in place. Tube analysis by the FFS product vendor was characterized only as "rudimentary."

The steam turbine was experiencing deposits, pitting, and cracking (Fig 4). Deposits were present on all blades (HP/IP/LP) and no carryover testing was being performed. The first and only turbine-deposit analysis was undertaken by Addison in 2019 during an overhaul and repair outage. Deposits were consistent with continuous carryover and spray-water contamination while operating with condenser tube leaks:

- HP. Silica, sodium, and chloride dominated deposits with high sodium and chloride amounts relative to the IP.
- IP. Silica, sodium, and chloride dominated deposits.
- LP. Silica dominated deposits.

None of the saturated- or superheated-steam sample points were functional.

Section 8 guidance

A key point made by Dooley at the Air-Cooled Condenser Users Group annual meeting in 2018 (CCJ No. 59, 4Q/2018, p 66) was the importance of correct application of IAPWS TGD 8-16, specifically Section 8 (sidebar, first page of article). It provides clear guidance for applying FFS to generating plants as a supplement to, or as a replacement for, the current chemistry regime—clearly something not apparent to the owner/operator of the plant discussed above.

Addison said that the following key activities had *not* taken place before conversion from AVT(R)/phosphate treatment to a film-forming product:

1. Tube samples had not been taken and analyzed to understand the oxide condition of the unit. Chemical cleaning might have been needed.
2. A detailed internal inspection of the plant had not been undertaken.
3. A full baseline set of functioning chemical analyzers did not exist.
4. There was no full baseline set of data for corrosion-product transport.
5. There should have been a full composition breakdown of the FFS product so thermal degradation products could be assessed.

TGD non-compliance. Addison's presentation at FFS2019 pointed out that FFS products, "if applied correctly and in the right circumstances, can actually work really well for offline protection." He continued, "Baseload is often a challenge to justify the cost versus the potential benefits, but if a combined cycle is off and on then it should at least be carefully considered to determine if a technical and economic use case is present."

Addison also is involved in development of international cycle-chemistry guidelines for industry, both IAPWS and EPRI. He is the vice chair of the IAPWS Power Cycle Chemistry Group and chairs the New Zealand Association for the Properties of Water and Steam (www.nzapws.org.nz).

The Australasian plant experience above was a classic example of failure to follow IAPWS TGDs for an FFS program or any other aspect of cycle chemistry, and of being entirely reliant on substandard technical advice from a chemical vendor.

The current FFS program at the plant in Australasia has been stopped, pending resolution of other issues. Boiler-tube-failure and turbine-deposit analyses are now underway to determine the precise root causes. A complete steam/water sampling system upgrade has begun, key elements of a boiler-tube failure reduction program are in place, and both cycle chemistry and IAPWS TGD familiarization training have been implemented.

Ongoing discussions

Other related presentations at FFS2019 included long-term preservation (two years) of a coal-fired plant in Germany (good hydrophobicity and no corrosion), and successful use of FFS as a corrosion inhibitor at a combined-cycle power station in the UK.

Also noted was a major challenge with layup and storage of combined cycles, namely the impact on air-cooled condensers. The topics of FFS and cycle chemistry are included in meetings of the Air-Cooled Condenser Users Groups (www.acc-usersgroup.org).

FFS2020 remains in the planning stages for early next year, with a probable location in France. Details will be announced in CCJ and at www.iapws.org.

The topic also will be included in the upcoming *HRSG Forum with Bob Anderson,* July 22-24, at the Hilton Orlando (www.HRSGforum.com).

Film-forming applications for selected component and surface protection are an ongoing target of active research and trial. Experiences, both good and bad, are finally getting the attention they deserve. Most deserving is the clear message to apply due diligence and tread carefully! CCJ

Learn from the experts on powerplant chemistry

David Addison, principal, Thermal Chemistry Ltd, a frequent contributor to CCJ on subjects concerning cycle chemistry, called to recommend attendance at the 2019 PowerPlant Chemistry Forum, Sept 26-27, in Washington, DC. Addison, who works globally out of his New Zealand office, chairs his country's committee to the International Association for the Properties of Water and Steam, which develops cycle-chemistry guidelines for industry. He also serves as the vice chair for the IAPWS Power Cycle Chemistry Group.

The fall meeting, which will focus on the latest developments in cycle chemistry of interest to asset and plant managers, operations personnel, plant engineers and chemists, services providers, and others, addresses the needs of combined-cycle, conventional fossil, and nuclear plants. Preliminary agenda topics include the following:

- Cycling operation and its chemistry challenges.
- Startup and layup strategies for chemistry control.
- Chemical control and monitoring.
- Sampling systems and instrumentation.
- Lifecycle chemistry optimization and management.

The steering committee is organizing a program that consists of both invited and contributed technical papers and provides adequate discussion time. Committee members, in addition to Addison, are:

- Chair Michael Rziha, PPChem AG (Switzerland).
- Steve Shulder, EPRI.
- Doug Hubbard, AEP.
- Chad McKnight, Southern Company.
- Erin Westberg, FPL/NextEra.
- Mike Rupinen, LG&E and KU.
- Randy Turner, Swan Analytical USA.

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Simple EMI test detects failing joints, promotes high plant availability

By **Clyde V Maughan,** Maughan Generator Consultants, and **James E Timperley,** Consultant

There are numerous instrumentation systems used in attempts to assess the condition of powerplant electrical equipment. The library of papers about them is vast. But papers discussing detection of failing electrical connections inside generators or bus systems are limited in number.

The focus here is on instrumentation that will readily detect joints in the early stages of distress, with the objective of preventing expensive in-service failures.

Bolted-joint deterioration. There are thousands of high-current (non-instrumentation) electrical connections in a powerplant. All are subject to deterioration, bolted joints in particular. They may eventually fail if not well designed and properly assembled.

Fig 1 shows the locations of several bolted connections internal to a large generator. Failure of these connections is rare but can be extremely costly when they do occur.

Deterioration from imperfect high-voltage-bushing flexible connection joints is shown in Fig 2. This condition is the result of high contact resistance attributed to less-than-specified torque on the connection bolts and/or improper cleaning of the joint faces. Repair would involve cleaning and re-plating of the connection surfaces on the plates and on the flexible links. Or replacement of links if significantly deteriorated.

A serious joint failure is illustrated in Fig 3. Restoration of this condition would involve local cleaning, replacement of lost metal, and reconditioning of the plated surfaces. Costs in outage time and repair would be significant.

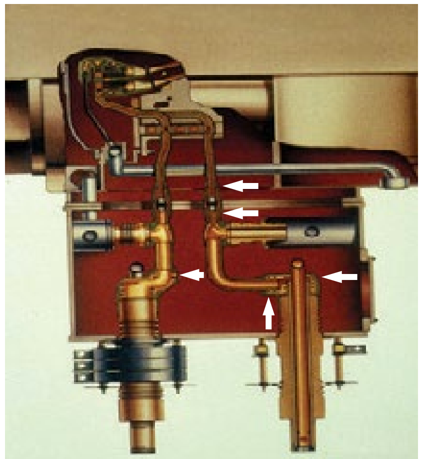
At the extreme high end of the damage spectrum is the failure of the 900-MW generator in Fig 4. Repair involved installation of a new stator winding, a rotating-field rewind to facilitate cleaning of the winding, and extensive and difficult cleaning of the core and frame. The failure was catastrophic in that it involved a six-month forced outage costing more than $100 million in repairs and replacement power.

All of these conditions would have been radiating high electromagnetic-interference (EMI) energy for some period before failure occurrence. This could have been detected and the failure prevented.

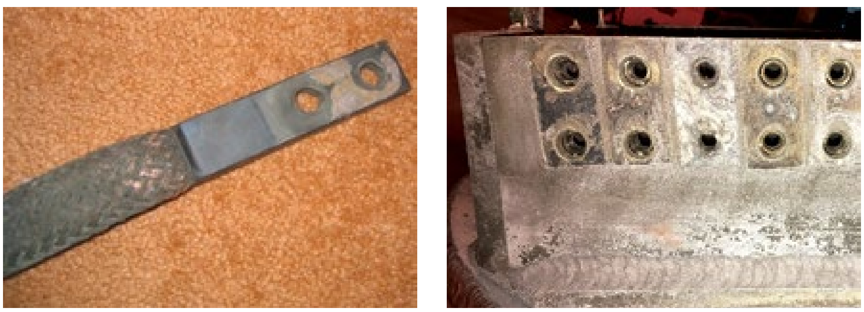
Assessing equipment condition can be difficult. The most powerful tool is visual inspection by a well-qualified individual. But this usually requires equipment shutdown and at least some disassembly. Thus, high emphasis always has been on testing, with online testing preferred.

For example, on a generator stator winding there are many such tests:
- Several types of over-voltage test.
- Various partial-discharge (PD) systems.
- Flux assessment.
- Winding modal analysis.
- Wedge tightness.
- Numerous special tests of winding direct-cooling systems.
- Electromagnetic interference testing.

EMI testing may be done by either of the methods described below:
1. Electromagnetic signature analysis (EMSA) is applicable to powerplant equipment such as generators, motors, and transformers. It is not



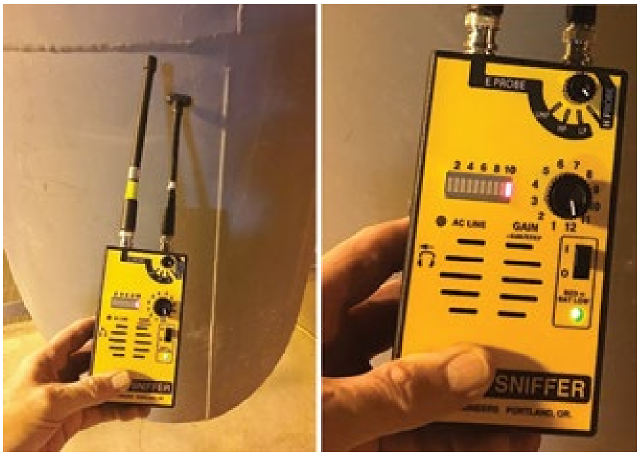
1. Flexible-lead bolt connections typical of those found inside a large generator



2. Arcing damage to flexible-lead contact surface is shown at left, to bus-connection surface at right

3. Failing flexible connection joint can be quite expensive to repair

4. What remains of a failed connection is at the left, melted copper from this failure is in the center, resulting contamination to the stator winding is at the right



5. Instrument for locating partial discharge and EMI

6. Plant is surveyed for electromagnetic radiation using Model 246A instrument from Radar Engineers

generally useful for locating joint deterioration. The EMI signal is obtained from a radio-frequency current transformer commonly placed on the grounding cable of the equipment in question.

This full-spectrum analysis, while valuable, does not have the ability to detect where a defect is located. Also, it can be very difficult to interpret the signal with accuracy relative to severity and isolation. As a result, the use of EMSA is limited.

2. A hand-held so-called "sniffer," which is discussed in the remainder of this article.

Measurement of radiated EMI using the hand-held sniffer has powerful condition-assessment capability for electric equipment. However, it also has not been a widely used technology relative to powerplant equipment. A common reservation regarding the sniffer revolves around the belief that a generator frame or bus enclosure acts as a Faraday Cage and does not allow EMI to escape.

Recall that a Faraday Cage is constructed of conductive materials with only a few well-shielded openings. Commercial EMI-free rooms are often two layers thick with the layers insulated from each other and with both layers grounded at a single location. Special conductive gaskets and grounding methods are used at the doors and other openings.

The steel enclosures of powerplant generators, motors, bus, and switchgear are very imperfect Faraday Cages. The strong EMI signals emitted by failing joints are able to pass through those enclosures.

This discussion focuses on the use of the measurement of radiated EMI for detecting deteriorating electrical-current connections for these reasons:

- Many types of highly important deterioration can be detected by in-service EMI testing.
- EMI testing is completely non-intrusive.
- There is no danger to personnel or equipment.
- Relatively little effort is involved; an entire turbine/generator and its associated electrical equipment can be assessed comfortably in an hour.
- The saving from avoiding a single forced outage on a single piece of equipment can be huge.

Detection of EMI radiation in powerplants for evaluating the condition of powerline insulators dates back many decades. More recently, its use in finding failing connections has proved very effective. The technology is basic and easy to understand: Any poor electrical connection produces arcing which, in turn, produces electromagnetic radiation. The strength of the radiation field depends on the magnitude of the arc, distance from the arc source, and any shielding of the arc that exists.

Since arcing is a common deterioration mechanism where electric current is flowing, this type of monitoring is a powerful tool for assessing the condition of powerplant equipment.

There is a small, hand-held instrument on the market that can readily measure the strength of this radiation, the Partial Discharge and EMI Locator (Model 246A, Fig 5) from Radar Engineers, Portland, Ore. There may be other instruments available with the capabilities of this device, but the authors are not aware of any.

This device weighs less than a pound. It is versatile and has a wide range of sensitivities—low using the magnetic H-field antenna, high using the LF/HF/UHF electric E-field antenna. The

Defects found in bus and switchgear

A variety of conditions have been detected inside bus and switchgear by the Radar Model 246A—including the following:

- Loose bolts on center conductor.
- Loose bolts on enclosure.
- Loose disconnect-switch parts.
- Broken high-current shunts.
- Defective PT connections.
- Open fuse links.
- Defective breaker contacts.
- Contaminated insulators.
- Cracked and loose insulators.
- Shorted enclosure insulation.
- Foreign objects inside enclosures.
- Loose connections to surge pack.

7. Generator is checked for radiated EMI above, bus below

instrument comes with written instructions for use in a powerplant and can be used without formal onsite training.

The Model 246A has been in use since about 2000. Widespread application has been limited primarily because its availability and capability were not promoted. With this instrument, sources of EMI are identified simply by scanning equipment on a plant walk-around and observing the output of the device (Fig 6). A typical generator or bus can be scanned in a few minutes (Fig 7).

Historical experience suggests that roughly 90% of typical equipment failure modes emit detectable radiation EM energy, thus accounting for the high potential value of the test.

By observing the location and magnitude of detected signals it is possible to make valid judgments relative to the nature of suspected deterioration. Based on this information, necessary inspection and additional tests can be planned to reduce the likelihood of further damage and/or forced outage on specific equipment.

8. Black oxide residue indicates joint sparking at multiple single-bolt locations. Arrow indicates where most severe sparking occurred

If signals of concern are identified, trending of signal magnitude over time can be helpful in assessing equipment condition.

Despite its limited use, the Model 246A and its predecessors have found many dozens of actual defects ranging from minor to serious (sidebar). A particularly instructive and important case involved the large generator that suffered the damage in Fig 4. After this generator was repaired, it was decided to use the Model 246A instrument to survey the repaired generator and an identical sister unit.

While the survey of the repaired unit did not detect any winding or connection problems, the survey of the sister machine identified minor EMI activity in the connection area (the location of the sister unit's failure). It was decided to monitor this area until the next scheduled outage one year later. A scan a few months before the scheduled outage showed continued minor sparking related to the endwinding or phase leads. Note: There was no difficulty obtaining the EMI signals through the imperfect Faraday Cage of the generator terminal box.

When the generator was removed from service, engineers found the bolted flexible joints from connection ring to neutral had started to loosen and were sparking. Flexible connectors for one joint are shown in Fig 8. The engineers believed this generator was well on its way to a catastrophic failure like the one suffered by its sister unit.

Wrap-up. Radiated radio-frequency EMI energy from defective electrical joints can be detected and the source localized with the use of a readily available instrument. Corrective actions then can be taken well before a failure occurs. The dollars returned for scans of radiated EMI are orders of magnitude more than the cost of the tests. CCJ

The authors

Clyde Maughan (left photo), closing in on 70 years of professional service to the electric power industry, can be reached at clyde@maughan.com. Jim Timperley, whose resume includes decades of service to a major electric utility, can be contacted at james.timperley@ctplc.com.

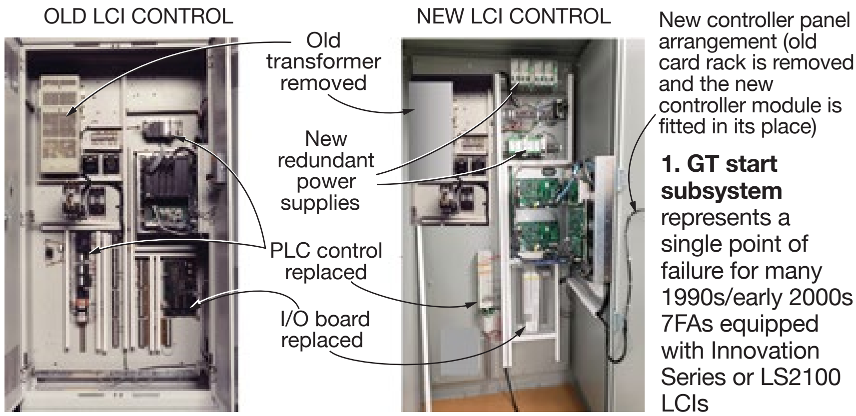
How to mitigate risks associated with LCI starting systems

It's no secret that many gas turbines are starting and stopping far more frequently than originally designed for. At the same time, independent system operators (ISOs) are imposing stiff fines for failure to meet startup and performance obligations.

Most plants have adapted to these more aggressive operating tempos and performance challenges, but one component that may be getting overlooked is the starting subsystem, especially for older machines equipped with a load commutated inverter (LCI).

According to John Downing, Turbine Control & Excitation Group (TC&E), the Innovation Series™ and LS2100 LCIs, introduced in the late 1990s and early 2000s, consist of three subsystems, or functions: control section, silicon-controlled-rectifier (SCR) bridge section, and cooling section. For units not originally designed for lots of starts, it was common to have one LCI for multiple GTs, often in a one-to-two ratio.

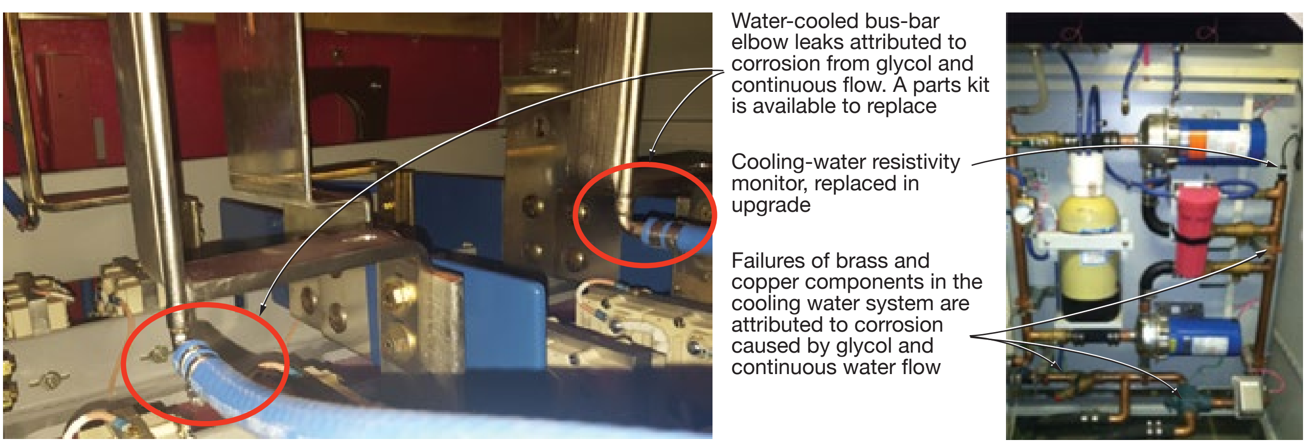
For nearly 25 years, the LCI has provided reliable service. However, with an expected life of 20 years, many have failed, and a substantial number are at, or past, end of life (Fig 1). Failures usually are experienced in the controls and/or the cooling system (Fig 2).



1. GT start subsystem represents a single point of failure for many 1990s/early 2000s 7FAs equipped with Innovation Series or LS2100 LCIs

Legacy CI control	LCI control upgrade
Older printed circuit backplane: ■ Obsolete circuit boards ■ Limited I/O capability	**Upgraded components:** ■ New hinge-mounted control circuit-board assembly to replace Innovation Series circuit-board rack ■ New I/O modules, gating/feedback boards ■ Interface boards to original SCR gating system ■ New power supplies
Hardware-dependent control: ■ Limited sequencer ■ Fixed block-diagram regulator ■ Terminal emulator ■ Repeated voltage feedback offset nulling	**Control software library:** ■ Flexible sequencing logic ■ Windows® based ■ Animated graphic displays ■ Integrated trending window ■ Immune to voltage feedback offsets
Old and unsupported PLC hardware and software	**New compact PLC**
Old control power transformer	**New redundant power supply**

3. A "digital front end" solution may be significantly less expensive than the complete replacement often suggested by the OEM



2. Cooling apparatus and the controls are the primary sources of failure

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Downing told the editors that in 2017 TC&E responded to 17 forced outages attributed to LCI failures, between Memorial Day and Labor Day, that averaged 36 hours each. The costs associated with lost revenues and penalties for non-performance typically dwarf the costs of replacing or upgrading the LCIs to eliminate this particular source of failure.

Last production of the Innovation Series and LS2100 LCI controls supplied with GE machines was in 2013. Today, replacement parts are difficult to locate; acquisition times of four to six weeks are common. Also, qualified service and field engineering personnel are becoming harder to find as they retire out of the workforce.

Mitigating the risk. Options to address this risk include the following:

- Complete replacement of the LCI.
- Locate, purchase, and inventory critical spare parts, especially those relating to the control and cooling sections, and identify the engineers and technicians qualified to make the replacements when the time comes.
- Install a "digital front end" (DFE) control section replacement (Fig 3). In this case, the controls are replaced with a modern alternative that extends LCI life by 20 years.

TC&E has partnered with TMEIC, one of the world's largest manufacturers of LCIs and drives, to provide a turnkey DFE solution that Downing said is far less expensive than the other two options. TC&E/TMEIC also can offer the complete replacement, or additional LCI system, for GE 7FAs and 9FAs. The partnership has more than 15 LCI-experienced field engineers at its disposal.

Guts of the partnership's offering are as follows: The obsolete programmable logic controller (PLC), standard VME (Versa Module Europa) rack, power supplies, and input/output (I/O) boards are replaced with new processor-based control circuit cards and a new PLC. The new digital controls fit in the existing panels and reuse most of the existing fiber optic cables and connectors.

The upgrade includes a local color touch-screen control panel and HMI interface.

In the control center, the associated software suite expands the programming, control, optimization, troubleshooting, and data logging of onsite operations, engineering, and maintenance personnel. The new LCI DFE utilizes appropriate communications protocol to talk directly to the GE Mark VI and Mark VIe control systems.

The typical upgrade project can be accomplished in five to seven shifts; a turbine shutdown is not necessarily required, although, of course, the LCI will be unavailable for that period.

Users react. The degree to which the starting system is a financial risk may depend on the type of owner/operator organization, age of the plant, and other factors. Experienced GT engineers and plant managers contacted about this issue responded that the risk is minimal as long as plant staff is diligent about regular inspection and maintenance, especially of the cooling system components. Older machines from the GT boom period (1997-2003), many of which were designed for baseload service but rarely, if ever, ran that way may be among the highest-risk assets.

All of the users contacted were not aware of an abnormal spike in GT starting-system failures, nor had they experienced failures rates at their facilities out of the ordinary.

According to one, LCI is a general term for one way to implement a medium-voltage variable-speed drive (VSD), variable-frequency drive (VFD), pulse-width-modulated drive (PWM), or static frequency converter (SFC). In other words, LCI, popular in the 1990s and early 2000s, is a very specific circuit and thyristor bridge arrangement that is different from other types of drives.

According to this source, they are less-expensive drives that have trade-offs—such as harmonics reflected back on the power system—requiring additional isolation transformers, and often can have lower power factors and efficiency.

When an issue arises, the OEM usually recommends upgrading the starting system to LS2100E, which Downing says is similar to the DFE solution offered by TMEIC.

Another user and seasoned GE gas-turbine controls expert adamantly stated that the LCI is very reliable, and "as long as you perform recommended maintenance and TILs (Technical Information Letter), it's like a forgotten part of the plant."

Nevertheless, many facilities are owned by financial engineering firms which are fond of cutting every penny of "unnecessary expense," and sometimes cut too much fat and into the bone. As one user noted, this is very specialized and complicated equipment and very few people have spent much time with their heads in these cabinets.

If this sounds like your site, you might want to take appropriate action, especially since it does represent a single point of failure, regardless of how reliable the original components are. CCJ

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Transformer armor helps ensure high availability

You don't hear much at industry meetings these days about physical security of power generation and delivery infrastructure and personnel. Cybersecurity topics get most of the attention. But that doesn't mean work on physical security solutions has stopped. Certainly not.

One recent development concerns transformer protection. Six years ago (Apr 16, 2013), you may recall, an electric substation in California was attacked by snipers with at least one high-powered rifle. Within 20 minutes, they knocked out 17 transformers and shut down the facility for nearly a month. The incident at Metcalf substation, although well publicized, was not an isolated one. But at least some experts believe this was a *planned* attack and of greater concern than incidents that had been reported previously.

Concerned about network safety and reliability, Siemens has taken significant steps to develop and test new materials and designs that enable its transformers to withstand ballistic attacks. Its early work indicated that the 0.375-in. steel sheet typically used for transformer oil tanks, could be penetrated easily by a UL752 Level 8 bullet, such as the 7.62-mm copper-jacketed (lead core) projectile.

So the company set about developing a material capable of deflecting a UL 752 Level 10 bullet, the highest class of rifle projectile (.50 caliber) addressed by the UL standard. Steel is preferred as a protective barrier because of its high strength and hardness, plus high ductility, formability, and durability.

Siemens' bullet-resistant panels for new and retrofit applications are supported on brackets that attach directly to the transformer foundation or to the oil tank and protect the tank, cooling equipment, conservator, turrets, and the bottoms of bushings—all while allowing air movement for efficient cooling. Neoprene strips isolate the panels from the support structure to minimize the transmission of vibration.

The transformer protection system, developed by Siemens' European R&D group after the Metcalf attack, is manufactured in offshore factories. Three systems have been retrofitted to date, one on a 230-kV transformer east of the Mississippi. Two more systems were supplied with new transformers. Customers were not available for comment because information on installations is on a "need-to-know" basis.

Siemens reported having several customer inquiries, both in the US and elsewhere, with a focus on their most critical transformers—all rated 100 MVA and above. The editors are not aware of any grid operator currently mandating the installation of a protection system such as that offered by Siemens.

Potential customers believe that the transformer components of greatest concern in a ballistic attack would be the main oil tank and radiators, with the bushings on top of the unit as attractive secondary targets. The suggestion is to switch to a different bushing material—a high-strength polymer. Bushings are considered "less critical components" because you can keep replacements in storage.

1. Doors provide access to control cabinets, pumps, fans, and other components requiring regular inspection and maintenance

If you're considering the retrofit of a bullet-resistant protection system for your transformer, the following timeline may assist in planning:

- First step is a site survey to review the condition, location, etc, of the transformer and its foundation. Only a few days are required for this effort once the survey crew is onsite. At this stage of the project it's important to decide where access doors will be required in the panels to allow, for example, maintenance of cooling fans (Fig 1).

  Expect the weight of the protective panels to run 50 tons. By comparison, a typical large transformer will tip the scales at 200 tons (350 tons with oil), which means some foundation work might be needed. In most cases it is possible to install a new pad to support only the panels.
- Second step is to provide applicable drawings and other materials required by the engineers in Europe who do the requisite analyses and engineering work. Figure this phase of the project to take a couple of weeks.
- Third step includes manufacturing offshore and shipping to the plant site. This likely will take several weeks.
- Last step, installation, will take a week or less (Fig 2). CCJ

2. Panels comprising the protection system are removed for major maintenance

Acoustic leak detection benefits boiler owners, but not all systems are HRSG-qualified

Independent users groups serving owner/operators at cogeneration and simple- and combined-cycle plants powered by gas turbines are an invaluable resource for station personnel. Almost all have online forums available 24/7/365 to help answer technical questions quickly and get you moving in the right direction with possible solutions. Most colleagues offering their unbiased assistance have deep O&M experience and understand your challenges; plus, there's no charge for their help.

Power Users (www.powerusers.org), the umbrella organization providing administrative support for the 7F, Combined Cycle, Generator, Steam Turbine, and Power Plant Controls Users Groups operates online forums for each of those organizations. Plus it collaborates with the *HRSG Forum with Bob Anderson* (www.hrsgforum.com) on an online discussion forum focused on heat-recovery steam generators. Anderson is the discussion moderator. Register today to participate at www.powerusers.org.

Recently, a user asked for advice through the forum on an acoustic leak detection system described in a brochure. Just so happens that Anderson has first-hand experience with instrumentation for detecting boiler leaks. By way of background, he managed both conventional steam and combined-cycle plants for Florida Power Corp, was manager of combined-cycle services for Progress Energy, and is recognized worldwide as an authority on boiler and HRSG design and O&M.

Anderson responded thusly, "Week before last I was in England and met with a company that sells a monitoring system like the one described in the brochure you forwarded. They have many systems on conventional boilers, but have never attempted to install one on an HRSG. The brochure you provided references HRSGs at the top, but all of the photos and information relates to conventional boilers. What specifically has this company done on HRSGs?

"I think online leak detection is an important tool for HRSG operators. But I'd be wary of buying a system today from anyone unless they can demonstrate a successful track record in multiple HRSG applications."

Anderson then dug into the history of boiler leak detection to provide valuable perspective and to suggest a direction for the user to pursue. He said acoustic online monitoring for leaks in conventional boilers has been used successfully since the mid-1980s. It was first developed to monitor P11 superheater headers for early signs of leakage associated with ligament cracking, users having discovered that the creep life of these headers was not meeting expectations.

Installation of a leak detection system, he continued, permitted a boiler with known ligament cracking to continue operating. When such damage was first discovered, it was not known how long ligament cracks that joined up, and/or went through-wall, would leak before breaking. Once fracture-mechanics techniques were improved and it was determined that ligament cracks were unlikely to fail catastrophically, leak detection systems became optional.

While several vendors made leak detection systems for conventional boilers, no one attempted to deploy one on an HRSG until a few years ago. These systems depend on filtering out all background noise except for the sound of the leak. Since the HRSG gas path is much noisier than that in a conventional boiler, no vendor attempted to spend the development money to see if their system could be made to work on an HRSG.

A few years ago, Anderson went on, EPRI contracted a company called Triple 5 to develop a leak detection system for HRSGs—and it worked (CCJ 2Q/2013, p 52). This system is now commercially available to anyone. Triple 5 was bought out by Mistras Group Inc a few years ago, but it still sells and monitors these systems. About two-dozen of the Triple 5 acoustic monitors have been installed on HRSGs to date (CCJ 4Q/2017 (No. 55), p 90).

The Mistras (Triple 5) system uses wave guides (rods) clamped to header/pipes and welded to casing. Hardwired accelerometers are attached to the wave guides. The monitoring system is remotely monitored by Triple 5 which notifies the plant when/if leaks occur. Very small leaks are detectable.

As the leak grows it is often possible to determine how many starts/stops remain before the leak goes critical. This is of great use in getting the unit to a less expensive time to repair the leak.

Interestingly, Nick Grigas of Triple 5 will be presenting on acoustic leak detection at the upcoming *HRSG Forum with Bob Anderson,* in the Hilton Orlando, July 22-25. Recent developments he will discuss include deployment of a wireless (Hart) system to facilitate installation. CCJ

Coating critical steam-valve parts with chrome carbide avoids stellite delamination issue

Stellite liberation from large valves installed in main and hot reheat (HRH) steam systems serving F-class combined cycles, considered a major industry problem 10 years ago, has been eliminated by substituting chrome carbide as the hard-facing material for critical valve parts.

The editors first learned of stellite delamination at the 2009 7F Users Group Conference (www.7fusers.org) where the liberated material from a 20-in. HRH block valve was displayed. The industry had been made aware of stellite liberation by GE, which issued Technical Information Letter 1626 about three months ahead of the 7F meeting. It advised steam-turbine owners to check the condition of the stellite inlay sections used in fabricating seats for the OEM's combined stop and control valves.

Revision 1 of that TIL, published at the end of 2010, recommended a "one-time seat stellite inlay UT inspection during valve installation or the next planned maintenance inspection"—this to identify any lack of bonding between the inlay and base metal on units with fewer than 50 starts.

Disbonding of stellite associated with combined-cycle plants has occurred primarily in parallel-slide gate valves and non-return globe

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valves. Hardfacing has been liberated from valve seats, guide rails, and discs. Tight shutoff of valves has been compromised in some cases.

Many incidents of stellite liberation were reported. To illustrate: CFM/VR-TESCO LLC (formerly Continental Field Machining), a leading valve services company said that in 2011 and 2012 it repaired 50 valves manufactured from F91 (forged body) or C12A (cast body) and ranging in size from 12 to 24 in. More than half of these jobs involved stellite liberation.

These repair projects were split roughly 50/50 between valves within the Code (ASME Boiler & Pressure Vessel Code) boundary and those that were part of the boiler external piping. Repairs on the former were performed according to guidelines presented in Section I of the Code and in the National Board Inspection Code; those outside the Code boundary were performed according to ASME B31.1.

There hasn't been much discussion on stellite disbonding the last few years—at least at meetings attended by the editors, which include the Combined Cycle Users Group (www.ccusers.org), Steam Turbine Users Group (www.stusers.org), and HRSG Forum with Bob Anderson (www.HRSGforum.com).

However, mention was made by one owner/operator regarding the successful use of ValvTechnologies Inc's (VTI) IsoTech® parallel-slide gate valves on his company's HRSGs in eliminating the need for stellite. According to the manufacturer, critical parts for its severe-service valves, used where steam temperatures exceed 1000F, are provided with its RiTech® 31 coating.

This chrome carbide refractory coating is much harder than Stellite 6 (68-72 RC versus 34-38 RC). It is applied in state-of-the-art HVOF (high-velocity oxygen fuel) spray booths using a proprietary compressive spray technique to achieve high bond strength. Applications extend up to ASME/ANSI Class 4500 at 1800F for valves up to 36 in.

The chrome carbide hard-coated web guide ensures the discs are kept parallel through the entire valve stroke. As the valve is cycled under differential pressure, the hard surfaces reportedly burnish and polish each other, avoiding the scratching and galling cited by some others.

The user sharing his experience with the ValvTechnologies product said VTI parallel slide gate valves have been operating on four or five of his company's HRSGs for three years or so and the only hiccup was a stem-packing leak on one valve which was quickly corrected.

This testifies to the vendor's claim that RiTech 31 hard-coating technology is impervious to the effects of high-temperature cycling typically experienced today in combined-cycle main-steam isolation and HRH applications. The company guarantees coating integrity for 10 years or 10,000 cycles—whichever comes first.

Finally, the user mentioned that a representative of the manufacturer annually visits each plant where VTI valves are installed to verify that they continue to meet expectations. CCJ

Keep your plant competitive: Obsolete legacy systems

Generation assets in competitive markets must perform at a high level year in and year out to meet their contractual obligations. Failure to embrace a philosophy of "continual improvement" in plant operations means it's only a matter of time before the competition will eat your lunch. The focal point of continual-improvement efforts typically is the gas turbine in the industry segment served by CCJ. It's certainly a priority, but failure to pay close attention to support systems and equipment can cause problems you're not prepared for and don't want.

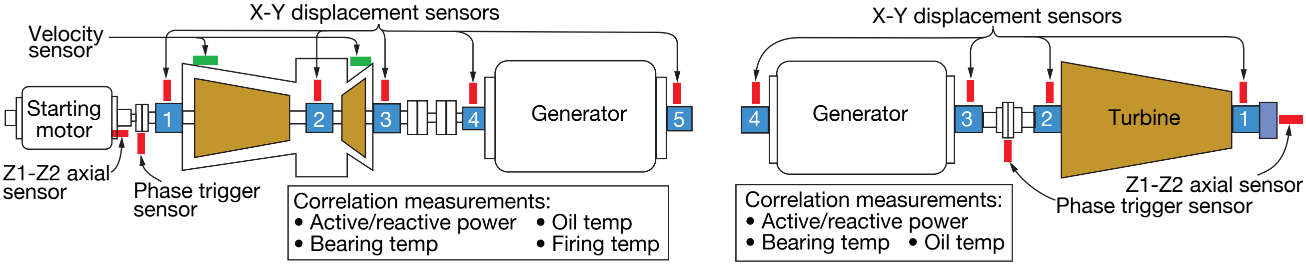
As plants get beyond 15 years of age, things that you took for granted begin reminding you of their presence. An analogy might be your home refrigerator, TV, washing machine, and/or hot-water heater. Problems with support systems and equipment will keep you up at night because there generally are no easy answers.

What you hear more and more at user-group meetings is that the plant person who knew all about the system of current concern has retired, or the manufacturer no longer makes the model you have (or, worse, has gone out of business), or you can't find spare parts, etc. It's important to conduct system reviews every couple of years, at least, and budget for upgrades and replacements before your plant's balance sheet suffers.

What follows is a case history on the replacement of an obsolete vibration monitoring system which illustrates how quickly advancements in I&C technology, monitoring, and diagnostics can impact your plant's risk profile. A similar article concerning LCI starting systems for gas turbines appears elsewhere in this issue.

The original machine protection system (MPS) for Ferndale Generating Station's gas and steam turbine/generators became obsolete in 2014, the year the plant turned 20 years old (Fig 1). The legacy supplier no longer supported the MPS and owner Puget Sound Energy (PSE) planned to replace it and implement a cost-effective machine condition-monitoring strategy (Fig 2). This strategy involved correlating other process data—including bearing temperature, oil temperature, and active/reactive power—with vibra-

1. Puget Sound Energy Inc's Ferndale Generating Station, a 270-MW, 2 × 1 combined cycle powered by dual-fuel 7EA gas turbines, is operated by NAES Corp. The Ferndale (Wash) plant was built by a Tenaska Inc affiliate, commissioned in 1994, and sold to PSE in 2012



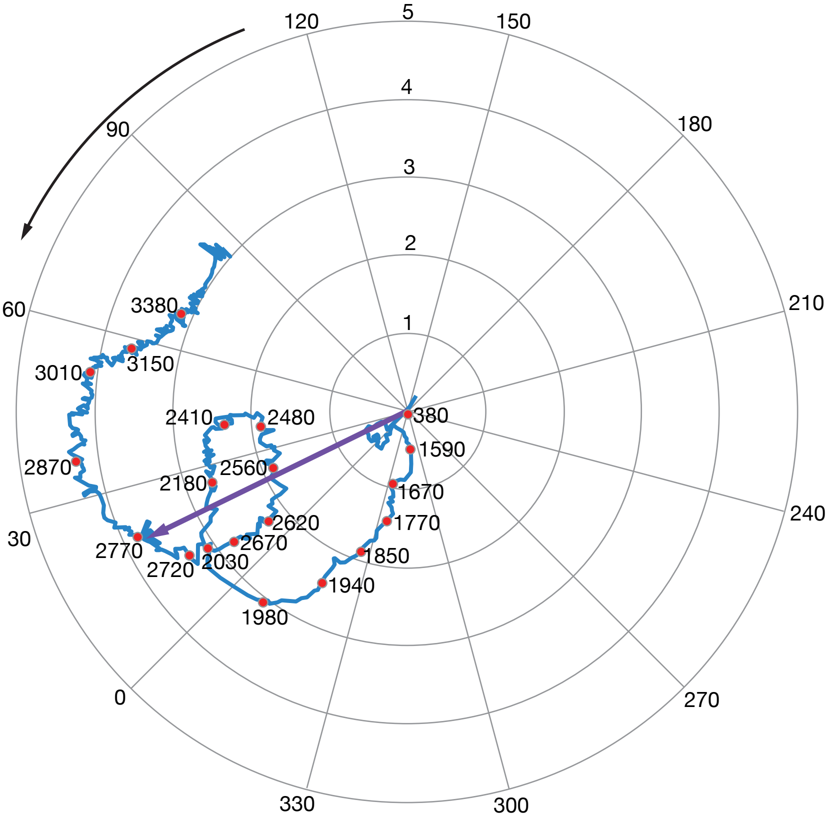
2. Machine condition monitoring strategy for Ferndale's 7EAs is at left; at right for the GE non-reheat, controlled-extraction condensing steam turbine

tion signals to increase the reliability of the diagnostics.

The original MPS did not have online condition-monitoring capability, and ad-hoc diagnostic services were performed on the generating units through the legacy MPS supplier. A specialist traveled to Ferndale with a portable data analyzer to diagnose machine vibration whenever in-depth analysis was required.

Onsite visits, plus follow-on processing of event data, are costly and time-consuming. Installing a new condition-monitoring system from the legacy MPS supplier, currently owned by the gas-turbine OEM, would have been expensive and required maintenance and IT infrastructure. Limited IT infrastructure resources and no onsite machinery diagnostic expertise at Ferndale encouraged PSE to consider other alternatives.

The utility needed a proven and reliable MPS and online condition monitoring capability with no changes to the existing DCS interface. PSE also chose to replace existing transducers with upgraded ones while retaining the original transducer mountings, reuse the field wiring, and fit the new MPS in the same panel cutout as the legacy system.



3. An imbalance was detected on Bearing 3 of one gas turbine shortly after the new machine condition monitoring system was installed. The polar plot shows a high-vibration response (over 4 mils, 100 μm) attributed to an imbalance on Bearing 3 at the second critical speed during a coast down

PSE investigated the market for machine condition-monitoring systems that provided the desired capabilities yet were cost effective to replace its legacy MPS. One particularly-relevant solution investigated was Brüel & Kjær Vibro's VC-8000 Setpoint MPS/Condition Monitoring Software (CMS). It offered modern protection and reliable advanced condition-monitoring capabilities without the need for a dedicated CMS server.

The CMS is based on the OSIsoft PI data historian used at Ferndale. VC-8000 eliminated the need for separate, special vibration databases. PI's user interface visualizes all vibration data including current values, alarm status, and trends.

Specialized measurements and plots (for example, time waveforms, orbits, shaft centerline, waterfall, cascade spectrum, etc) are provided via the CMS's visualization tools that augment PI's native visualization capabilities. Other third-party products and services—such as statistical data analysis, automatic decision support, and thermodynamic performance monitoring of the generating units—can be integrated as well.

Another benefit of the VC-8000 MPS is its capability to continuously back up data on the local Secure Digital (SD) card. If PSE's network went down, no data would be lost. Data can be manually retrieved, used, and retroactively stored in PI. Monitored data can be remotely uploaded by File Transfer Protocol (FTP) or emailed to an analyst at any time without a remote connection to the database—benefitting the utility with the capability to quickly make decisions, remove firewall navigation efforts, and reduce costly site visits.

The SD function proved immediately useful. The PI connection to the MPS was delayed, but no data were lost because of the connectivity interruption.

PSE benefits from correlating process and vibration data—improving the reliability of fault analysis and improving root-cause analysis (RCA) results. Coincidentally, the first diagnostic evaluation performed using VC-8000 occurred during a training session when a machine fault was suddenly detected: An imbalance occurred on Bearing 3 of one gas turbine. Personnel were notified of the issue immediately, enabling an expeditious assessment (Fig 3).

The bottom line: The VC-8000 provided comprehensive condition-monitoring capabilities at a lower cost than what would be achieved by upgrading the system using the legacy MPS supplier. CCJ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Overhaul, upgrade legacy fog systems to maximize performance

Turning a profit in the business of electric generation can be challenging given the competitive nature of the industry today. Be prepared to take advantage of revenue opportunities, which can surface quickly, by upgrading equipment capable of improving your balance sheet tomorrow.

A case in point concerns fogging systems. Those responsible for gas turbines know they can squeeze more power from their engines on hot days by injecting a fine water mist (a/k/a fog) into the inlet air ahead of the compressor. Market and ambient conditions dictate when operating the fog system makes economic sense.

Some plants stopped fogging years ago, but increased use of capacity payments has them interested in getting their systems running again. In areas where coal plants have been shuttered there may be a need for more gas-turbine output when intermittent renewables can't meet demand. Fogging can help fill in that gap. There are other opportunities as well. The positive outcome of a simple cost/benefit analysis may be all the justification needed to move forward.

What to do? The editors met with Mee Industries Inc's (www.meefog.com) CEO Thomas Mee and his brother John, the company's marketing manager, at the vendor fair during the 501F Users Group (www.501fusers.org) meeting in Scottsdale, Ariz, Feb 17-22, 2019, to discuss upgrade options for fog systems. Mee is an industry leader, having installed more than 1000 fog systems in the last 25 years.

The discussion began with pumps. Ceramic-plunger pumps often were specified for the early fog systems, with many installed during the "bubble" when about 200,000 MW of gas turbines were commissioned at simple- and combined-cycle plants. These pumps suffered from premature seal failure because the demineralized water used for fogging is a poor lubricant. The legacy pumps can be replaced with newer seal-flushed pumps, which can operate up to 6000 hours between seal changes. Mee has upgraded many fog pumps to seal-flushed pumps over the past several years.

Water-lubricated pumps, another upgrade option, can run up to 8000 hours between rebuilds and eliminate the need to change pump crankcase oil every few thousand hours.

The left-hand photo shows a typical skid with four legacy ceramic-plunger pumps which were replaced by the two water-lubricated Danfoss pumps at the right. The new arrangement is designed to easily remove a pump at its 8000-hr maintenance interval and install a spare (often a rebuilt pump), allowing for a shop rebuild by experts to reduce in-plant maintenance requirements. Mee has converted skids serving three dozen engines to Danfoss pumps.

Other suggestions offered for improving fog-system performance include the following:

High-pressure filters. Seal wear introduces small particles into the pump's high-pressure discharge pipe and they can cause fog-nozzle plugging. Filters installed downstream of the pump can prevent plugging.

Inspect fog nozzles annually to ensure proper operation, recondition as necessary. Replace nozzles beyond repair. Some plants keep a spare set of nozzles so they can be changed out quickly during a short outage and the used set returned for reconditioning.

Replace old rubber hoses with ones of high-quality incorporating braded stainless steel to assure years of maintenance-free operation.

Reweld old joints. Many legacy fog systems have nozzle adapters soldered or brazed onto the stainless-steel fog lines. Wear and tear over the years has caused some marginal joints to fail. Nozzle lines can be replaced with new lines having TIG-welded nozzle-adapter joints that will last indefinitely.

Control systems. Early fog systems may have PLCs that are no longer supported by the manufacturer, which makes reprogramming them virtually impossible. If programming is lost, the only option is to install a new PLC. A MeeFog replacement PLC, complete with the latest programming, can be installed in a few days.

Wide-range fogging. Early fog systems were designed to operate only when the gas turbine was at or above baseload. This was problematic for gas turbines often operating at less than baseload: When the engine ramps up to baseload, fogging starts and GT output spikes. New control software can allow for below-baseload operation of the fog system, without over-spraying water when the machine airflow is reduced.

Inlet-duct drains should be capable of removing any flowing or pooling water from the duct so un-atomized water is not sucked into the compressor. Some early installations did not have properly designed drain systems; these should be corrected to prevent airfoil damage. Consider installing windows and cameras to allow visual inspection of the fog-nozzle manifold and conditions at the compressor inlet; they can provide advance warning of problems you don't want.

Location, location, location. It's important that the fog-nozzle grid be designed to distribute its atomized product across the entire air stream. If nozzles are not properly located, some areas in the air stream may have more fog than can be evaporated, other areas may have little to no fog. This can result in poor cooling performance, excess water accumulation on duct surfaces, and temperature differences across the compressor inlet. For example, nozzle lines that have nozzles spaced close together, but have large gaps between nozzle lines, can result in poor fog system performance.

Maximum output. Wet compression is the process of spraying more water into the inlet duct than can evaporate before the saturated air enters the gas turbine. The additional fog is carried into the compressor where it evaporates and provides an intercooling effect, thereby reducing the work done by the machine and increasing power production.

Thomas Mee said the company has installed many wet compression systems on turbines ranging from aeros to the latest F-class units, with fog flow rates as much as 2.5% of engine air mass flow. Injecting 1% of the air mass flow as wet compression can boost power output by 5% or more depending on the GT model. CCJ

Legacy fog system skid with ceramic-plunger pumps is at left, upgrade to water-lubricated Danfoss pumps is at right

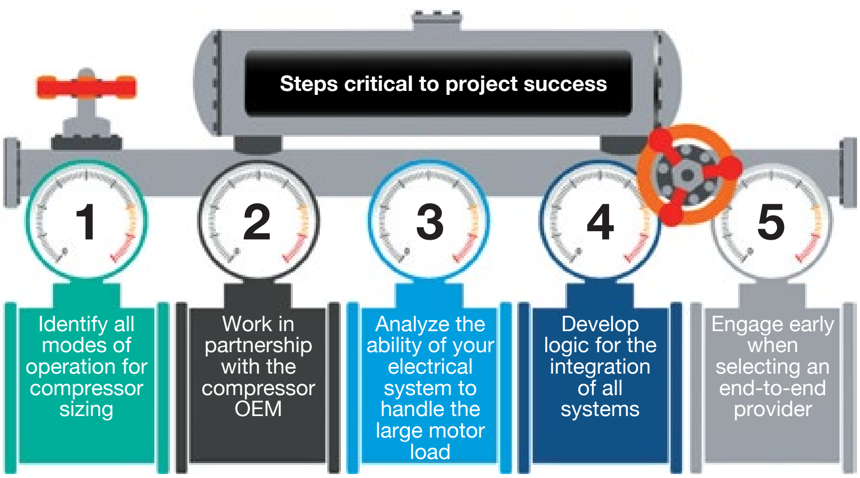
Pitfalls to avoid when adding a fuel-gas compression system to an operating plant

With the power-generation sector shifting its fuel mix to an increased dependence on natural gas, the decreased downstream volume and unreliable gas pressure can wreak havoc on legacy power production facilities. It can be challenging for an ageing plant to remain a relevant, competitive, and reliable resource.

"If your gas supply system operates at a borderline pressure, investing in a new compression system will improve performance, reduce risk, and provide peace of mind," Vincent Segale, a project engineering manager for SNC-Lavalin Constructors Inc, told the editors in a telephone interview. The successful integration of a new compression system into an existing plant is critical to maintaining—likely improving—the reliability and availability of that facility.

However, the original design probably didn't account for this addition. Developing and managing a project of this nature requires resources and expertise that facilities may not be able to support internally. Segale should know. He has two decades of experience in powerplant design and detail engineering, much of that time spent on large combined cycles.

Segale's involvement in fuel-gas compression systems typically extends from the proposal stage through commissioning and final testing. Based on his experience, which includes projects with reciprocating, centrifugal, and oil-injected screw compressors for both aero and frame gas turbines, there are five things critical to success that you should be aware of when preparing to add a fuel-gas compression system to an operating plant (diagram).



They are the following:

1. Identify all modes of plant operation to assure proper compressor sizing. Define the envelope of operation, including startup, turbine partial load, baseload, and turbine trip. Provide appropriate margins to safeguard that the compression system will support the plant for its envisioned lifecycle. Additional compressor sizing considerations related to pressure and flow capacity should be considered if gas-turbine upgrades, such as a gas path or flexibility improvements, could be in your future.

2. When researching the equipment, make sure your commercial agreement with the compressor original equipment manufacturer (OEM) works in partnership with you. If you have custom long-lead equipment, keep your OEM to the schedule. This is not a commodity purchase, so incorporating a proper milestone payment schedule and liquidated damages allows for the complete attention of the OEM with proper placement on its priority list.

   Operating facilities have limited windows available during spring and fall outages when upgrade projects can be commissioned and proven out prior to returning to normal dispatch modes. If you're not used to negotiating big commercial contracts, rely on your experienced end-to-end solutions provider to help you navigate relationships with suppliers and follow the nuances of the commercial terms and conditions to confirm delivery of technical information and equipment to support the schedule.

3. Analyze your existing in-plant electrical system for available capacity, short-circuit, arc flash, and voltage drop to accommodate the large compressor motor load. It has been known to stress existing systems. Many facilities may not have spare capacity in their medium-voltage motor control centers, necessitating a creative solution to accommodate the new load. Again, your end-to-end provider can help you analyze the situation and collaborate with you on solutions to add capacity and keep costs down.

4. Collaboratively develop controls descriptions and integrate logic for the new system with all key components. Be sure to consider integration of the gas-turbine OEM's control requirements, balance of plant, DCS plant interface and communication, and compressor OEM's standard PLC into a master control-logic description. Your end-to-end service provider has experience in system integration and can help you address all of the above early in project development to avoid a logistics nightmare during equipment commissioning.

5. Engage early: Select an end-to-end solutions provider that can provide the necessary support with engineering, construction management, and in-house commissioning expertise. This will ensure a fully integrated solution is delivered to support project goals and requirements. While reaching out to smaller, local consultants may be tempting, they often lack the specific powerplant experience and cradle-to-grave expertise. A fully integrated service provider can help eliminate potential gaps between design and construction, and commissioning.

Wrapping up the interview, Segale stressed that a significant plant upgrade, such as the addition of a fuel-gas compression system, requires in-depth knowledge of power generation facilities, structured execution methods, and careful coordination with plant operations for smooth integration into the existing facility infrastructure. "Through careful planning and investigation, understanding of equipment limitations, and finding the right engineering partner," he said, "you'll be prepared to make the case for successful system integration saving on rework, cost, and schedule." CCJ

PLANT SOLUTIONS IN BRIEF

HRSG inspection tips

It's important to have a comprehensive checklist of what to inspect on your HRSG, and how, before conducting a condition assessment of your equipment for plant management and/or due diligence purposes. Your checklist may have scores of items to review but it's impossible to identify everything to look at—usually because your depth of knowledge and experience is lacking in one or more areas for a particular boiler design.

Bob Anderson was in the middle of noting "hot topics" for the open discussion sessions at the upcoming *HRSG Forum with Bob Anderson* at the Hilton Orlando, July 22-25, when the editors called the other day. We asked him to identify a couple of things he believes plant personnel might forget to check during a walk-down.

Ensuring proper lubrication of sliding feet found under the column supports on the hot end of some HRSGs was the first thing he mentioned. He explained that it's important for these plates to move freely as the boiler expands and contracts during startup and shutdown to avoid stressing structural steel unnecessarily. Another tip Anderson offered was to check that the washers under the hold-down nuts are free to rotate. He sometimes finds the nuts tight, as they should be for non-moving columns, thereby preventing sliding.

Another simple check that owners often forget, Anderson continued, is the proper routing of the discharge pipe from the atmospheric vent at the top of a Consolidated safety valve body and/or the proper routing of the drain at the bottom of the valve. It's important that the vent not point at the walkway, to protect personnel; also, that it not point upward, allowing the collection of rainwater. Important, too, is that the vent and the drain not be tied together, as that would affect the valve's blowdown setting. Finally, be sure the shipping plug has been removed from the vent hole. CCJ

Sometimes it takes a good turbine mechanic to solve a generator problem

Paul Tucker called CCJ's editorial offices a few weeks back with a *generator* experience to share with users. Say Whaaat? Tucker is well known to engineers and technicians at power and process plants for his ability to identify the root causes of *turbine* problems.

There isn't much he hasn't experienced in his 50 or so years of manufacturing, inspecting, repairing, and upgrading rotors for both steam and gas turbines. A frequent speaker at user-group meetings, Tucker is generous in sharing his extensive knowledge.

This case history is about the planned maintenance outage of a steam-turbine/generator at a paper mill. The work scope included a generator rewind at a third-party shop. "Not surprising," said Tucker, "seems like generator rotors need rewinding all over the map these days." The Houston-based consultant suggested to the owner that one of his companies, FIRST Consulting, follow the rotor through the shop to witness various things like balance, runouts, etc—which are basically the same for any rotor, turbine or generator.

Not necessary, he was told. The plant "trusted" the vendor's work and declined the offer. Shop work complete, the field was returned to the plant and installed in the generator (Fig 1). All seemed well, until a month later when vibration spiked on the Nos. 4 and 5 bearings to more than 0.8 in./sec or about 7.8 mils. The unit wouldn't run and Tucker was called to assist in finding the root cause of the vibration-induced emergency outage.

Lesson learned No. 1: *TRUST your valued partner (the shop in this case), BUT VERIFY! Audits of procedures and personnel are recommended before any shop work is conducted given the generally high level of turnover in the power industry today. You want to know who is working on your project and what their qualifications are.*

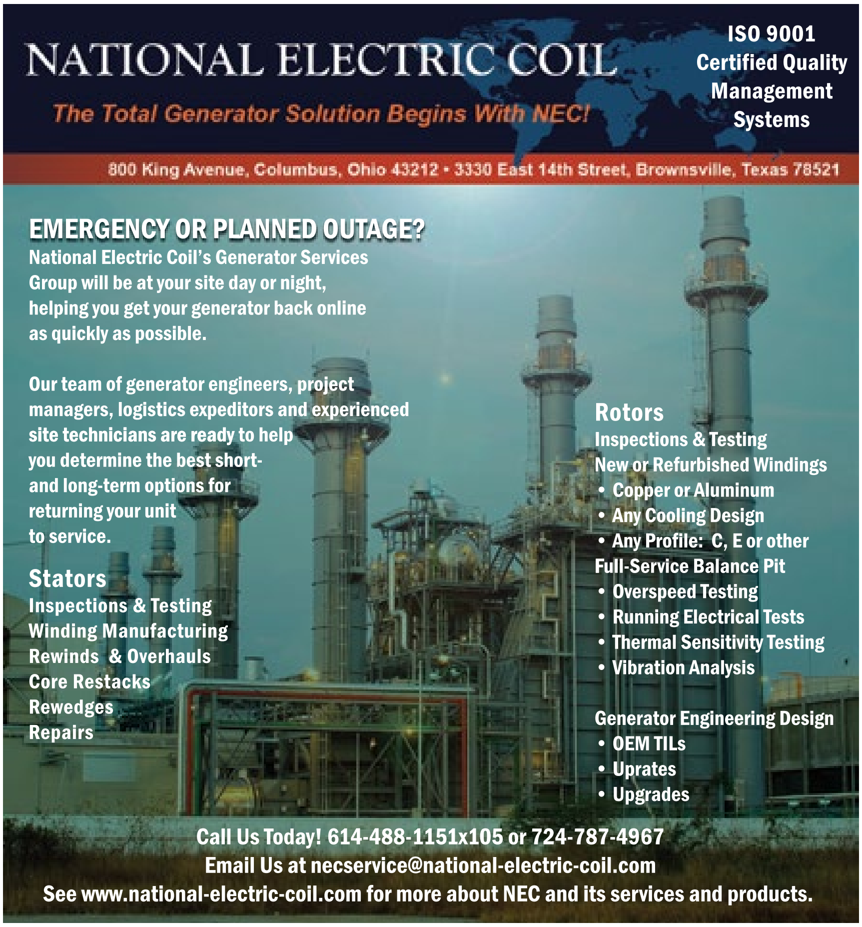
After over 40 days of downtime for fact-finding, investigation of everything imaginable, checking and re-

1. Generator rotor (field) awaits reinstallation following a shop rewind

2. Radial runouts on retaining rings were checked following unit trip on high vibration

3. Troubleshooting vibration issue at the coupling between the turbine (at right in the left-hand photo) and generator (at left in the left-hand photo). Use of Allen-cap screws (right-hand photo) in the coupling to reduce vibration proved ineffective


TO BOLDLY GO...



checking, FIRST's Alec Crabb discovered radial runouts of more than 35 mils were recorded on both retaining rings at the repair shop after the rings were reinstalled and before the rotor was high-speed balanced. "The most you ever want to see is about 10 mils," Tucker said.

The shop high-speed balanced the rotor believing the centrifugal force created at 3600 rpm would straighten the shaft and the radial runouts would return to "normal." Shop personnel "assumed" the runouts were acceptable; they were never re-measured after balancing.

Lesson learned No. 2: *Assume nothing. Check everything—at least twice. People make mistakes, particularly in the distracted world of today.*

Thus, the large spike in vibration a month after restart of the overhauled field was caused by the retaining rings "self-straightening" and the shift in weight that accompanied that phenomenon.

FIRST was able to recommend a fix. First step was to access the generator retaining rings, and for Crabb to measure the radial runouts (Fig 2). Both had "corrected" to less than 10 mils. Next step was to add balance weights at each end of the rotor near the retaining rings—opposite to where the weights were added during the high-speed balance.

But it took a while to get to his point because the owner's field-service company had attempted a balance correction several times by adding weights at the coupling (Fig 3). That never helped to reduce the vibration because the unbalance created by centering/shift in the positions of the retaining rings was far too great.

Months later, the vibration at bearings Nos. 4 and 5 continues to measure less than 3 mils.

The bottom line: Measuring incoming runouts on retaining rings at the shop, as well as after the electrical work has been completed and the rings are reinstalled, is critical to success. If the rings are cocked and there is excessive runout, this should be addressed prior to balance. Tucker told the editors that relying on an at-speed balance to reseat the retaining rings is dangerous and extremely risky. Finally, don't forget to check the runouts after balancing.

Lesson learned No. 3: *Skilled turbine mechanics with deep rotor experience can help resolve generator rotor issues as well. In some cases they may be the optimal choice if shop personnel are focused primarily on the electrical side of the generator.* CCJ

TURBINE TIPS, No. 3 in a series

Be sure your GT maintenance plan includes auxiliary (fluid) systems

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

Turbine Tip No. 3, from the PAL O&M solutions library, applies to General Electric Frame 5 models K-LA and M-P, early 6Bs, 7Bs, and 7Cs.

Gas-turbine auxiliary systems require periodic maintenance to assure that your engines achieve the availability and reliability metrics necessary to satisfy plant and grid operational objectives. Often taken for granted and not regularly serviced are the following fluid systems:

- Lube oil and/or hydraulic supply.
- Coolants (cooling water).
- Fuels (gas and liquid), fuel nozzles, and check valves.
- Atomizing air (if liquid fuel).
- Cooling and sealing air for turbine bearings.
- Control air (if pneumatic controls).
- Fire protection (CO_2).

Auxiliary devices that rely on these systems include:

- Diesel starting engine.
- Torque converter.
- Jaw clutch.
- Rotor ratcheting device (or turning gear).
- Fuel regulator.
- Spark plugs and flame detectors.
- GEMAC and 65EP temperature control transmitter.
- Fuel nozzles and related check valves.
- Liquid-fuel forwarding and treatment skids.
- Compressor bleed air (10th- to fourth-stage recirculation).

Here's an example of a systems issue:

A user was having difficulty with the reliability of the hydraulic ratchet (rotor turning mechanism) shown in Fig 1. It wasn't stroking reliably during the startup of a Frame 5L gas turbine. It often did not turn the rotor with the "breakaway torque" required to assist the starting means (diesel engine). Also, it often was unreliable during engine shutdown when required for uniform cooldown after the rotor coasted down to 0 rpm.

Note that the OEM recommends the rotor be ratcheted about 15 degrees every three minutes to assure uniform cooling after fired operation. The unit should remain "on ratchet" until the turbine-section wheel-space thermocouples drop below 200F—usually many hours.

In this case, the dc motor and pump **(88HR)** were tested and found in good working order (Fig 2). The four-way sequencing valve **(20HR)** also was tested, as was the hydraulic ram and

1. Hydraulic ratchet assembly sits on top of the Frame 5L's accessory gearbox

pneumatic engaging mechanism. Oil depth in the sump feeding the pump suction was verified as adequate.

Later, when a starting attempt was made, operators found that the lube-oil header feeding the generator pedestal bearing would not close—and this is a permissive to activate pressure switch **63QT**. Thus, the start attempts kept aborting. Finally, inspection of the lube-oil system filters was suggested. They were clogged!

Note that filter manufacturers generally recommend that cartridges installed in oil systems should only function as "one year wet."

The above example underscores the need to regularly change lube-oil filters. But the old expression "never 'assume' anything" is well reinforced: It makes an ASS of U & ME! Regular (planned) maintenance of the lube-oil filters would have saved several days in troubleshooting, plus the associated cost of field engineering services.

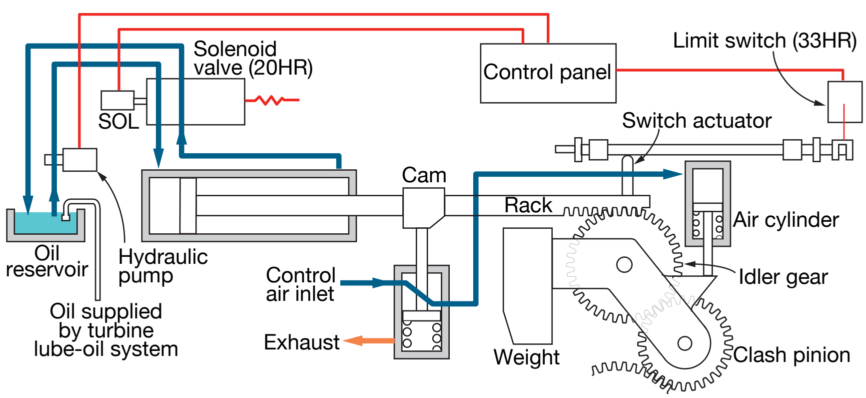
Seemingly unrelated to the ratchet system, the lube-oil supply was insufficient (at times) to keep the feed sump adequately filled.

GE provides owner/operators some useful piping diagrams along with their associated device summaries. Each fluid system is described in a detailed schematic that includes a list of supporting drawings as well as an explanation of abbreviations and symbols used by the OEM.

The referenced drawings are useful because they depict how a given system functions. It usually is possible to "trace out" an entire system to find out where the individual devices are installed. Others may be familiar with similar P&ID system drawings.

The accessory-base design for GE engines changes from model to model. For example, the accessory base for a Frame 5L differs from a 5P in many respects. Similarly, by necessity of design, a two-shaft Frame 3 compressor drive will be arranged differently than a single-shaft generator drive. Frame 5s have integral accessory bases; Frame 7B, C, and E engines, and some Frame 6Bs, have separate accessory bases.

The first documents I seek out upon arrival to a jobsite include these

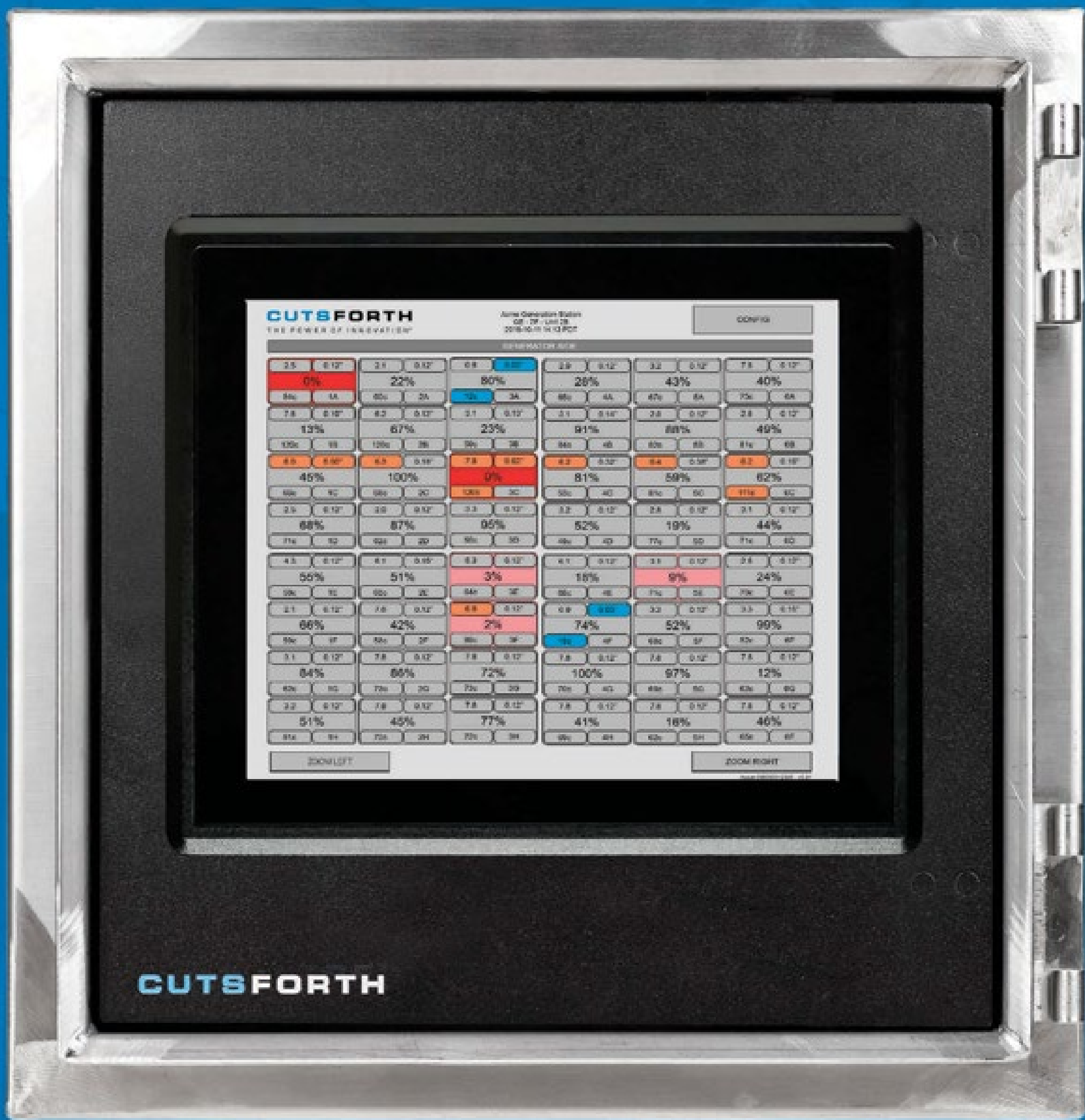


2. Simplified hydraulic-ratchet schematic is invaluable for training new personnel schematics. My philosophy is that you can't fix it if you can't find it. Furthermore, I want to trace-out the schematics to find components and verify their condition on Day One.

Another important set of documents to have in hand are the control specifications, specifically the control-system settings. These documents and performance graphs help in knowing the proper settings and adjustments of the auxiliary systems in advance of trying to start and operate the gas turbine.

The importance of meeting expectations with respect to availability and reliability was mentioned in the first paragraph. Bear in mind that if the control-panel master selector switch is set in the *remote* position, the powerplant generally is thought to be "available" to run when dispatched. Starting reliability is a particularly important metric for "black-start" units. And, if the plant has a "dead-bus" starting feature, the engine is expected to start when line voltage is sensed to be zero.

It is not possible to achieve these goals unless the recommended maintenance for your gas-turbine and generator auxiliary (fluid) systems is performed regularly and rigorously. CCJ


CUTSFORTH

Diffuser-duct upgrade mitigates reliability concerns

By Steven C Stultz, Consulting Editor

CCJ's reports on the last *HRSG Forum with Bob Anderson* (1Q/2018, p 63) and Australasian HRSG Users Group annual meeting (4Q/2018, p 58) discussed ageing issues associated with steam systems installed in the late 1990s and early 2000s, calling these combined-cycle and cogeneration facilities "pesky millennials."

As these systems reach halfway in their design life, overheating of all components has become a growing concern. High operating temperatures and gas flow velocities are taking their toll. Outage inspections must become more refined.

1. Diffuser-duct liner plates are supported by studs, ultimately attached to the casing

A closer look

Things hidden. That's the theme behind a series of diffuser-duct liner and insulation upgrade projects by HRST Inc, Eden Prairie, Minn. It is, of course, more complex than that. But HRST has found some driving concerns.

A common 7FA diffuser-duct inspection discovery is loose or broken studs, those components that secure the liner plates and C-channels within the casing. A typical diffuser-duct liner installation can have 1500 to 2000 (or more) studs. Traditionally, these studs are welded to scallop bars, imbedded in insulation, and, in turn, welded to the casing. The studs secure the liners, while allowing them to expand and contract with temperature changes (Fig 1).

The first key indicator of a problem is loose or broken studs, often 10 to 20 or more studs per inspection (Fig 2). Simply fixing the studs can become one of the final tasks during an outage. Crews do what they can with the time available.

As one owner/operator reports, "It starts with a few broken studs, and there's never a real budget to fix that stuff. You do what you can."

The result can be improper (incomplete) repair, perhaps more cosmetic than structural. As one field hand puts it, "You've got limited time to do 20 studs. So you weld them up and get out of there." But the loose or broken studs could indicate something much more severe.

Another clear and related damage indicator is liner sheet fatigue cracks propagating from the stud holes (Figs 3 and 4).

2. Loose or broken studs can indicate a deeper problem

Scallop bars and temperature

HRST has seen a lot of this. According to Rich Miller, site technical advisor for HRST, "Most scallop bars either are of the single-stud or three-stud design (Fig 5), and the duct designs we've changed out are predominantly scallop bars in segments of varying length."

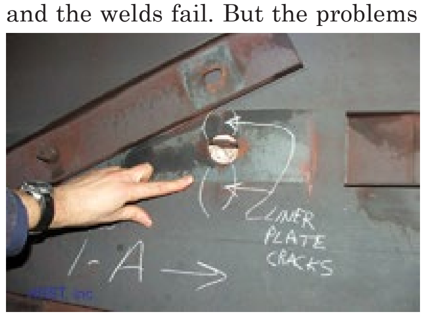
Discussing the effects of operations and temperatures, he explains "The bottom of the scallop bar welds to the casing and is buried in insulation. The top is where the studs attach, so there is a radical temperature difference between the bottom and the top."

The top experiences typical 7FA exhaust temperatures of 1100F to 1200F. The bottom will be at 200F to 300F, or less.

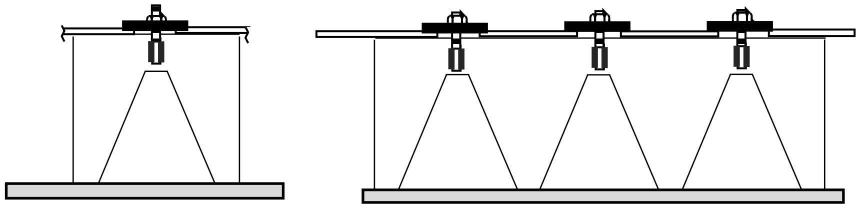
Miller points out, somewhat in its favor, that "the scallop bar design works well—until the bars start breaking, as Fig 6 illustrates." This is where both age and temperature change can create the problem, and cycling can accelerate the damage.

Most scallop bars are Type-409 stainless steel (same as most liner plates). The studs are Type-304 stainless steel, normally welded with more temperature-resistant Type 309. The expansion rates are not compatible and the welds fail. But the problems

3. Some stud repairs can be cosmetic, not structural



4. Liner cracks around the stud holes indicate long-term damage



5. Scallop bars typically have single (left) or three studs (right)

6. Cracked scallop bars will vibrate; studs will loosen or break free

7. Exposed insulation can break free and foul tubes and catalyst

are not only with the welds. Once a scallop bar breaks, it vibrates. And for all diffuser-duct materials, fatigue strength decreases with temperature.

If plates and C-channels begin to work loose, insulation materials can be released and can foul the tubes and catalysts (Fig 7).

As Miller puts it, "The only way to know what's going on under the liner is to tear it apart." That's precisely what HRST did at an installation in Iowa.

Experience

HRST's first 7FA diffuser-duct redesign/retrofit was at a 2 × 1 system commissioned in 2004.

Stud failures began 2005, but the frequency increased steadily. By 2013, with the number of stud failures continuing to escalate, the owner/operator became concerned about possible scallop bar cracks hidden under the liner materials.

In 2015, one unit experienced liner-sheet liberation, causing a forced outage. The liberation led to immediate insulation fouling of the CO catalyst, and a backpressure jump of 4 in. H_2O. Outage costs included both liner repair and catalyst cleaning, and operators became wary of repeat events.

The site had recorded stud repair data for each unit through each maintenance outage, and kept an accurate cost history. Upgrade justifications included annual stud and liner repairs, scaffold costs and time, backpressure-induced derates, catalyst cleaning costs, and a recognition that previous repairs were not addressing the root causes.

Owners ordered an upgraded diffuser-duct insulation and liner system from HRST, which had proposed eliminating the scallop bars. Instead, HRST would use one of its liner stud types, namely shoulder studs and square washers. In the end, the studs work "independently," says Miller, which "removes the whole thermal expansion issue. The top of the stud does not care what the bottom is doing."

Demolition began, and stripping off the old liner plates revealed that most of the scallop bars were either cracked or broken (refer back to Fig 6).

Future stud and liner failures were just waiting to happen, explains Miller. "Some might say a repair has lasted a couple years and they would hope to get another five out of it. I don't think it works like that. Once the bars start breaking, the failure rate can radically increase. It could be twice as bad in two years instead of five."

Pre-planning was important for both materials and contractor selection. Early award of liner design

8. The stud-location process was refined as installation progressed

9. Scaffolding was installed on the new lower liners

allowed installation drawings to be part of the contractor bid package, and materials were ordered months in advance. This reduced unknowns and potential supply issues, and allowed meetings to begin with the installation contractor.

After demolition, crews supervised by HRST installed the bottom half of the liner first. Because the scallop bars had been eliminated, studs were welded to the casing one at a time in a density for heavy duty service (Fig 8).

Then, with the lower half complete, scaffolding was erected on the new liners and upper-half work began, first the studs, then the insulation, and finally the liner panels and corner angle (Fig 9).

"It's a complicated geometry," notes Miller, "round and tapered with an expansion joint to work around. It's like a cone with the end cut off. And you can't rely on the original drawings to get it just right. Early hands-on inspection and measurement are critical."

The diffuser-duct sections at this site are unusually long (total 31 ft), but the process would have been the same for a more traditional 19-ft installation.

The first replacement, completed on schedule, has now been running since 2016.

Moving on

After these two units, HRST performed diffuser duct retrofits in Georgia then

10. Innovative scaffold system accommodates simultaneous activities

11. Completed upgrade of 7FA diffuser duct moved to Wisconsin, to a 2 × 1 7FA.03-powered combined cycle that began operating in 2004. Both units received diffuser duct replacements in 2018.

By this time, each HRST project had gained efficiency from experience. The first unit in Iowa was completed in three weeks working two shifts around the clock. The first Wisconsin unit was completed in about three weeks working one 12-hr shift. The second unit was completed in 15 working days, Monday through Friday, one 10-hr shift per day.

But the design had also changed.

"At the first Iowa unit we put the studs in one at a time. But in Wisconsin we decided to put these on a bar fabricated previously at a shop. The bars are however long they need to be, based on the geometry. The weld point in the field then becomes bar plate-to-casing."

He continues: "The studs upstream to downstream are evenly spaced, but the distance in the lateral position upstream to downstream can be different stud-to-stud (perhaps a sixteenth of an inch). And the liner sheets reflect that. We pre-design and pre-make the liner sheets and stud bars, and the vast majority don't need any trimming. There is just some custom fitting."

Ya' gotta' listen

"A lot of the details become even more clear with experience," reflects Miller "And at our most recent site we had a 28-year-old foreman, *sharp as a tack,* who wanted to show the world we could do this more efficiently." The result was an innovative scaffold system that allowed multiple, simultaneous activities (Fig 10).

"They put some outriggers on the interior side of the duct," explains Miller, "and they outfitted it so we could work on the top and the bottom at the same time. This was huge!"

"It's like a suspended scaffold," noted the owner/operator. "You can work top and bottom at the same time, and there's room to get more people in there than you would think."

This innovation was used on both Wisconsin units.

"Each job is contractor-dependent, and you need to listen to everyone's ideas," states Miller.

Technical advice

Attention to detail is critical. "No single operation of the installation by itself is all that complicated, but there is a learning curve to each one. Secondly, there are always unique minor issues that require solutions you want blessed along the way," stresses Miller.

And even with the best installation contractor, he continues, "there's enough going on that you need a technical advisor out there."

The editors then asked if this retrofit was unique to the 7F machines. "I can't imagine why it wouldn't work in a 7EA, likely a Frame 6, or really anything," said Miller. "And if it needs to be bigger, we'll make it bigger."

HRST has gained some experience performing various isolated in-kind repairs of the scallop bar design, but sees some benefit in their removal. "I think this is the way to do it," suggested Miller. "It's what I would do."

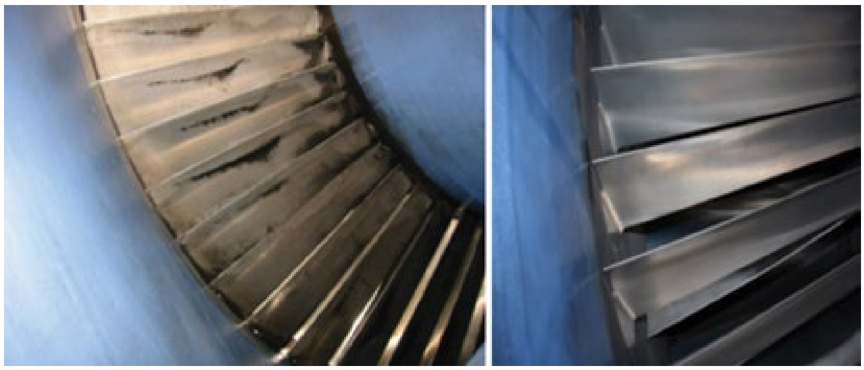
Miller has been HRST's field installation supervisor and technical advisor on several of these projects, and obviously takes great pride in what his company and the plant-selected site crews have accomplished.

And after discussing the latest project (Fig 11), he summed it up: "These jobs are some of the most rewarding due to the final visuals when complete. In that last five minutes before I throw my hard hat in the bag and go home, I'll stand there, take a few pictures, and think 'Wow… I had a big part in this.' And you see the same thing with the contractors, and the site personnel." CCJ

‘Three Pillars’ methodology helps users select the optimal filter for plant conditions

By Michael Roesner, Donaldson Company Inc, Gas Turbine Systems Div

Editor's note: *Given the existence of several standards for the classification of gas-turbine inlet filters, which can cause confusion in the minds of at least some owner/operators, Donaldson has developed a user-friendly filter rating system that measures efficiency and two other properties crucial to power output and cost control. The company's goal is to build a consensus to support adoption of this three-part rating system industry-wide. The article that follows provides the details.*



1. Dirty air can lead to fouled components, such as the inlet guide vanes at left after 1200 hours of running time with Er3 filtration. IGVs at right operated for 5000 hours with Er5 filtration

Gas turbines are designed to mix dry, clean air with fuel to produce energy. Because intake air quality is critical, effective inlet design and air filtration are required for top performance. Based on EPA data, approximately 1300 pounds of particulate matter could enter an F-class gas turbine inlet house and filters in a typical year of operation. Airborne dirt and contaminants can cause power loss, drive up fuel costs, and damage vital components.

Three performance factors important to selection of the proper filter for your plant are efficiency, water-tightness, and, in pulse-cleanable applications, pulse recovery rate. Think of them as the key filtration "pillars" that support optimal gas-turbine operation. In most cases, all three performance factors are important, but their ranking may vary depending on the local environment and operating conditions.

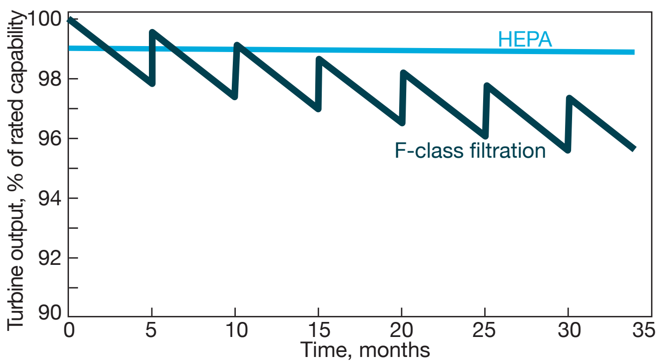
The Three Pillars can be described as follows:

Efficiency. The proportion of particulates entrained in the inlet air and captured by the filter is the most widely recognized performance metric. Because higher-efficiency filters have associated costs, operators need to determine an efficiency rating that delivers the best return on investment (ROI).

Water-tightness. In humid or ocean-front locations, resistance to moisture becomes a high priority. Salts and other dissolved solids carried by water can be highly corrosive and oftentimes more detrimental than airborne contaminants.

Pulse recovery rate. How readily filters regain peak performance after pulsing is a third key concern. High pulse recovery rises to top priority in desert or arctic environments, where there is either continual exposure to dust, snow, and ice buildup, or potentially sudden episodes of heavy loading.

Careful evaluation is necessary on a case-by-case basis to determine the ranking of these factors for a local situation and operating budget. Identifying priorities enables the most appropriate inlet design and filter combination to be incorporated into your gas turbine system.



2. Multiple compressor washes are required over time to recover efficiency and power output

Balancing ratings with cost. Higher filtration efficiency produces cleaner air, which translates into more efficient combustion, sustained power output, and longer-lasting turbines. Dirty air introduces particles that can foul turbine components, decrease compression efficiency, and adversely affect compressor health, as shown in Fig 1.

Compressor water washing can be used to regain power output lost to fouling; however, an overall decrease in efficiency may occur after repeated washings. Fig 2 compares the performance of a GT equipped with a typical F-class filter, after multiple washings, to a similar engine with high-efficiency particulate air (HEPA) filters that did not require online washing.

The downward-sloped lines for the standard filter represent output decreases caused by fouling, followed by upward swings from washing. Note that after multiple washings, output of the engine with a standard F-class

filter is less than that of a HEPA filter with no online washing.

A HEPA filter can reduce the need for compressor washing and maintain higher turbine efficiency. This also reduces "soft costs" related to maintenance and equipment downtime. With turbine availability often a key factor in evaluating the financial bottom line, outage costs can be significant.

Other factors affecting filter efficiency include airflow and pressure drop. Reductions in inlet pressure from blockages or poorly sized filter elements can compromise turbine output. If a filter operates at a flow rate that exceeds design specifications, the resulting pressure drop can adversely impact system performance. Pressure drop will often increase as the filter loads.

However, there are trade-offs to consider, and a balance must be achieved. Because the increased pressure drop of a higher-efficiency filter can still support long-term gains, system owners and operators should work closely with their filter supplier to determine optimal ratings and filter characteristics.

Various efficiency rating systems have been developed (Sidebar 1). Donaldson has designed an efficiency tool that combines the different approaches into one, easy-to-use efficiency scale, ranging from Er0 to Er5—the higher the number the greater the degree of particulate capture.

Water-tightness. Much like dust that escapes an inefficient filtration system, water also can impact turbine performance. Moisture that enters the airstream can introduce dissolved salts and other solids. Compounds such as iron oxides, chlorides, and other contaminants can cause corrosion over time. Turbine blades then have to be repaired and re-balanced—another expensive maintenance task and contributor to extended downtime.

Water-tightness is particularly important in coastal areas, with salt-laden ocean moisture subjecting equipment to accelerated corrosion. Consequently, protection from saltwater represents a key factor affecting the life of gas turbines. OEMs usually recommend that less than 0.01 ppm of salt enter their gas turbines.

In coastal environments, airborne salt can easily range from 0.05 to 0.5 ppm on a typical day. According to data compiled by the National Atmospheric Deposition Program, chloride concentrations in the atmosphere along coastal areas are sometimes more than 10 times the concentrations of inland areas (Fig 3).

Petrochemical environments also present challenges, as hydrocarbons can enter the airstream without ade-

1. Efficiency rating and classification methods

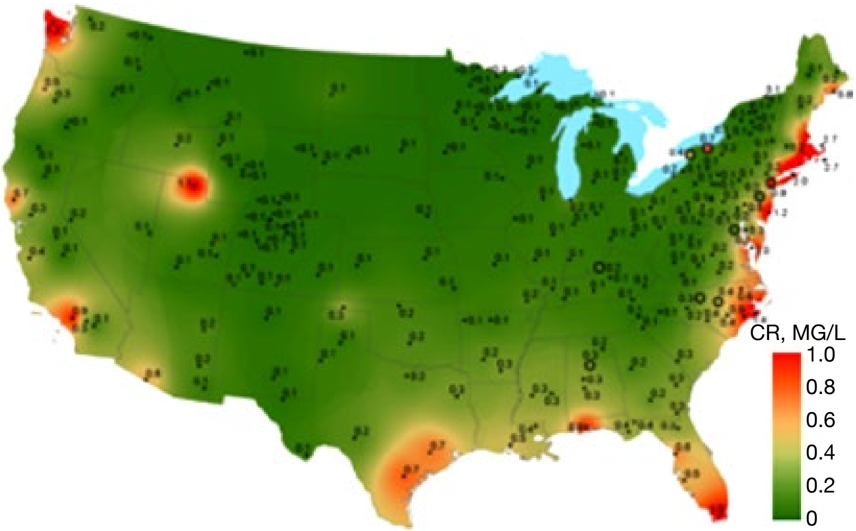
Filter efficiency indicates how well a filter performs by comparing the concentration of particles upstream and downstream of the filter. Removal efficiency typically is expressed as a percentage of capture. However, filtration-efficiency classifications have varied.

In the US, filters historically have been classified with a Minimum Efficiency Reporting Value (MERV) rating, which was developed by the American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE). MERV ratings range from 1 to 16, with a higher score indicating better performance. In Europe, two standards have been used: European Normative (EN) 779 and EN 1822. EN 779 standards include ratings of G1-G4, M5-M6, and F7-F9, which generally encompass the same range of efficiencies as MERV ratings 1-15.

The terms "efficient particulate air" (EPA) and "high-efficiency particulate air" (HEPA) are the most familiar measures regarding premium levels of filtration efficiency. According to the EN 1822 standards, HEPA is defined as a minimum of 99.5% removal of the most penetrating particle size. EN 1822 filters have ratings of E10-E12, generally corresponding to EPA and HEPA filtration levels.

More recently, a new standard, ISO 16890 (CCJ No. 57, 2Q/2018, p 88), has been introduced worldwide to unify how filters are tested and rated. The methodology focuses more on particulate matter (PM) classes. The ISO 16890 test protocol challenges filters with particulates in a broad range of diameter sizes, then measures average capture in three specific ranges: PM1, PM2.5, and PM10.

The complex nature of multiple testing standards motivated Donaldson to design a tool that combines these testing standards into one, easy-to-use efficiency scale, ranging from Er0 to Er5 (refer to Fig 6 in text), and to develop ratings for two other performance factors equally important in filter performance—water-tightness (W0-W5) and pulse recovery (PS to P5)—for a more accurate filter profile.



3. Chloride concentration in ambient air generally is higher in coastal areas

quate water-tightness. These products can place gummy deposits on blades and adversely affect performance.

Water-tightness should be simple for an operator to evaluate. Ask your filter supplier to provide an independent laboratory test report verifying that a particular filter option is water-tight and if not, how it will perform under wet conditions.

Donaldson developed a new methodology for testing filters in a controlled environment to determine how much, if any, water can pass through a filter. The test directs a 60-liter/hr water spray at the filter over an 8-hr period. The filter pressure drop and volume of water passing through the filter are recorded.

Based on this information, the company rates its gas-turbine filters on a scale of W0 to W5, with higher values indicating greater water-tightness. A filter rated at W0 would not be able to withstand any moisture, while a W5 filter could survive the test with at least 99.5% water stoppage and no more than a 2-in.-H_2O increase in pressure drop. Donaldson has tested and rated its most commonly used GT air filters on this scale of water-tightness. Fig 4 shows how higher rated filters reduce

the increase in pressure drop over time.

Recovery rate for pulse cleaning. When dust builds up on filters, the resulting drop in airflow compromises power output. Inlet filtration designs include either static or self-cleaning (pulse) systems. Pulse recovery rate measures how often filters in self-cleaning systems can stand up to pulse cleaning and how much pressure drop can be recovered each time.

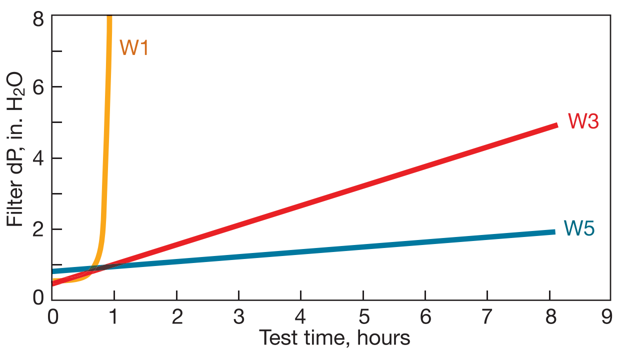
In pulse-designed inlet houses, filters are cleaned automatically with compressed-air "pulses" from the clean-air side of the filter. This dislodges dirt particles and debris from the surface loading media of the dirty filter, thereby reducing the cost of operation by minimizing pressure drop, extending filter life, and preventing shutdowns because of filter fouling. Self-cleaning systems operate with the GT online.

The recovery rate is the rate at which the filter comes back to a "like-new" condition and stabilizes the pressure drop to allow continuous operation. The higher the pulse recovery rate, the more cleanable a filter is. Recovery rates in pulsed systems are largely dependent on the environment and media type in the filter: surface-loading or depth-loading.

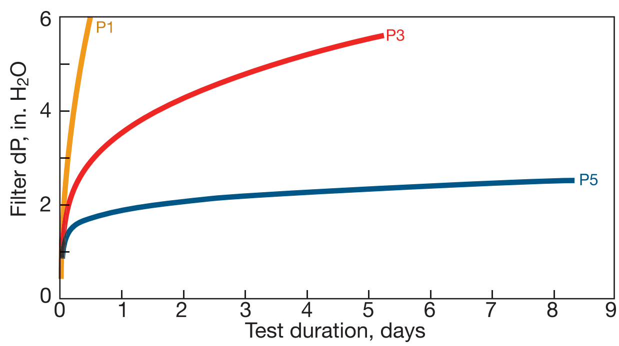
The latter have layers that trap progressively smaller particles on each layer. While they retain a wide range of particle sizes, they cannot be cleaned easily. Surface-loading filters, on the other hand, trap all particles on a single media layer, and form a slight "dust cake" that is easily removed, extending filter life.

As with efficiency and water-tightness, pulse recovery can be rated using laboratory test data. Donaldson developed a process for measuring this characteristic. Exposing filters to a long duration of simulated sandstorm conditions, filter pressure drop and efficiency are measured to arrive at pulse recovery ratings.

On the Donaldson scale (Fig 6), a static (S) filter cannot be pulse-cleaned without damaging it. The ratings from P1 to P5 in the figure indicate the level



4. Testing indicates pressure-drop increase is reduced with filters offering top water-tightness performance



5. Filters with high pulse-recovery rates generally maintain lower pressure drops for longer durations of pulse recovery. There are a variety of performance factors with static filters and Donaldson is developing an independent rating system for these applications.

If your filter housing does not have a pulse system, static filtration solutions are most appropriate. A typical static solution utilizes depth-loading filter media and focuses on maximizing filter life by balancing pressure drop and dust holding capacity.

However, the advantages of a pul-

2. How to select the optimal air filter for your plant

Donaldson's inlet air-filter rating system was developed to help plants convert to the optimal filtration solution for their unique operating and environmental conditions. If plant conditions change, the appropriate filtration option can be identified based on efficiency, water-tightness, and pulse recovery—the three attributes that differ most from one filter to another and, in combination, also drive operating cost.

Using a baseline profile of the *current* filter, the owner can select replacement filters with stronger ratings on the properties that matter most under the new conditions. An Er/W/P profile provides an apples-to-apples comparison and enables a better match. Donaldson uses standardized testing to determine the Er/W/P on a 0 to 5-point scale, as described in the text, for both the current filter as well as the proposed solution.

Below are two hypothetical case examples of a beneficial filter conversion using Er/W/P ratings:

Case 1: Environmental issue. A plant in an agricultural region is coping with a dusty harvest season by using a pre-filter wrap on a depth-loading filter. The pre-filter and filter begin to quickly load and require frequent replacement. The owner discovers a nearby rock quarry has reopened, compounding the dust problem.

Donaldson removes and tests the plant's current filter, discovering it has medium-high capture efficiency (Er3), moderate water-tightness (W2), and weak pulsability (P1). The trouble becomes apparent: The existing filter's limited pulse recovery rate (P1) cannot keep pace with the high dust load.

Using this comparative information, Donaldson recommends an Er3/W1/P5 replacement. No water-tightness is required in the filter, but it has to deliver the highest possible pulse recovery rate (P5) to shed the heavy dust load. With this change, the plant runs continuously through high dust occurrences and projects a rapid ROI.

Case 2: Operational change. A peaking plant running 1500 hours annually on demand needs to convert to a baseload system that can run 8000 hours. Since downtime becomes a new concern, water washing is no longer an option to optimize compressor efficiency. Compressor health and stable power output become the plant's main management concerns—and the answer is a different kind of inlet air filter.

In a consultation, Donaldson removes and tests the original synthetic filter and finds that it provides medium-high efficiency (Er3), minimal water-tightness (W1), and maximum pulsability (P5). It recommends switching to a filter rated Er5/W5/P1—providing greater efficiency and water-tightness, with less emphasis on pulsability. The recommendation enables the plant to minimize downtime and maximize power output.

sable filter system can be illustrated by way of the following simplified example: If 10 grams of particles are captured daily by a filter, in 100 days, a total of 1000 grams would be collected. The buildup of particles would also result in a pressure drop in the system. If the pressure drop were deemed to be approaching allowable limits, the filter would either need to be replaced or cleaned. A surface-loading filter could be cleaned during operation, while a depth-loading filter would have to be replaced.

Pulsable systems are often most valuable in areas with significant dust, snow, and potential ice buildup. In these conditions, the longevity benefits of the filtration system can far outweigh the additional cost of a pulse cleaning system. In areas less prone to dust, snow, and ice, pulsable systems may not be as cost-effective.

There are considerable advantages to operating a pulse-cleaned system. Much like an automobile windshield wiper, pulse-cleaning may be mainly a contingency for adverse weather events. But when a demand occurs, and a power interruption could be catastrophic, the value of pulse-cleaning becomes clear.

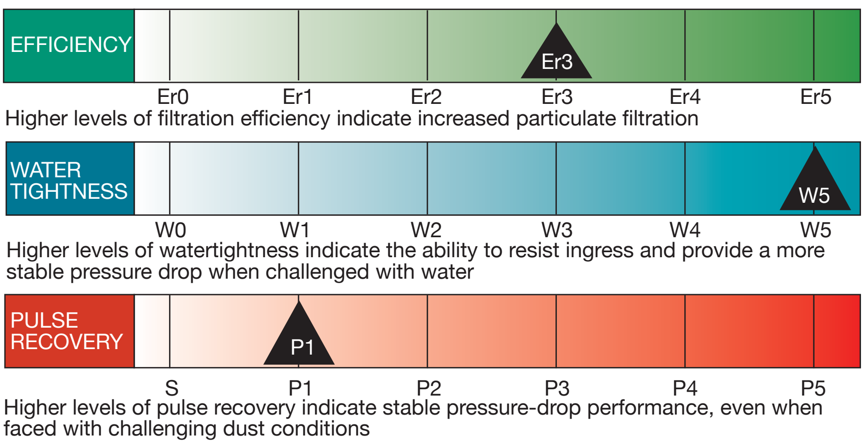
A fully functional system—including elements compatible with pulse-cleaning—can provide operators peace of mind. If you inherited an existing system with pulse-cleaning, in most cases the advantages of maintaining and equipping it with a pulsing-compatible filter outweigh the costs of an unplanned outage.

The relationship of recovery rate and pressure drop can be seen in Fig 5. This graph illustrates how long three filters with various pulse-recovery rates maintained acceptable filter pressure drop over time in a simulated dust-challenged environment. Generally, filters with higher recovery rates maintained lower pressure drops for longer durations.

Operation of pulse-cleaning systems also needs proper consideration. Systems generally are operated by one of three methods: manual, automated based on pressure drop, or automated based on time intervals. Regardless of whether manual or automated methods are used, cleaning needs to occur before fouling reaches a problematic state. For example, if a cleaning is not triggered by an appropriate time interval, fouling can reach the point of causing significant operational problems.

As it is with any O&M function, neglect increases the risk of failure.

In some instances, the pulse system



6. A filter with Er3, W5, and P1 ratings might serve the needs of a coastal peaking plant will only be needed to prevent catastrophic fouling. In periods of ice, snow, extreme frosting, and sandstorms, the pulse system can actually keep the turbine running by using the pulse system as a preventive measure.

Evaluate your needs. Environmental conditions largely drive decisions on inlet system design and filters. The Three Pillars—efficiency, water-tightness, and pulse recovery rate—typically do not stand alone, but require integration. Identifying the ideal balance and combination for your gas turbine should factor in potential downtime costs and long-term ROI.

In evaluating ROI, numerous factors can impact filtration costs. Each operator's scenario must be evaluated: Not everyone's ROI will be the same. For example, in evaluating filtration efficiency, a higher efficiency rating cannot always be justified. Only if increased output and operational savings offset the cost of a slightly increased pressure drop can a financial ROI be realized.

Lower efficiency can sometimes actually be more cost-effective in the long run. Similarly, water-tightness might outweigh efficiency in coastal areas, but not in arid locations, where exposure to corrosive ocean air is unlikely.

Every situation is different, and thorough review of operator needs is necessary to identify the optimum filter design. Economic impacts, not just technical factors, require consideration. The bottom line is to evaluate which factors are most important to meet the operator's needs.

As an example of how efficiency, water-tightness, and pulse recovery should be integrated in filter selection, consider a peaking plant in a coastal environment. Because the plant only operates for short durations, a high-efficiency filter may be difficult to justify economically. The payback for the additional cost of high-efficiency filters would likely be much longer than for that of a continuously running plant.

Because the plant is in a coastal area, water-tightness may be important, but pulse recovery may be less critical if dust exposure is minimal. A filter with Er3, W5, and P1 ratings in efficiency, water-tightness, and pulse recovery, respectively, might serve the needs of such a situation.

Finally, Sidebar 2 offers examples of evaluations at two plants that suggested changing the existing filters for a more-effective and economic alternative. CCJ

About the author

Mike Roesner is aftermarket manager for Donaldson's Gas Turbine Systems group.

How to achieve reliable pressure regulation

By Rishi Velkar and **Frank Romans,** NV Energy

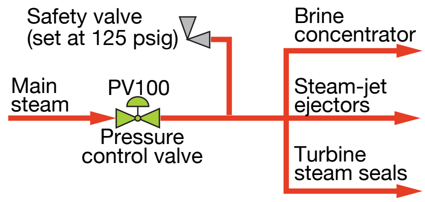
Silverhawk Generating Station underwent a period in which the safety valve for the plant's auxiliary steam system failed repeatedly. Consequences of the failures included frequent valve replacement and loss of production through forced outages.

Examination of the failed safety valves revealed seating-surface erosion associated with high-velocity steam flow. Historical process data (Fig 1) showed transitional phases where the auxiliary-steam pressure would break down into uncontrollable oscillations. Testimonials from plant operators conveyed the only means to stop the oscillations was through manual intervention.

During the course of startup, the auxiliary-steam control valve PV100 (Fig 2) is required to maintain constant downstream pressure with a supply pressure that varies from 110 to 1600 psig. Concurrently, operation of the condenser air ejector (hogger) introduces practically an "all-or-nothing" demand on the aux steam system.

A varying main-steam supply pressure, combined with extreme changes in demand, apparently caused the oscillations and subsequent safety-valve failures.

Comparison of the Silverhawk auxiliary steam system to arrangements used at other plants highlight a stark



2. Aux steam system serves brine concentrator, steam-jet ejectors, and turbine steam seals

difference. Most others use two steam sources to supply the auxiliary steam system: main steam and reheat steam. Each has a control valve to regulate downstream auxiliary steam pressure.

The advantage of the two-source scheme: Auxiliary-steam control valves regulate downstream pressure for a much lower range of supply pressures. Thus, they are less likely to break down into oscillations.

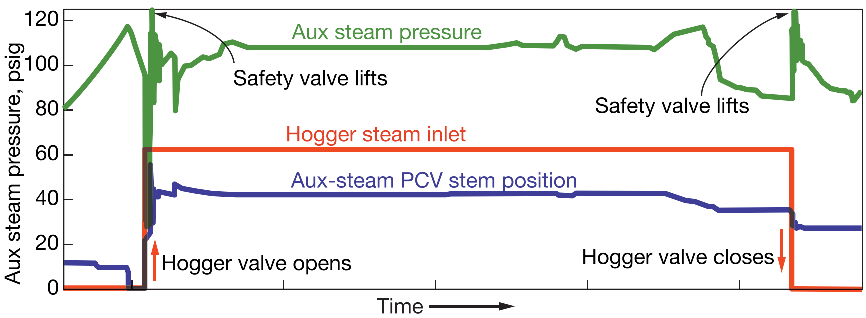
Installation of a system similar to that used successfully by others is a possible long-term solution. For the immediate need, any solution had to incorporate existing equipment.

Solutions

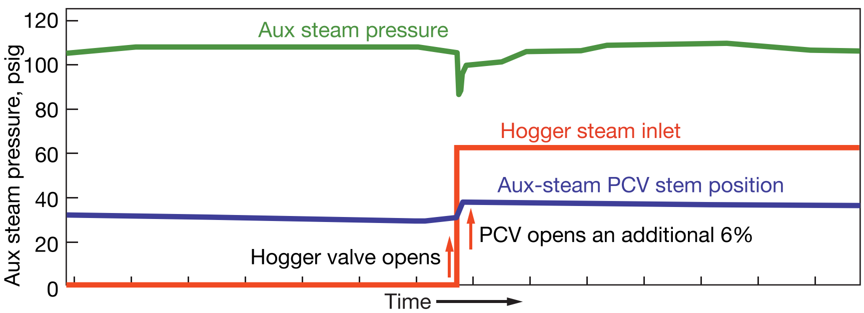
Here's what was done:

1. Modified the control-system program so the auxiliary-steam-pressure control algorithms used variable proportional and integral values.

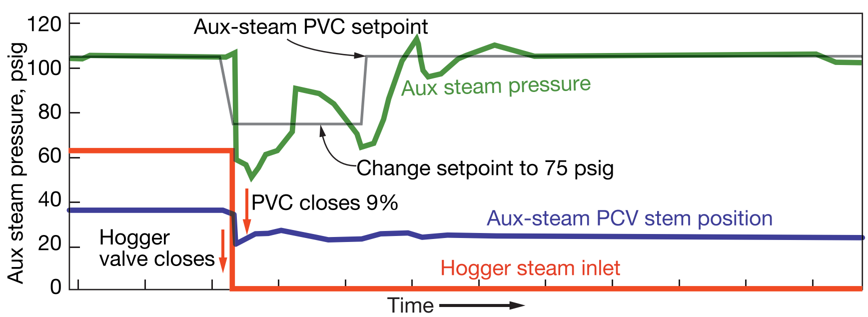
   Prior to this change, the proportional and integral values were constant. Now, these values change as the main-steam supply pressure varies. Deploying this strategy made the pressure-control response appropriate for a given supply pressure.



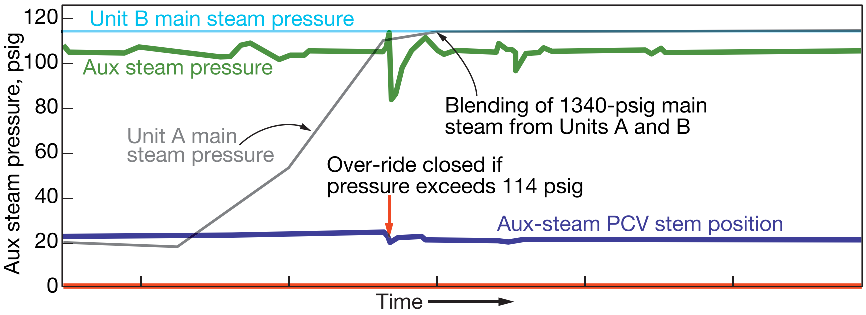
1. Historical data reveal transitional phases where, prior to system changes made in 2018, auxiliary steam pressure would break down into uncontrollable oscillations



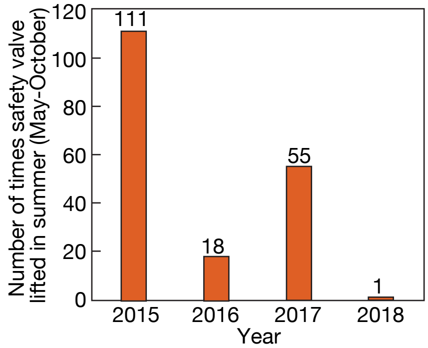
3. PV100 opens an additional 6% when the hogger enters service to keep steam pressure at the level required for effective operation



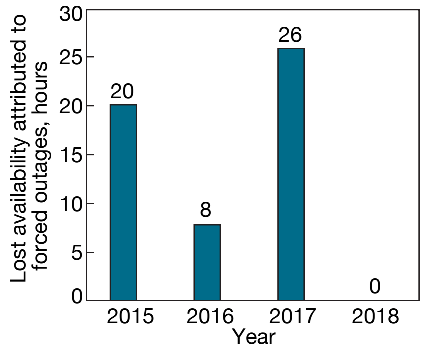
4. PVC valve position when hogging stops



5. Override feature closes PV100 if pressure exceeds 114 psig



6. Prior to aux steam system changes in 2018 safety valve lifted frequently



7. Lost availability hours attributed to upsets in aux steam system operation dropped to zero in 2018

2. Changed the control scheme to mitigate the impact of "all or nothing" demand on the auxiliary steam system.

   When hogging begins, the demand for auxiliary steam increases rapidly and steam pressure drops below that required for proper operation. Conversely, when the hogger is removed from service, the demand for aux steam drops to zero and its pressure spikes, typically causing the safety valve to open.

   Changes to the control scheme comprised feedforward signals that adjust the steam-pressure regulator valve whenever the hogger is placed in, or removed from, service. Automatic changes to the aux steam pressure setpoint also occur.

   Once the hogger begins operating, the regulator valve (PV100) *opens* an additional 6% to keep pressure at an effective level; the auxiliary-steam pressure set point stays at 105 psig (Fig 3).

   Whenever hogging stops, the regulator valve (PV100) *closes* an additional 9% to limit the pressure increase. Simultaneously, the pressure setpoint drops to 75 psig. The lower setpoint holds for a period of 10 minutes. The 10-min hold assures the pressure stabilizes before the automatic return to the normal setpoint of 105 psig (Fig 4).

3. The aux steam system must function throughout a variety of dynamic operating conditions. Obviously, the hogger is most critical, but other scenarios can upset the system as well. Installation of an "override" control scheme reduced sporadic opening of the safety valve.

   The override activates when aux steam pressure exceeds 114 psig. While the override is active, the regulator valve (PV100) *closes* a percentage that is proportional to the rise of steam pressure above 114 psig. More specifically, an aux steam pressure slightly above 114 psig will result a small percentage of regulator-valve closing; a pressure significantly above 114 psig produces a higher percentage of valve closing (Fig 5).

4. The company's engineering team reviewed the aux steam piping system, concluding that the safety-valve setting was conservative and most likely determined during plant commissioning. The team decided to raise the safety setting to 140 psig, which allows a larger margin of operation.

Results

Since implementation and tuning of the 2018 solutions summarized above, there have been no safety-valve failures or loss of production hours (Figs 6 and 7). Additionally, the safety valve opened only once, in May, and a minor tuning change corrected the issue. Afterwards, the safety valve did not open again for the remainder of 2018. CCJ

Best practices shared by aero users benefit frame owner/operators as well

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

Jackson stressed the value of the joint program during the user organization's annual meeting in Las Vegas, March 17-20, 2019, at the South Point Hotel and Spa. He encouraged attendees to support the initiative and explained how they would benefit from the experience. The latest fruits of that effort are the best practices profiled here, submitted by the 12 plants identified in the figure.

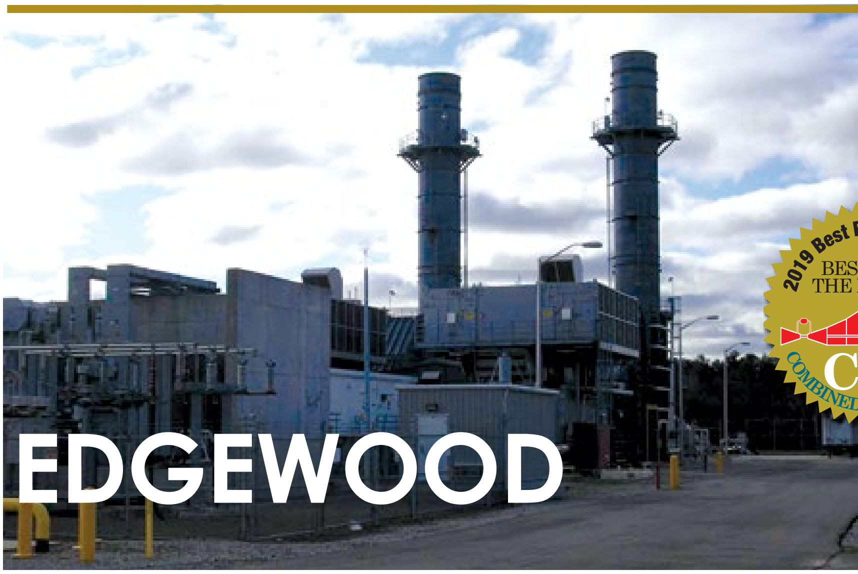
Recall that CCJ launched the industry-wide Best Practices Awards program in late 2004. Its primary objective, says General Manager Scott Schwieger, is recognition of the valuable contributions made by owner/operator personnel to improve the safety and performance of generating facilities powered by gas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

Industry focus today on safety and performance improvement—including starting reliability, fast starts, thermal performance, emissions reduction, and forced-outage reduction—is reflected in the lineup of proven solutions profiled below.

Use of multiple service providers reduces the cost of LM6000 repairs

Challenge. The standard approach for selection of a service provider for major turbine repairs was to solicit multiple vendors to bid on an established work scope, evaluate the proposals, and then provide a recommendation to site ownership based on the best value provided by a single vendor. The challenge was to improve upon that process and deliver further value by finding ways to reduce cost while not negatively impacting work quality or outage duration.

Solution. Site managers, during the course of evaluating bids for Spring 2018 gas-turbine work, took the opportunity to explore the feasibility of having multiple service providers each get a portion of the larger repair work scope. While some service providers declined to participate in that effort, others recognized that receiving some work might be better than receiving no work at all. This required that interested bidders modify their previous proposals to provide an *a la carte* proposal, allowing the selection of individual bidders for specific aspects of the turbine



Edgewood Energy LLC
Owned by J-Power USA Development Co
Operated by NAES Corp
90-MW, two-unit, peaking facility located in Brentwood, NY
Plant manager: Kenneth Ford

repair scope.

Ultimately, one bidder was selected to provide a replacement combustor (Fig 1), a set of fuel nozzles, and perform all field service work; a second was chosen for providing a second-stage high-pressure-turbine nozzle assembly (Fig 2); and a third was selected to perform low-pressure-turbine repairs (Fig 3).

Results. The decision to award the turbine repairs to three separate LM6000 service providers resulted in a savings of $350,000 when compared to the price offered by the lowest single service provider. Though the decision to utilize multiple service providers significantly increased the time required by site managers to coordinate and oversee the project, the effort paid dramatic dividends.

Project participants:
Kenneth Ford, NACE area manager
John Lawton, Edgewood O&M manager

1. Combustor replaced during Spring 2018 overhaul

2. Replacement second-stage nozzle assembly for high-pressure turbine

3. Low-pressure turbine is loaded into shipping container for trip to repair shop

Lifting hoist for water combination skid filter mitigates risk of injury

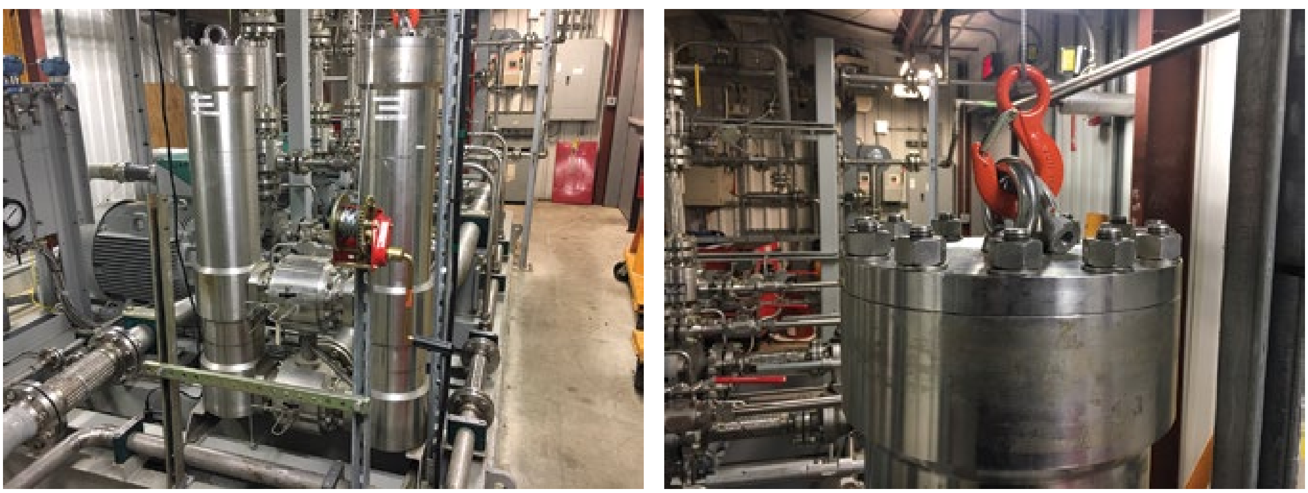
Challenge. Routine replacement of the combo skid suction filter for Edgewood's LM6000s required a technician to work in an awkward position, with both arms extended at, or above, eye level. Additionally, the filter element, which is approximately 40 in. long, would need to be manually lifted out of the filter assembly and a new filter inserted. An exhausted filter, saturated in demineralized water, is estimated to weigh between 30 and 40 lb.

The challenge in this instance was to provide an ergonomically friendly solution that would make this routine task safer by eliminating the potential for injury caused by shoulder, back, and/or neck strain.

Solution. Plant employees designed a simple lift system, utilizing a locally purchased manual winch. The winch provides a means of lifting the filter element out of the frame by using its inherent mechanical advantage.

Results. The lifting hoist has been a great success, with employees happy to have a simple and effective method to perform an unpopular task.

Project participants:
Nicholas Post, OMT
Anthony Angieri, chief engineer



4. Winch, shown here installed on the plant's "east filter," can be moved to the west filter to remove that element when needed

Washable prefilter key to performance improvement at EVM I

Energía del Valle de Mexico I

Owned by EVM Energia SAPI de CV

Operated by NAES Corp

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

Plant manager: Javier Badillo

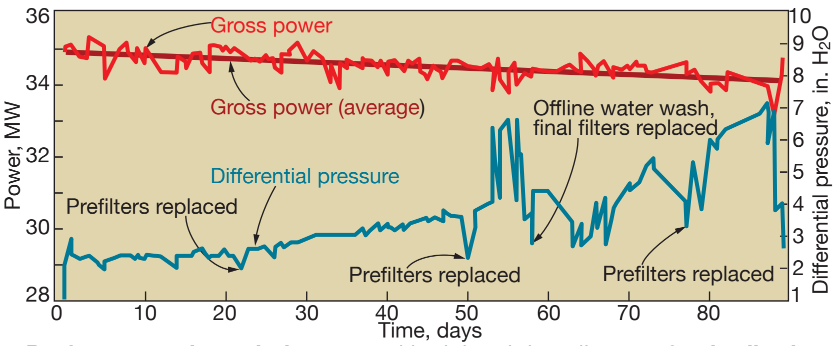
Challenge. The semi-arid climate in the agricultural area home to the 3 × 0 LM6000-powered Energia del Valle de Mexico (EVM I) powerplant is conducive to a large amount of dust during the dry season. In addition, a new combined-cycle plant (EVM II) is being built 300 meters from EVM I, contributing still more dust as a consequence of earthwork, excavations, and heavy-equipment transit.

Dust clouds caused the gas-turbine prefilters to load to capacity in about five weeks. The higher pressure drop at the inlet, combined with excessive fouling of the compressor, led to a rapid loss in power production.

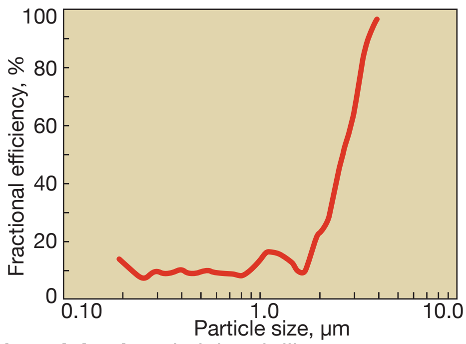
EVM had installed a chiller for power augmentation, but the large amount of dust that accumulated in its coils made it almost impossible to operate the system in a continuous and efficient manner.

In less than a year of operation, the plant had replaced its final cartridge-type filters twice and suffered a 4% decrease in output, on average. Fig 1 illustrates the performance degradation over time.

Solution. After analyzing the causes of the sudden increase in differential pressure across the "typical" air filters installed, staff decided to tackle the root cause of the problem: Reduce the quantity of large-size particles in the inlet air to avoid rapid filter plugging. This required use of an additional

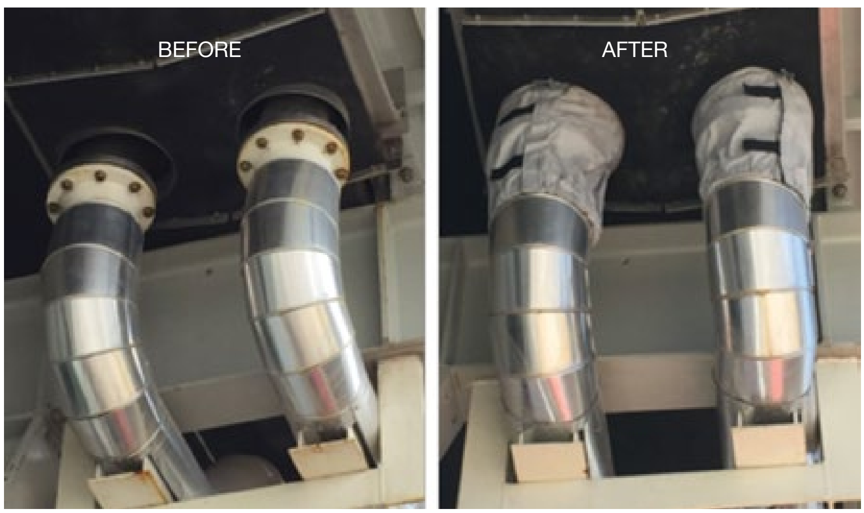


1. Performance degradation caused by inlet air heavily laden with particulates reflects challenge plant staff faced in maintaining desired electric production and availability



2. Distribution of particle sizes in inlet air illustrates area of concern addressed by the blanket filter installed in front of the prefilter

3. Blanket filter proved optimal for capturing the 2- to 5-µm particles that dominate in the inlet air at the plant location



4. Penetrations for the chiller's cold-water coils, as installed (left), allowed leakage of unfiltered air into the filter house. Expansion-joint-type covers were installed to protect against this (right) level of filtration to improve the performance of the original filters.

Plant personnel contacted several specialists in air filtration to advise on prefiltration options. Among them was an inexpensive filter blanket, which was installed. The Poret® polyurethane foam filter from EMW has 10 pores per inch (PPI). It was installed as a prefilter curtain, taking advantage of the mesh installed in the weather hood of the filter house. Claimed advantages of polyurethane foam are its density, resistance to compression, and difficulty to break.

The cost of implementing this filtration solution was $1000 for each of the plant's three turbines.

Installation and testing were conducted in May 2018. The 10-PPI filter selected proved optimal for capturing the 2- to 5-µm particles that dominate in the inlet air at this location (Fig 2). In addition to Poret's favorable filtration characteristics, it is supplied on a roll and easy to install (Fig 3).

Plus, it's washable and reusable. The washing interval at EVM I is five months. Compressor offline washes and prefilter blanket washes are done at the same time to minimize the impact on plant availability. Expected lifetime of the filter blankets at EVM is three years.

In addition to the foam filter, some expansion-joint-type covers also were installed to prevent unfiltered air from entering the fine filters and to reduce premature fouling of the compressor (Fig 4). The unfiltered air had been leaking into the filter house via the penetrations provided for the chiller's cold-water coils.

Results. Installation of the filter blankets and pipe-joint covers was done with in-house labor to minimize project cost. The pressure drop of clean (new or washed) foam filters is 0.28 in. H_2O; washing is done when the pressure drop reaches 0.50 in. H_2O. Note that the very low pressure drop incurred by the blanket filters does not significantly impact the total pressure drop across the entire air filtration system; hence, impact on electric production is minimal.

The blanket filters enable the plant to achieve a nearly constant electrical output throughout the year and a higher capacity factor than was possible before their installation. More specifically, the reconfigured air filtration system (1) increased the interval between compressor offline washes from quarterly to semiannually, while improving plant performance (table); (2) extended the life of the original prefilters from a nominal four months to one year; and (3) enabled a doubling of the replacement interval for fine filters from one year to two.

Plant personnel predict a cost saving of about $800,000 (net present value) in prefilters and fine filters over the next 20 years because of the Poret blankets.

	2017 (before filter implementation)		2018 (after filter implementation)	
Month	Capacity factor, %	Power production, MWh	Capacity factor, %	Power production, MWh
May	89.1	65,639	94.1	69,290
June	97.4	69,428	98.1	69,887
July	79.5	58,568	94.6	69,655
Aug	99.2	73,030	100	73,811
Sept	66.7	47,569	94.4	67,268
Oct	87.7	64,559	87.5	64,414
Nov	82.9	59,057	81.7	58,235
Dec	59.8	44,027	66.7	49,161
Avg/total	82.8	481,877	89.6	521,721

Project participant
Alonso Saldivar, O&M supervisor

Plant-wide upgrade of control systems makes for smoother, more reliable operation

Exira Station

Owned by Western Minnesota Municipal Power Agency

Operated by Missouri River Energy Services

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

Plant manager: Ed Jackson

Challenge. A decade and a half after COD, Missouri River Energy Services' (MRES) Exira Station, a 3 × 0 LM6000PC-powered peaking facility, located in southwestern Iowa, found itself with obsolete control systems in a rapidly evolving industry requiring the latest technology to assure safe, reliable, and profitable operation.

Here's an overview of the situation:

- Gas turbines were equipped with the OEM's Mark VI controllers and Fanuc PLC sequencer. In addition to being obsolete, the Mark VI had levels of control that limited what MRES staff could access.
- The PLC controlling the cooling tower and chilled water system required for performance-enhancing turbine inlet cooling prevented plant staff access because of licensing issues.
- The BOP DCS, critical for simplified total plant control, was in need of upgrades to assure continuity of system support. Note that the BOP DCS independently controlled three of the plant's subsystems and tied together all of the other control systems and subsystems, making it appear like Exira was run by a single system. This simplified control by plant operators and by the company's dispatchers and schedulers more than 200 miles away in Sioux Falls.

Chiller purge and control systems also required upgrading, to restore vendor support. The purge system had to be replaced and to do that chiller controls had to be upgraded.

Fuel and water valve drivers were of an analog type that continued to supply a dither signal to the valves even when they were shut down. A dither signal is good when the unit is in operation, to keep the valve from sticking and ready to respond to any load changes. But continuing to dither the valve when it was shut down, increased wear and was conducive to premature failure.

Upgrade to a new digital valve positioner allowed more options—including a 0% cutoff that shuts off the valve if the unit is not running. These valves cost about $20,000 just to rebuild, so reducing premature failures improves availability and saves maintenance dollars.

The security cameras were old and the software was still running on a Windows XP machine. The video image was not satisfactory and some cameras were failing.

The digital network at Exira, and between the plant and the Sioux Falls control center, had to be refreshed. This brought the IT department into the project.

Solution. There were two main goals to accomplish in support of Exira's Controls System Upgrade Project. They were:

- Upgrade the main obsolete control systems to something that would serve MRES well into the future.
- Simplify the more than the dozen or so control systems at Exira to put them on one platform or to aggregate them into one system. Several benefits were obvious: facilitate maintenance and training, reduce spares, etc.

Work on the project started about two years before the physical effort began, with the development of a preliminary scope which was sent to various vendors for budget estimates. The budget submitted to the board for consideration was for $3.3 million.

Outages and equipment installations scheduled in 2016 were as follows:

- Sept 19-Oct 10. Installation of fiber-optic network cable and UPS cable.
- Oct 5-Nov 4. Chiller control system and purge upgrades.
- Oct 17-Nov 4. Installation of IT systems, servers, switches, and security cameras.
- Oct 17-Nov 15. Plant outage to upgrade the gas-turbine and BOP control systems.

Results. Today, Exira has all the main control systems—turbines, BOP DCS, and cooling tower/chilled water—on the same Rockwell Allen Bradley platform. Because all the systems are Allen Bradley, the interfaces among the systems are seamless, eliminating the server formerly used to translate the communications among all subsystems to get them to work together.

Plus, with all systems on the same platform, training and maintenance are simplified, dependence on specialized service providers (such as OEM reps) is lessened, finding new employees with applicable control system experience is easier, spare parts are shared among systems, reducing warehouse inventory, etc.

Project participants:
Ed Jackson, MRES plant manager
Reece Chambers, MRES resource engineer

New rules on waste-water discharges dictate conversion to ZLD

Challenge: Stricter limits on waste-water discharges imposed as part of the NPDES permit renewal process made it impossible for Exira Station to consistently comply with the new rules as the facility was originally designed and operated. Challenges faced included the following:

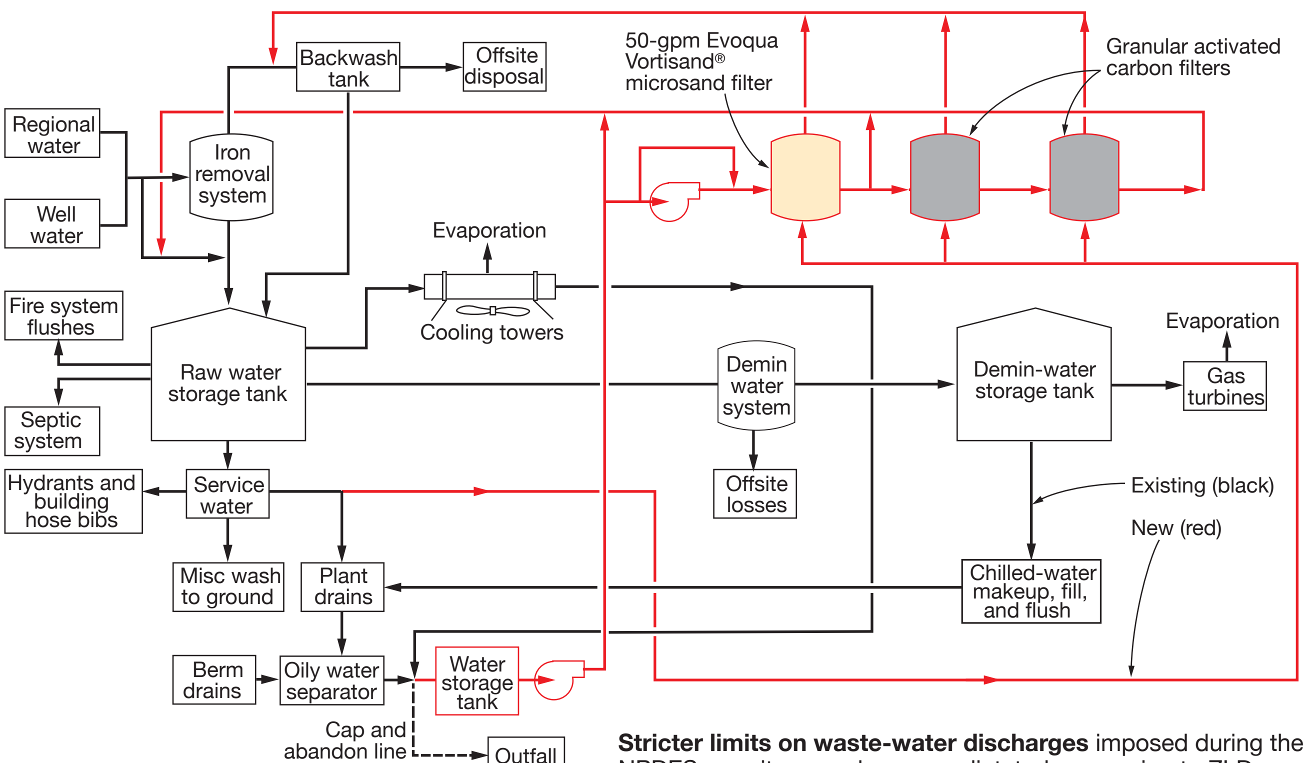
- The allowed concentration of copper in drinking water was 60 times greater than the new discharge limit.
- Trace constituents in rainwater—such as iron, copper, zinc, and lead—can exceed the new standards.
- Makeup, both withdrawn from plant wells and supplied by the regional water (potable) provider, is unsuitable for direct discharge.

Background facts:

- Simple-cycle peaking plant with three LM6000PC gas turbines.
- Inlet chillers/cooling tower.
- Demin water for NOx suppression.
- Makeup water from wells (10% to 25% of total); potable water from regional provider (90% to 75%).

Solution: Plant management decided that the optimal solution strategy was to eliminate the discharge of waste water from the plant. Their options:

- Redesign the waste-water system to collect cooling-tower blowdown and water from plant drains and containment berms and haul it offsite for disposal.



Stricter limits on waste-water discharges imposed during the NPDES permit renewal process dictated conversion to ZLD

- Evaporate the liquid and dispose of the solids.
- Recycle all waste water.

The last alternative was selected. A recycle-water treatment system was installed. It consists of an underground collection tank for blowdown, plant drains, etc, and a high-efficiency filtration system that recycles processed water back to the raw-water storage (makeup) tank. Filter backwash is retained for offsite disposal.

Critical to the success of the ZLD concept employed is the relatively small amount of makeup required for the cooling tower compared to that needed for NO_x control. This differential assures the dilution of blowdown required for economical operation of the demin system.

Here are some typical summertime (June through September) round numbers to put all this in perspective:

- Raw water storage tank (makeup) capacity, 510,000 gal.
- Total water use (includes blowdown), 44,000 gal/day.
- Demin-water consumption, 31,000 gal/day.
- Cooling-tower blowdown, 5000 gal/day (conductivity of 3000 µS/cm).
- Raw-water conductivity, 600 µS/cm.
- Conductivity of water in the storage tank (mixed raw water and blowdown), 850 µS/cm.
- Recycle-water treatment system throughput, 50 gpm.

Results: The cooling tower was designed for four cycles of concentration in summer but was limited to less than two cycles to keep all of the monitored parameters below the required NPDES limits. Negative impacts of fewer cycles: Excessive blowdown (increased makeup) and inability to maintain inhibitor/dispersant chemical levels at optimal levels to protect piping and equipment.

Conversion to ZLD (diagram) restores the original as-designed capability, thereby reducing blowdown (and makeup) and improving the effectiveness of cooling-water chemicals. Plus, collection of all drains means rainwater gathered from the berms also flows to the makeup tank (via the recycle-water treatment system). This reduces the consumption of water from wells and the regional provider.

Finally, because the plant doesn't discharge, there's no need for sampling and analysis, and no violations.

Project participants:
Ed Jackson, MRES plant manager
Reece Chambers, MRES resource engineer
Diane Martini, Kyle Vester, Sandro Tombesi, Burns & McDonnell

Channel Islands Cogen

Continuous blowdown realignment saves water, chemicals

CI Power Cogeneration Plant

Owned by California State University Channel Islands

Operated by NAES Corp

30 MW, gas-fired, 1 × 1 combined-cycle cogeneration plant located in Camarillo, Calif

Plant manager: Jeffery Smith

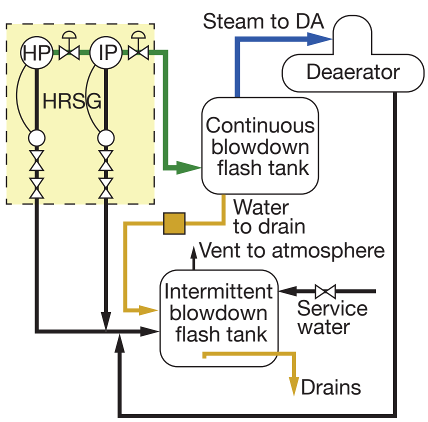
Challenge. The Channel Islands Power Cogeneration Facility, a 30-MW combined cycle equipped with a single LM2500, a Vogt Power International HRSG, and a Shin Nippon Machinery Co steam turbine/generator, operated for 30 years under a baseload power purchase agreement with the local utility. In April 2018, it began operating under a dispatch-style PPA.

The change in operating profile required keeping the HP and IP drums warm to meet startup times specified in the new PPA. Heat is provided by a sparging system which injects steam at the bottom of the steam-drum risers, thereby developing a natural-circulation pattern to sustain chemical mixing. The use of sparging steam increases drum water levels over time. Operators managed drum levels by venting steam from the tops of the drums and by opening the bottom drains when necessary.

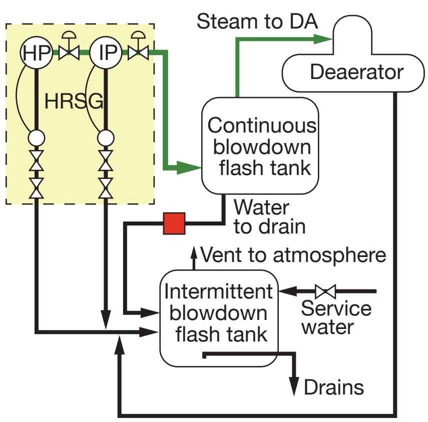
The process of adding and draining water dilutes the boiler chemicals necessary to protect drum internals. Continuous injection was required to maintain chemistry levels within the baseload target ranges.

Solution. Plant personnel began looking for ways to recapture the water from the blowdown/venting process. In reviewing the system configuration, investigation of the continuous blowdown system (CBS) showed that during baseload operation it was designed to recover some steam. After further discussion, this question arose: Could water be directed to the deaerator (DA) rather than just the steam?

During the baseload operating period, continuous blowdown valves rarely were used; most sat idle. Most



1. Blowdown system operation following steam recapture path

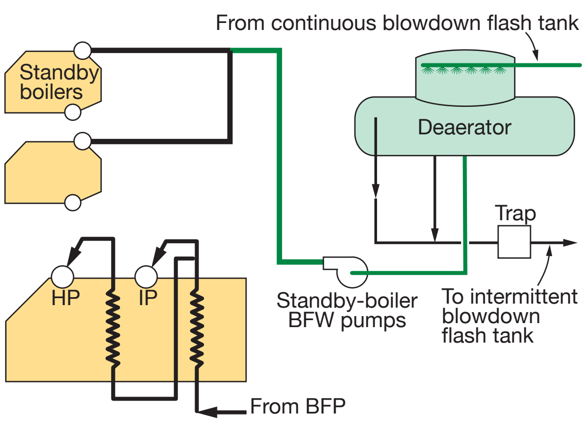


2. Blowdown system operation following water recapture path years they only were operated during annual valve maintenance. The blowdown control valves and associated manual valves were checked to verify full working capability. After a little maintenance, the system was cleared for use.

Starting with the IP drum, the system was tested to prove the concept of pushing the water from that drum to the DA. It took a couple of tries to get it to work because IP drum pressure was not high enough to overcome the water-column head pressure and DA steam pressure. After a couple of adjustments (closing the drum vent and boosting sparging-steam pressure), water could be moved into the DA via the steam path.

The chemical supplier was contacted to discuss the possibility of shifting control ranges for phosphate, pH, and O-alkalinity under the new operating profile. Plant personnel were told they could reduce the phosphate range from 10-20 ppm to 1-2 ppm. pH also would adjust slightly.

During warm standby, the chemistry levels were low enough to assume that there would be little to no chemical deposition in the feedwater system. Values were in the ppb range because of their dilution in the feedwater system. This would allow the minute amount of chemicals in the steam drums to flow through the DA to the standby boiler feedwater pumps (BFP) and finally into the standby boilers.



3. Feedwater path from the deaerator to the standby boilers

During the first few days of September, the standby BFP discharge conductivity was monitored; no change was noted. The chemistry levels in the drums of the standby boilers remained steady. The amount of chemicals transported out of the HP and IP drums did not significantly affect standby-boiler drum chemistry over the short term.

The chemical supplier also recommended that the plant monitor iron levels in the HP and IP drums. Silica typically was monitored to protect steam-turbine blades. Chemistry protocols were adjusted to check for iron when in warm standby and for silica when operating. Three months of iron sampling gave no indication of issues with the warm-standby chemistry protocol. Iron levels in the HP and IP drums are consistent with historical iron levels throughout the condensate and feedwater systems.

Fig 1 shows how the CBS works during baseload operation. Hot water moves from the HP drum to the IP drum to the flash tank (green circuit). Here the thermal drain trap holds the hot water, allowing it to steam off. Steam is routed to the deaerator (blue); water is released to drain (yellow) when the thermal drain trap cycles. In this operating profile, the control valves on the steam drums were programmed to operate based on conductivity levels in the drums.

Fig 2 illustrates the alternative operating condition for the CBS. The thermal drain trap (red) is isolated from the drain line. Hot water moves from the HP drum to the IP drum to the flash tank to the deaerator (green). For this operating profile the control valves were reprogrammed to operate based on drum level. No water or chemicals are routed to the drain.

Fig 3 shows the water path from the DA to the standby BFW pumps to

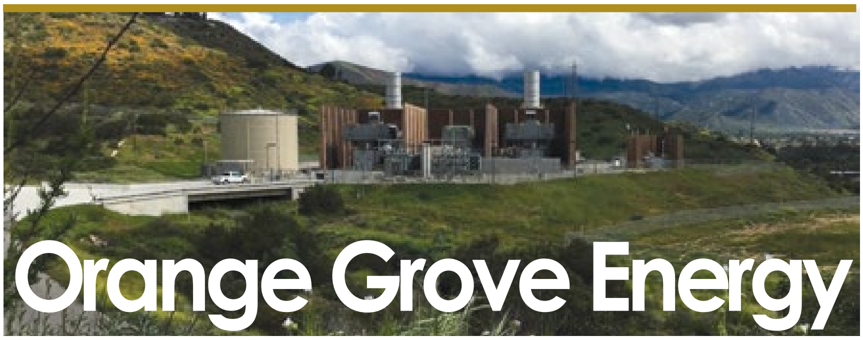
the standby boilers (green). A detailed review of the water flow path shows that there are no system components—such as attemperators—that could be impacted by the introduction of low levels of phosphates.

Both May and September were zero-dispatch months. During May the plant was maintained in warm standby utilizing venting and blowdown operating profile described in Fig 1; September used the repurposed CBS described in Fig 2.

Results. The table below compares operating parameters and chemical consumption for warm standby operation using the venting/blowdown scheme (May) and the repurposed CBS (September).

Parameter	May	September
Demin train runs	1	1
Mix-tank chemical pumps	Two on 24 hr/day	Two on 6 hr/day
HP phosphate, quarts added	5.5	2.75
HP caustic, quarts added	8.5	5
HP pH, min-max	9.77-10.90	8.90-9.90
IP phosphate, quarts added	8	2.5
IP caustic, quarts added	13	3.5
IP pH, min-max	9.80-11.00	9.00-9.90
Standby boilers phosphate, quarts added	3.5	0
Standby boilers caustic, quarts added	11.25	0
Raw water, 1000 ft^3 for month	64	45
HP iron, mg/l	–	0.002
IP iron, mg/l	–	0.003

Project participants:
Raul Perez, Dale Helin, Ben Barraza, Pete Corral, operators
Steve Hughes, I&E Tech
Michael Mackey, Nalco



Controls upgrade, redesign improve reliability

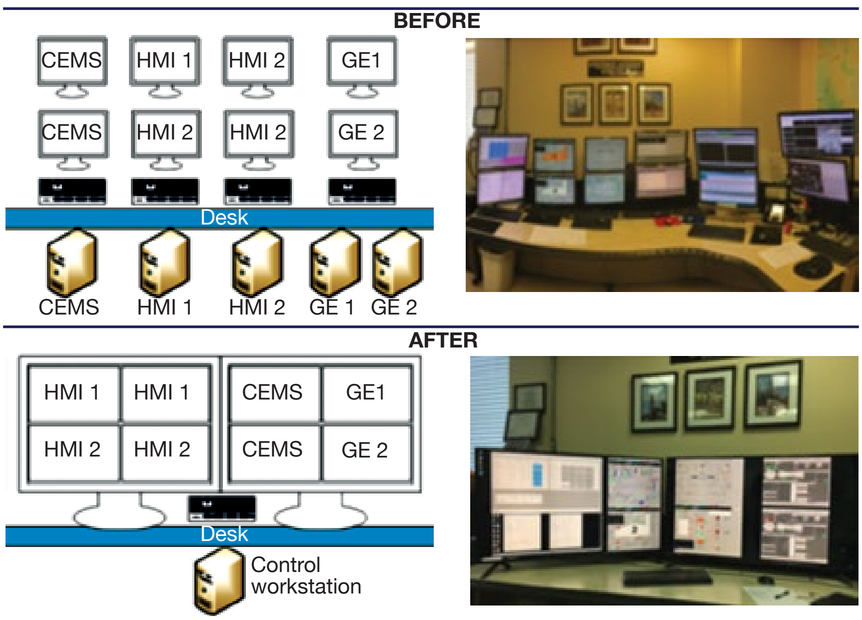
Challenge. The controls network for Orange Grove Energy (OGE) was antiquated. Old software and a complex structure exposed it to breakdowns and outages, which were attributed to the lack of redundancy and knowledge on how to restore lost components (figure). OGE's control room was home to eight displays and five stations equipped with a computer, keyboard, and mouse.

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

Additionally, there were another four HMI displays, keyboards, and computers at the facility for the OMTs.

Solution. The entire OGE control system was converted to virtual machines (VMs) running from a single Microsoft hypervisor. The VMs include balance of plant, CEMS, historian, engineering workstation, ADS, domain controller, and surveillance-camera server and workstation. To make this virtual system redundant, there are two workstations that use a remote desktop to control the VMs and two hypervisors that replicate the VMs between each other.

The two workstations can operate the plant concurrently and independently of one another. In the unlikely event that one of these VMs should fail, the VM can be recovered by either starting the replicated VM from the other hypervisor or even restored from a nightly backup.



Upgraded controls network is fully redundant to minimize downtime and enable plant operation from two locations

Results. Orange Grove now depends less on hardware upgrades and maintenance since the VMs are running from a newer robust server. This is a fully redundant system to minimize downtime and operate the plant from two different locations. As an added benefit, staff can access the VMs from a remote location for troubleshooting or remote plant operation. The control room workspace is much cleaner, less noisy, and requires less power and space since there is only one workstation, keyboard, and mouse as opposed to five.

Project participants:
John Hutson, plant manager
Ramiro Garcia, compliance manager
Anthony Moretto, lead O&M technician
Al DeLuna, Gregg Stephens, and Paul Braemer, O&M technicians
Vince Torrey, JPUSA, senior director IT
Regan Stricker, JPUSA, assistant director IT
William Taylor, JPUSA, director asset management

Shoreham

Lighting upgrade makes liquid fuel unloading area safer

Challenge. The high-pressure sodium lighting in the fuel oil (FO) offloading area at Shoreham was dim and existing light fixtures were heavy and prone to failure. Whenever one did fail, it was a challenging task requiring complete removal of the fixture from the underside of the roof in order to replace any failed components (starter, ballast, wiring, etc). The frequency with which these older, heavier fixtures were failing suggested that a more permanent solution was necessary.

Solution. Plant staff engaged a vendor whose core business is to provide LED retrofit assemblies for most commercially available standard lighting fixtures. The aim was to replace the existing fixtures with LED retrofits that offer a much lower profile, thus preventing the bases from being impacted by the wind (the most common cause of failure of the older style models).

Cost also was an important consideration because replacement parts for the existing light fixtures were proving more and more expensive, and harder to come by.

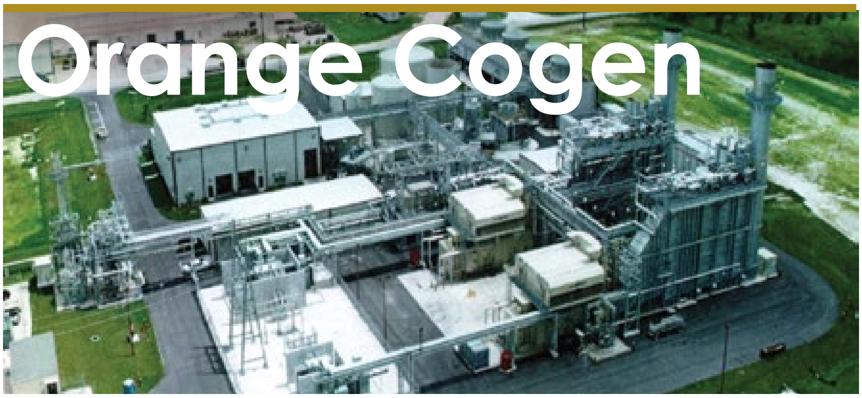
Shoreham Energy LLC
Owned by J-Power USA
Operated by NAES Corp
90-MW, two-unit, peaking facility located in Shoreham, NY
Plant manager: Kenneth Ford

Results. Since replacing all the fixtures within the FO offload area with LED retrofit kits, there has not been any unexpected maintenance. The low profile of these lights secures tightly to the box mounts, so wind is no longer a factor. Plus, the area is dramatically brighter, providing much safer walking and working surfaces for plant staff.

Switch to LED lighting saves money, makes for a safer working environment

From a financial view, the LED retrofit kits, on average, were less than half the cost of replacement incandescent fixtures.

Project participants:
Eddie Lozada, I&C technician
Anthony Angieri, chief engineer
John Lawton, O&M manager



Low-cost thermal imaging camera aids operators during rounds

Orange Cogeneration
Owned by Northern Star Generation
Operated by Consolidated Asset Management Services LLC
104 MW, gas-fired 2 × 1 combined-cycle cogeneration plant powered by DLN-equipped LM6000 engines, located in Bartow, Fla
Plant manager: Allen Czerkiewicz

Challenge. Orange Cogeneration exports power to the local utility and sells steam from its condensing/extraction steam turbine to an orange-juice plant and an ethanol plant across the street for process use. Plant reliability is important.

Like many plants today, Orange Cogen owns a thermal camera for use by technicians in troubleshooting and inspecting various mechanical and electrical issues that present symptoms as thermal gradients.

These cameras are precise and can measure very high temperatures, but they are also expensive and cannot be treated roughly by inexperienced or users.

Solution. Orange Cogen personnel found a small plug-in thermal camera, made by FLIR® Systems Inc, that does not have the full capabilities of the company's more sophisticated models but offers a wide usable range of detection and is relatively inexpensive (photos).

Although designed for attachment to a smart phone, Orange Cogen has mated it to an Android tablet which allows a very large display. Also incorporated into the plant's assembly is a rugged tablet case that has a built-in strap allowing secure one-handed operation. The complete setup cost less than $650, allowing the purchase of multiple devices to outfit the operations staff.

Results. Using this device on normal rounds, operators have found hot spots in the HRSG outer casings, motor bearings that have begun to get

Thermal imaging camera tablet, tablet case, and protective storage box are shown in the left and center photos with an example of an image provided by the camera at the right

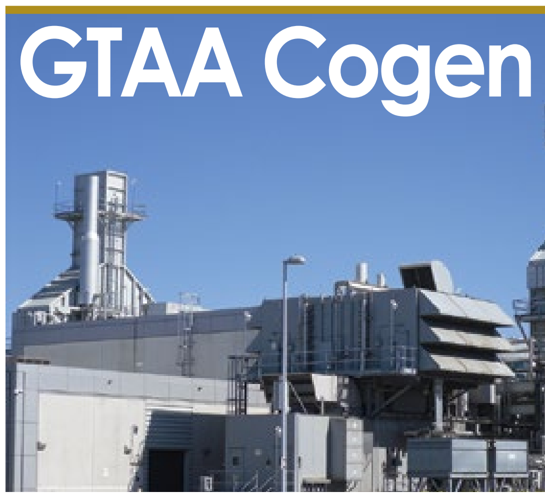
hotter than expected, as well as electrical contacts that have become hotter than neighboring phases because of higher electrical resistance. This device also allows the easy capture and sharing of pictures of these identified issues so that follow up with the more advanced unit, if required, can be quickly made.

Best of all, although this system appears to be rugged and the plant has not encountered any issues in operation, management is comfortable knowing that if the unit gets damaged, it will not be too significant a financial burden if replacement is required.

Having this preventive-maintenance tool handy for the operations staff allows personnel to get ahead of any issues that show themselves through thermal variances and gives us an improved predictive approach to Orange Cogen's maintenance activities.

Project participants:

Allen Czerkiewicz, plant manager
Joe Shaffer and Lee Bland, maintenance managers
Jason Wolfe and Jason Leverette, operations managers



Instrument relocation promotes safe, easy access to vital data

Challenge. The combined-cycle cogeneration plant serving the Greater Toronto Airport Authority (GTAA) has two gas compressors, one for each of the plant's LM6000s. Proper operation of

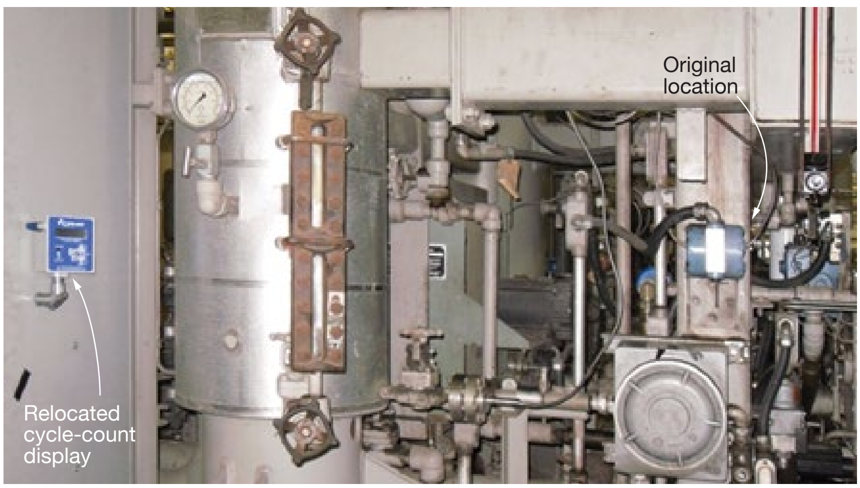
GTAA Cogen Plant

Owned by Greater Toronto Airport Authority
Operated by SNC Lavalin O&M Inc
117-MW, gas-fired, 2 × 1 combined-cycle cogeneration plant located in Mississauga, Ontario
Plant manager: Don Tiffney

the compressors is critical for achieving high engine availability.

Each compressor is equipped with a lubricator cycle-count display. It's important for cycle count to be relatively constant to ensure against excess oil which could mix in with the natural gas being compressed. The display was in a location difficult for personnel to access and take readings. Plus, ever-present oil mist made for a slippery deck.

The safety hazard was exposed when an operator slipped and lost his balance while gathering data, hurting his back in the process. The injury was not a major one, but the incident provoked a thought process to mitigate this risk.



Cycle count display was moved from crowded area to an accessible location

Solution. Plant staff initiated measures to ensure that the area is maintained clean and also installed anti-skid strips on the floor. But this was a temporary solution. Next step was to examine the feasibility of relocating the cycle-count display away from the unit in a location more accessible to operators. Personnel installed a limit switch next to the lubricator and wired it to a new cycle-count display mounted on the main panel, as shown in the photo.

Results. Relocation of the display mitigated the risk of injury to operators during their shift rounds. Also, the new location prevented oil mist from depositing on the display, making it easy to view the parameter displayed.

Project participants:
Socrates Furtado, O&M manager
Dolores Nicolica, electrician and H&S coordinator
James Chen, instrumentation engineer

Safety mod for easier filling of LM6000 hydraulic start reservoir

Pinelawn Power LLC

Owned by J-Power USA Development Co

Operated by NAES Corp

80-MW, dual-fuel, 1 × 1 combined cycle located in West Babylon, NY

Plant manager: Kenneth Ford

Re-plumbed fill port benefits ergonomics

Challenge. The challenge was to find a safer way to add fluid to the gas-turbine hydraulic starter reservoir. Photo shows the reservoir is located under a system radiator and tucked away in the corner of its auxiliary enclosure. The original design situated the fill port in a cramped and hard-to-reach location, thus creating the potential for staff injury as a result of strain or from a slip/trip/fall.

Solution. The site looked at several solutions, but in consideration of the challenging enclosure configuration, decided to relocate the fill port (lower left in photo) by adding several short lengths of piping. The relocated fill port is now in an easy to reach location and at a greater vertical height thus creating a much-improved ergonomic work space for the task of filling the reservoir.

Results. This simple solution of relocating the fill port has reduced the chance of injury from awkward body positioning. The modification has also generated very positive feedback from the site operations and maintenance staff who recognize the importance of a safe workplace.

Project participants:
Frank Pagano, OMT
Mark Whitney, O&M manager

Lawrence Generating Station

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

Operated by NAES Corp

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

Plant manager: Robert VanDenburgh

Custom platform, I-beam facilitate maintenance, improve safety

Challenge. At Hoosier Energy's Lawrence Generating Station certain maintenance evolutions inside the gas-turbine package required technicians to use an extension ladder. Example: The Kvaerner package does not have a deck at engine level so technicians had to use an extension ladder to work on the low-pressure compressor (LPC).

The ladder was lowered 4 ft from engine level so the footing could be safely secured to the package floor. This required the technician to don fall protection to complete both routine and non-routine LPC maintenance and created an ergonomically uncomfortable work environment.

Another challenge was to eliminate the rigging necessary to remove the LPC case. Rigging chains create a major safety hazard to the technicians and to the equipment. Chain-falls become a trip hazard and create several pinch points and hand traps. Chain-fall rigging requires extreme care while removing the LPC case in order to prevent airfoil damage.

Solution. The safety committee discussed options and decided that a custom diamond-plate platform would eliminate the need for an extension ladder and fall protection (Fig 1). It also would allow technicians to work safely from an ergonomically friendly position.

The operations team discussed options and concluded installing an I-beam above the LPC case would allow technicians to remove the case

1. Installation of a custom platform eliminated the need for an extension ladder and fall protection

2. I-beam centered above the LPC allows case removal without extensive rigging

without extensive rigging (Fig 2). One technician can comfortably work from the installed platform to complete the LPC case removal without the dangers associated with ladders and rigging.

Results. The custom platform installed in the LPC work area eliminated the fall hazard. The LPC now can be accessed without the need for an extension ladder or fall protection. Plus, ergonomics of this work environment have been improved dramatically.

The I-beam installed above LPC aft of the VBV ductwork allows for safe and level case lifts without need for extensive rigging.

Project participants:
Matthew O'Hara, lead O&M technician
Kevin Wildner and Jared Thomas, plant operators

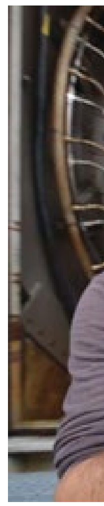
Kearny

How to conduct leak checks on an operating engine without entering the package

Challenge. Continually improve work practices at PSEG Fossil's generating plants to ensure the safety of plant and contractor personnel.

Solution. PSEG Fossil's focus on creating a world-class work environment included the development of new pro-

> **Kearny Generating Station**
> *Public Service Electric & Gas Co*
> 456-MW, 10-unit, peaking facility located in South Kearny, NJ
> **Plant manager:** Peter Van Den Houten



Camera's mobility enables operator to conduct leak checks from outside the package

cedures for its Kearney Generating Station, making tasks safer and more efficient. One example: The peaking team introduced an innovative application for GoPro Inc cameras, to put "eyes" inside the engine package. The compact camera system enables staff to capture photos and video under extreme conditions.

During post-maintenance testing or oil commissioning of the station's peaking units, leak checks are a routine task, The ability to safely look for leaks has been greatly improved with the use of this camera system, developed in-house by the peaking team.

The GoPro cameras are seated on mag-base remote mounts, giving operators pan and tilt capability. The cameras can capture a live feed and send it to an operator outside the package in a safe environment. The camera's mobility enables the operator to conduct a full set of leak checks without entering the package. Video at https://vimeo.com/306229398 illustrates the process. This has significantly improved the safety of those who perform this work and has reaffirmed staff's continued focus on two of PSEG's core commitments: safety and continuous improvement.

Results. While some other peaking plants with LM6000 gas turbines use high-cost stationary cameras for leak detection, the PSEG team took the inspection task to the next level by using GoPro cameras with pan/tilt mounts to provide greater flexibility at less cost.

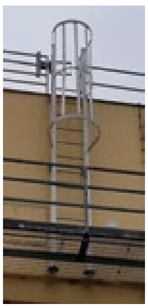
Project participants:
Al Van Hart, technical manager
Glen Davies, SOS

Mitigating hazards associated with inspection of air-inlet chiller coils

Challenge. Hoosier Energy's Worthington Generating Station relies on four 1800-ton chillers during summer peak operations to provide 40F water to the air inlet houses of its four LM6000s, thereby ensuring top gas-turbine performance.

To protect against freeze-up during the winter, 40% glycol is added to the chilled-water loop; a small boiler maintains loop temperature at 54F. The warm glycol/water mixture circulates through the inlet coils, heating inlet air to maintain the optimal temperature for efficient generation.

Periodic coil inspections required removal of the upper panels on the filter house which can be accomplished only from the top of the structure. This dictated an aerial lift and fall protection. The aerial lift created a safety hazard and fall protection increased the time required to complete inspections.



Fixed ladder (left), guardrails (center), and access-plate handles contributed to a safer workplace

Among the challenges facing plant personnel were the following:

- How to eliminate the need for an aerial lift.
- How to engineer out the need for fall protection.
- How to remove the access panels without need for a pry bar.
- How to decrease the amount of time needed to complete coil inspections.

Solution. The operations team concluded that the safest way to access the coils was to install a fixed ladder to the top of the filter house (photos). The team also decided to install a guardrail on top of the filter house package to remove the fall hazard.

Plus, handles were installed on each of the four coil cover plates to eliminate the need for a pry bar. The handles eliminate pinch points and hand traps which will allow the technician to remove the coil plates with increased safety and greater ease.

Results. By installing ladders and guardrails, the fall hazard associated with the coil inspections has been eliminated. Plus, the amount of time needed to perform inspections also has been reduced.

Because many inspections are conducted during cold weather conditions, minimizing exposure to the elements also created a safer work environment. Installing handles to the coil access plates completely eliminated pinch points and hand traps, adding another layer of safety to this task.

Plant personnel created a much safer work environment while reducing the time needed to complete inspections. The safety improvements have enabled an increase in inspection intervals, thereby boosting gas-turbine performance.

Project participants:
Matthew O'Hara, lead O&M technician
Jason Robertson and William Hooker, plant operators

Worthington Generating Station

Owned by Hoosier Energy Rural Electric Co-op Inc
Operated by NAES Corp

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

Plant manager: Robert VanDenburgh

Budget-friendly asset integrity monitoring

Sponsored by MISTRAS Group

It is imperative that plant owners and operators remain aware of their assets' conditions at all times, but purchasing the necessary inspection and monitoring equipment your plant needs can be a challenge with so many priorities to consider. This can lead to damages potentially going unnoticed, leading to even greater costs and safety hazards down the line.

That's where MISTRAS Group (NYSE: MG) steps in.

MISTRAS Group is a leading, global, OneSource provider of asset protection solutions, specializing in inspection, monitoring, consulting, maintenance, data management, and acoustic emission (AE) and ultrasonic (UT) equipment. The company offers a hardware-as-a-service (HaaS) model to make budget-friendly asset monitoring a reality.

After a MISTRAS monitoring system is installed onsite at a customer's facility, MISTRAS techs remotely monitor the data and alert plant personnel when changes may indicate a problem, reducing the need to send technicians into hard-to-access areas of a plant to perform regular inspections. This enables clients to reduce spending in the short term—by spreading out their purchase over an extended period—and in the long term, by helping to reduce the chances of damages potentially forming down the road.

MISTRAS provides not only the hardware and monitoring service, but also performs maintenance and light mechanical services, helping to ensure that the system is operating in a fit-for-purpose manner throughout the length of the contract.

Clients are able to choose between a range of contract length options, depending on their individual needs. Clients are also able to extend contracts or work towards a full purchase of the system.

The HaaS model is ideal for heavy-duty equipment like MISTRAS' Acoustic Monitoring System (AMS™) and Acoustic Combustion Turbine Monitoring System (ACTMS™), both of which offer significant benefits for powerplant asset integrity.

For example, the ACTMS provides early warning of cracking in combustion-turbine stator vanes, a necessary component for combined-cycle production. Since heat-recovery steam generators (HRSGs) can fall victim to overheating, corrosion, cracking, and other defects, and boiler tube leaks can affect multiple assets across combined-cycle plants, MISTRAS' AMS provides real-time monitoring of tube leaks, and is proven to detect tube leaks faster than traditional methods.

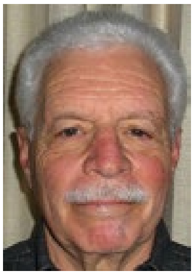
These systems save operators thousands of dollars annually, by reducing the risk of secondary damages and safety hazards, while also helping to ensure plant assets operate at peak efficiency.

MISTRAS knows the importance of its clients' equipment in combined-cycle operations. MISTRAS' budget-friendly HaaS model helps to ensure clients can continue to operate safely and successfully.

For more information, call +1-609-716-4000 or visit www.mistrasgroup.com/how-we-help/monitoring/.

BUSINESS PARTNERS

Ron Natole hangs up his cleats



Ron Natole, a positive force in the electric power industry for more than 50 years, called to say he and wife Bonnie had closed down Natole Turbine Enterprises (NTE); it was time to take a break.

Ron will be remembered as the consummate professional, always willing to share his deep knowledge of rotating equipment and to dedicate the personal time necessary to help advance the goals of the industry's professional organizations. Add in Natole's genuine good nature, storytelling skills, and love of fine red wine and you have what the editors consider the perfect colleague.

For the last 25 years, Ron provided consulting, inspection, and repair-vendor verification services primarily to users. His knowledge of gas-turbine parts interchangeability—in particular among the various versions of GE frames 3, 5, 6, and 7; Westinghouse 191, 251, and 501 engines; ABB GT 8s and 11s; Siemens V64, V84, and V94 machines—has been of great help to many owner/operators.

Ron's resume prior to establishing NTE included the following highlights:

- Manager of turbine component repair and overhaul activities at Hickham Industries.
- Manager of gas-turbine component repair at Chromalloy.
- Various positions at GE over a 16-year period—including Large Steam Turbine Manufacturing (Schenectady), first as an apprentice machinist then as a rotor test technician; and Apparatus Service (Buffalo and Baltimore), sales and shop management.

The foundation for Natole's career development was GE's 7500-hr (you read that correctly, 7500 hours) machinist and technician program in Schenectady and his BS degree from SUNY Albany. He completed various other training courses over the years on gas-turbine design, NDT, vibration analysis, metallurgy of superalloys, etc.

Ron was active in both ASME and the International Gas Turbine Institute (IGTI) for decades, serving a term as chairman of the IGTI Board of Directors plus terms as the chair of the Electric Power and Manufacturing Materials and Metallurgy Committees.

A frequent speaker at industry meetings, Natole has given over two-score invited presentations and conducted several workshops and tutorials on various subjects, including: component refurbishment, turbine operation and maintenance, engine uprates, long-term service agreements, parts interchangeability, etc.

OEM 1Q/2019 highlights

Siemens Gas & Power and Mitsubishi Hitachi Power Systems (MHPS) generate more press releases than any other company in the vendor community serving owner/operators of gas turbines in the Western Hemisphere. Below, find sound bites from releases published during the first quarter of 2019 which may be of interest to CCJ subscribers.

Siemens

Arja Talakar was named CEO of Siemens Oil & Gas as 1Q/2019 ended. He had been responsible for Siemens Saudi Arabia and has close ties to leading energy companies worldwide. Talakar began his career with Siemens in 1996 as a rotating-equipment and automation systems engineer.

Braskem, Latin America's largest petrochemical company, selects Siemens to modernize a cogen plant at its Petrochemical Complex in Sao Paulo, Brazil, and then operate that facility for 15 years. Project includes the addition of two SGT-600 gas turbines.

Gas Natural Acu (GNA) selects Siemens for the turnkey construction of a new 3 × 1 H-class combined cycle for the integrated LNG-to-power GNA-1 project in the state of Rio de Janeiro, Brazil. The OEM owns one-third of the project company and is providing an equity investment in the 1300-MW plant, already under construction.

Emirates Global Aluminum, said to be the world's largest producer of so-called "premium aluminum," signs the first power services agreement for an H-class gas turbine in the UAE. The 20-yr agreement includes maintenance, repairs, and onsite personnel support.

Qatar's Umm Al Houl, the country's second largest powerplant is "inaugurated." The facility consists of two 3 × 1 power blocks (SGT5-4000F gas turbines) capable of producing 2500 MW and 163-million gal/day of drinking water. OEM support is underpinned by what is termed a 25-yr long-term service "partnership."

Siemens H-class gas turbines passed 1-million fired hours of commercial operation midway through 1Q/2019. The company reported 70 engines in operation at that time and almost a hundred machines sold.

The maintenance service agreement with Abu Dhabi's 1500-MW Shuweihat S2 power and water plant is extended by 18 years.

Cooperative Energy's coal-fired Morrow Generating Station will be repowered with the OEM's SGT6-9000HL gas turbine. A 20-yr service agreement was part of the deal.

Oman's Duqm Integrated Power & Water Project orders five SGT-800 gas turbines and five SST-300 steam turbines to produce 326 MW and 9.5-million gal/day of desalinated water for refining and petrochemical operations. Service contract for the project spans 25 years.

An EPC firm orders two SGT-300 gas turbines for a gas-processing facility in Alberta, Canada—the first application of an SGT-300 in that country. The mechanical drives will be non-enclosed, allowing the plant-wide fire detection and suppression system to ensure worker safety throughout the facility.

Qatar Power Co extends the service agreement for its Ras Laffan B combined-cycle plant for an additional 15 years. Three SGT5-4000F gas turbines and two SST5-6000 steamers, and their associated generators, are included in the LTSA.

MHPS

As the first quarter of 2019 ended, MHPS's J fleet passed 750,000 hours of commercial operation. This fleet now includes 39 turbines in commercial operation (28 with more than 8000 hours of service); fleet leader has amassed more than 45,000 hours. The first J engine began commercial operation in 2011; fleet reliability since that time is 99.3%.

Falcon Group signs a multi-year service agreement for its Altamira II and Rio Bravo II, III, and IV 501F-powered plants, all located in Mexico. As part of the agreement MHPS will provide F4 technology and service upgrades to improve reliability and availability while extending inspection intervals to 32.000 hours.

McCoy Reports, an industry publication, says MHPS was the 2018 global leader in market share for gas turbines rated 100 MW and above, at

COMBINED CYCLE Journal No. 60 (2019)

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49%. The OEM attributed the success of its J fleet to the 64+% efficiency and 99.5% reliability recorded by those engines.

Chickahominy Power LLC orders three 1 × 1 combined cycles powered by J engines to produce in excess of 1600 MW. The Virginia plant is slated for completion in 2022.

Entergy Texas Inc selects air-cooled MHPS G-series gas turbines to power its Montgomery County Power Station. COD is expected in 2021.

Danskammer Energy LLC orders an air-cooled J-class gas turbine to repower its Newburg (NY) steam plant, built in the 1950s and 1960s.

Briefs

501F Users Group launches a new website at www.501fusers.org. Check it out! Have questions? Contact the developer, Chad Boschert, founder and CEO of Apt Crowd LLC, at chad@aptcrowd.co.

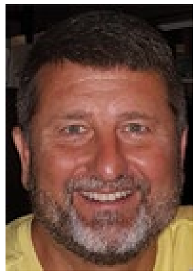
Russ Snyder, chairman and president of the 501F Users Group, was promoted (day job) to VP of generation operations for Cleco Power LLC; he had been GM of the company's Southern Gas Fleet.

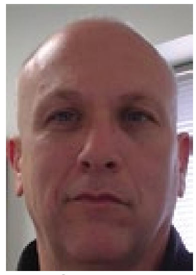
Robert Threlkeld, plant manager of Tenaska Inc's F-class 3 × 1 Central Alabama and Lindsay Hill Generating Stations, was appointed by the governor of Alabama to the state's STEM Council. The retired naval officer comes from a family of educators, with his wife, mother, grandmother, mother-in-law, and sister active or retired teachers. Threlkeld continues as a member of CCJ's editorial advisory board.

Dr Robert Mayfield and his staff at Tenaska Westmoreland Generating Station in western Pennsylvania bring the nominal 900-MW (unfired) 2 × 1 combined cycle into commercial operation a couple of days before Christmas 2018. Gas turbines are Mitsubishi J-class, the fifth and six units in this model series to operate in the US.

Mike Hoogsteden, director of services for Advanced Turbine Support LLC, will be bicycling across the country in September to raise awareness and funding for the Crohn's & Colitis Foundation—the largest investor worldwide in research aimed at curing IBD (inflammatory bowel diseases). You can support Mike on his 42-day journey by visiting online.ccfa.org/honoringWendy.

TICA, The Turbine Inlet Cooling Assn, announces officers and directors for 2019-2020. They are:


Kohler


Shepherd

Chairman, Rodney Kohler, Victory Turbine
Vice Chairman, Don Shepherd, Caldwell Energy
President, Andrew Sickler, Baltimore Aircoil Co
VP, Rob Pugh, Danfoss
Secretary, Guy Frankenfield, DN Tanks
Treasurer, Patricia Graef, Patricia Graef Consulting Inc
Director, Justin Rose, Munters


Sickler

TICA is offering a complimentary one-year membership to gas-turbine users (offer good through June 30, 2019), which saves new members up to $1000. Executive Director Dharam (Don) Punwani encourages a visit to the group's website at www.turbineinletcooling.org. You'll gain access to the online users forum, TIC performance calculator, TIC installation database, access to experts for all TIC technologies, and other benefits.

Contact Punwani at exedir@turbineinletcooling.org (630-357-3960) with any questions.

Ring eight bells for Chris McCallum who did "the right thing" by trying to break up a fight outside the American Legion hall in Quincy (Mass) back in January but was killed in the attempt. The Massachusetts Maritime Academy grad (BS Engineering in 1996 and MS Facilities Management in 2006) was well respected in the power industry. His resume includes stops at Northeast Utilities as a nuclear systems operator, International Power as operations manager and later asset manager, Next Era Energy Resources as operations manager, and Veolia Energy North America as project manager for green capital projects. McCallum was a principal consultant for Lummus Consultants International at the time of his death.

PROFESSIONAL SERVICES

Contact Susie Carahalios today at: susie@carahaliosmedia.com • Voice: 303-697-5009 • Fax: 303-697-5709

Your direct connection to CCJ's Online Buyers Guide

at www.ccj-online.com/bg

Products and services from over 100 companies support new unit construction, retrofit and maintenance activities at existing facilities, and plant operations. Solutions span gas and steam turbines, HRSGs, pumps, valves, piping, cooling towers, condensers, etc

Advanced Filtration Concepts

Offers new and innovative filtration products for the GT/ CC power industry. Invest to save with inlet air filters that are high efficiency, low back-pressure, and long lasting. As the largest stocking distributor of industrial air filters in the West, AFC is equipped to meet your most urgent GT inlet filtration needs. Turnkey installation available.

Advanced IAQ Care UScleanblast.com

Dry ice blasting of HRSGs, stators, rotors, turbines, substations, and other power equipment. ISN "A" rating for safety. 21 years of references from plants including Emera, NRG, Dominion, NY /NJ plants, NAES, and EthosEnergy. Price competitive and guaranteed excellent results.

Advanced Turbine Support

Has delivered unbiased fleet experience and superior customer service for more than a decade. Company provides users high-resolution borescope inspections, cutting edge ultrasonic and eddy-current inspections, and magnetic-particle and liquid dye-penetrant inspections in accordance with OEM Technical Information Letters and Service Bulletins.

Aeroderivative Gas Turbine Support

AGTSI offers a full range of aeroderivative gas-turbine, off-engine, and package parts from the most basic to the most critical. An expansive inventory of spares and replacement parts is maintained at our warehouse for all models of GE LM2500, LM5000, LM6000, and LMS100, as well as P&W GG4/FT4.

AGTServices

Over 200 years of combined, proven OEM engineering, design, and hands-on experience; known in the industry for its schedule-conscious, cost-effective solutions with respect to generator testing and repairs.

American Chemical Technologies

Provides state-of-the-art synthetic lubricants to the power generation industry. Founded more than 30 years ago in the US, ACT has grown to become an international supplier of value-added lubricants that provide superior benefits to equipment, the environment, and are worker-friendly.

ARNOLD Group

th more than 550 installed insulation systems on heavy-duty gas and steam turbines, company is the global leader in designing, manufacturing, and installing the most efficient and reliable single-layer turbine insulation systems.

Associated Fire Protection

Specializes in the design, installation, commissioning, and 24/7/365 service and aftermarket support of all types of fire protection and life safety systems for the power generation and petrochemical industry. ISO 9001:2015 certified company.

BBM-CPG Technology

Leader in industrial noise control with a proven engineering team and high-quality manufacturing, specializing in design and manufacturing of enclosures, exhaust plenums and ducts, shrouds, flue-gas and steam silencers, and air filtration systems.

Bearings Plus Inc

Provider of repairs and custom technology upgrades for turbomachinery. Designs and manufactures an integrated solution to meet specific requirements for every operating environment, applying the latest fluid film bearing and high-performing seal technology to legacy equipment to optimize performance.

ABOUT QR CODES

A wealth of data in the palm of your hand. Visit your App Store and download one of our suggested QR readers for your smartphone or tablet to access enhanced digital content and information.

Recommended, free, and easy-to-use apps:

- AT&T Code Scanner
- QR Reader for iPhone
- QR Reader for Android

Available on the Android App Store

Available on the App Store

Bremco

Full-service industrial maintenance contractor since 1976. Company experience in combined-cycle projects includes header, tube, and complete panel/harp replacements. We also have significant experience in liner repairs/upgrades, duct-burner repairs, penetration seals, and stack-damper installations.

C C Jensen Oil Maintenance

Manufactures CJC™ kidney-loop fine filters and filter separators for the conditioning of lube oil, hydraulic oil, and control fluids. Our extensive know-how ensures optimal maintenance of oil systems and equipment reliability.

Caldwell Energy

Power augmentation, including inlet fogging and wet compression solutions, boosts the output and efficiency of gas turbines. With more than 400k hours of operating experience in power generation, these systems offer proven performance and are backed by a three-year warranty.

Camfil Farr Power Systems

A world leader in the development, manufacture, and supply of clean air and noise reducing systems for gas turbines. A correctly designed system minimizes engine degradation, leading to lower operating costs, optimum efficiency, and less environmental impact.

Catalytic Combustion Corp

Designs, engineers, and manufactures the catalyst – the heart of an effective emissions system. CCC also manufactures the housing and all the critical components at our Midwest facility. Our process of producing folded catalyst substrates is a proven method to quickly manufacture robust catalysts.

Cemtek KVB-Enertec

Leading supplier of custom-engineered extractive, dilution, and mercury CEMS from single units to multiple complex units in cabinets and shelters; and provider of support for compliance and non-compliance applications.

Chanute Manufacturing

Contract fabricator of HRSG products—including finned tubes, pressure-part modules, headers, ducting, casing, and steam drums.

Cormetech

The world's leading developer, manufacturer, and supplier of catalysts for selective catalytic reduction (SCR) systems to control emissions of nitrogen oxides from stationary sources. Cormetech SCR catalysts are highly efficient and cost-effective where systems must be capable of reducing NO_x by more than 90%.

Crown Electric Engineering & Manufacturing

Engineers, designs, fabricates, and installs isolated phase bus, large bus duct systems, and outdoor switchgear. Specializes in rapid response needs such as IPB for GSU change-outs, quick-ship fabrication, and emergency on-site service needs.

Cust-O-Fab Specialty Services

Provides the latest technology in exhaust plenums, exhaust ductwork, and exhaust interior liner upgrades that will drastically reduce external heat transfer, making the unit safer and more efficient and easier to operate and maintain.

Cutsforth

Our experience and innovative designs have brought best-in-class brush holders, collector rings, shaft grounding, and onsite field services for generators and exciters to some of the world's largest power companies.

DEKOMTE de Temple

Manufactures fabric and metal expansion joints which compensate for changes in length caused by changes in ductwork temperature. Axial, lateral, or angular movements can be compensated for. Company has gained a global reputation for ingenuity of design and quality of products.

Donaldson Company

Leading worldwide provider of filtration systems that improve people's lives, enhance equipment performance, and protect the environment. Donaldson is committed to satisfying customer needs for filtration solutions through innovative research and development, application expertise, and global presence.

ECT-Engine Cleaning Technologies

Offers R-MC and PowerBack gas turbine and compressor cleaners to eliminate compressor fouling. Additionally, ECT designs specialty nozzle assemblies and custom pump skids for the proper injection of chemicals and water for cleaning, power augmentation, and fogging.

Environex Inc

Engineering and consulting experts in post-combustion NOx and CO control technologies. Primary focus is SCR and oxidation catalyst testing and system maintenance, catalyst management and selection, troubleshooting, and design.

Emerson Automation Solutions

Ovation™ control system offers fully coordinated boiler and turbine control, integrated generator exciter control, automated startup and shutdown sequencing, fault tolerance for failsafe operation, extensive cyber security features, and embedded advanced control applications that can dramatically improve plant reliability and efficiency.

EthosEnergy

This JV between Wood Group and Siemens is a leading independent service provider of rotating equipment services and solutions. Globally, these services include EPC; facility O&M; design, manufacture, and application of engineered components, upgrades, and re-rates; repair, overhaul, and optimization of gas and steam turbines, generators, pumps, compressors, and other high-speed rotating equipment.

Evapco-BLCT Dry Cooling Inc

Specializes in the design and supply of air-cooled condensers (ACCs) and air-cooled heat exchangers (ACHEs) for the power industry with over 5000 MW of operating references in the USA and considered a premier ACC supplier for the global power market.

EvapTech Inc

Full service provider of new towers and aftermarket services for field erected cooling towers. World leader in evaporative and hybrid cooling technologies specializing in design, component manufacturing, construction services, parts, upgrades, and consultation.

Falcon Crest Aviation

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 power-plant 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

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.