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CCJ COMBINED CYCLE Journal

Reports from user-group meetings

Frame 6 Users Group — The user group's 2020 meeting was canceled because of Covid-19, like so many other forums. The report here is from the 2019 conference. Highlights include roundtable discussions on safety, auxiliaries, I&C, and best practices; presentations by users on high wheel-space temperature issues, exhaust-plenum replacement, and rotor life extension; a case history discussing the effects of cyclic duty on air-cooled generators; highlights from GE Day; and the details of two best practices shared by BASF Geismar **10**

AOG — The 2020 conference of the Alstom Owners Group was conducted early in the year and was face-to-face. This proved to be a "breakout" year for AOG with nearly two equipment/services providers and 50-plus users participating in a four-day program that included presentations on a wide range of subjects, a shop tour (Doosan Turbomachinery Services), and several training sessions—all having value to the large majority of O&M personnel at simple- and combined-cycle plants **22**

7F USERS GROUP — This, the first web-based annual meeting conducted by a user group serving owner/operators of gas-turbine-powered simple- and combined-cycle generating plants in the US, was a blockbuster. The 13-day event, conducted over five weeks from June 16 through July 16, involved nearly 700 owner/operators, 10 sponsors, and more than 40 vendors in the exhibit hall. CCJ's report runs more than 30 pages. **70**

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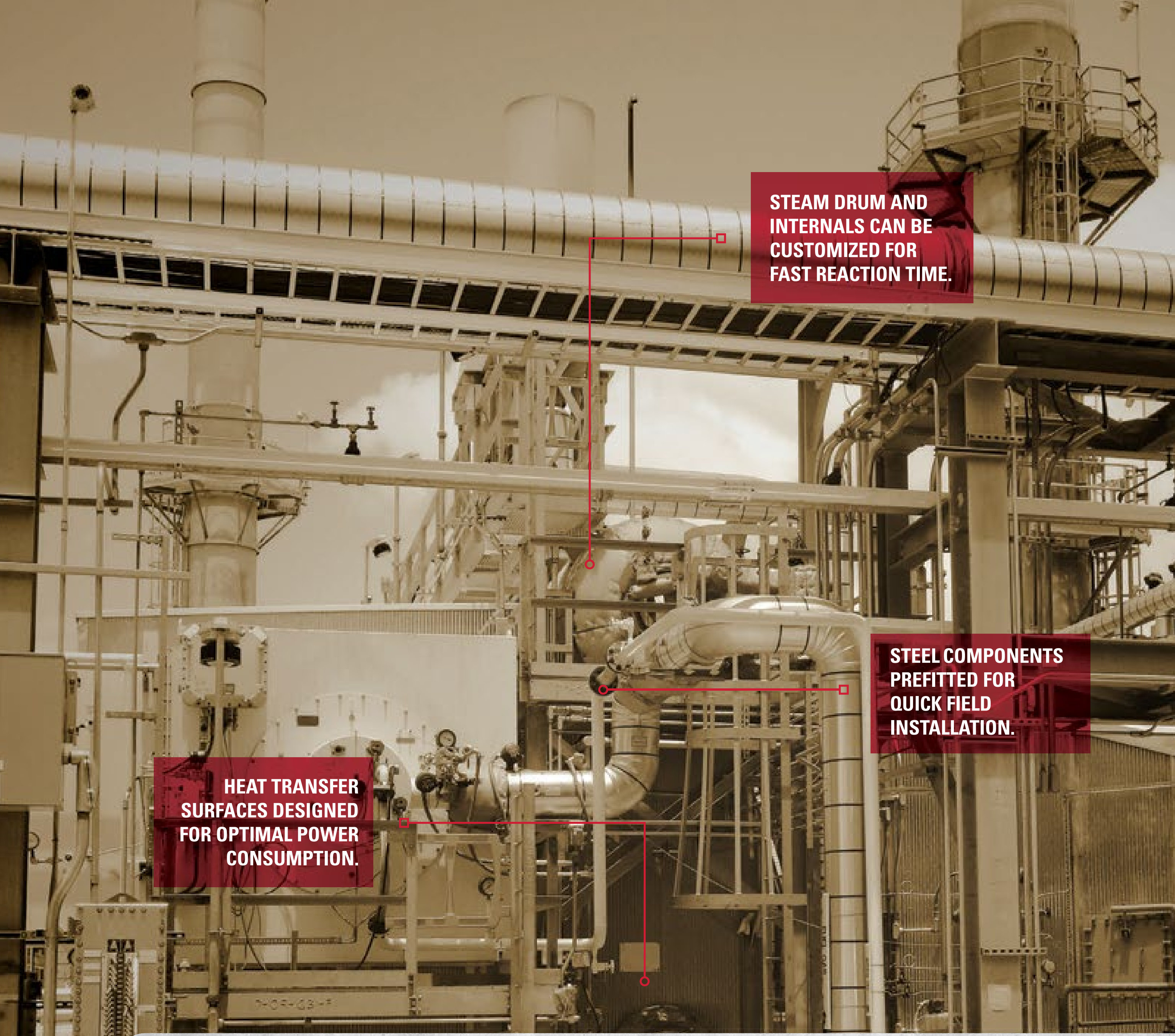
INDEPENDENT VOICE OF THE GAS-TURBINE-BASED GENERATION SECTOR


STEAM DRUM AND INTERNALS CAN BE CUSTOMIZED FOR FAST REACTION TIME.
STEEL COMPONENTS PREFITTED FOR QUICK FIELD INSTALLATION.
HEAT TRANSFER SURFACES DESIGNED FOR OPTIMAL POWER CONSUMPTION.

The value of remote technical support during generator inspections, maintenance

By Clyde V Maughan, president, Maughan Generator Consultants

Cost-containment initiatives over the past several years have encouraged the move to more offsite technical support of outages in powerplants. More recently, Covid-19 travel restrictions have made onsite technical support difficult. Thus, offsite support via video-chat technology has become more common. This has encouraged discussions questioning the adequacy of such offsite support. Recently, a roundtable was convened on this topic on the website of the International Generator Technical Community (IGTC, www.generatortechnicalforum.org).

Participants requested examples of successful specialist remote support. Response was high: six from engineers employed by owner/operators, 36 from consultants. Few of the responses provided information on successful remote support; most were comments on the adequacy of offsite support (sidebar). Owner responders all preferred onsite support but considered remote support as having value.

Remote support. Offsite support can have important benefits to owner/operators. Most importantly, perhaps, is that the convenience of remote support expands the available pool of consultants and the travel money saved can be used for second, possibly third, opinions.

Why is this important? Not all "experts" are experts on all topics; some, in fact, may not be expert at all. But when a generator owner/operator brings an "expert" onsite, that individual likely will be the only expert with whom it will talk. There have been incredible errors made by such "experts." Here are three examples:

- Unqualified expert. On a routine inspection of a large, modern generator the owner brought in a local "expert" who advised misuse of a common stator winding test. This resulted in a recommendation to rewind, which cost close to $100 million in unnecessary rewind and replacement-power costs.
- OEM engineer error. A 20-yr misunderstanding by OEM engineers of a stator-winding wear mechanism on a line of large generators resulted in rewind and loss-of-generation costs approaching a billion dollars.
- Multiple experts onsite. A very large, very old 4-pole generator with asphalt stator windings was being operated 40 hours annually in a university research laboratory. During a field-out inspection, both an OEM engineer and an independent consultant recommended the following: "Rewind now or risk catastrophic failure." A consultant with extensive experience on asphalt windings recommended the plant "Hipot the winding at 1.5E, and plan for the next field-out inspection 200 years from now." The university is following the latter recommendation and avoiding a difficult $3-million rewind—at least for now.

Had the owners in the first two examples been able to tap into a pool of competent consultants and obtain the guidance of a second or third opinion, these very costly situations might have turned out quite differently. Furthermore, the second example illustrates the potential value to owners of having access to a pool of skilled experts when an OEM may be recommending questionable actions.

The availability of talented offsite support will make obtaining the views of multiple consultants convenient and cost effective and will offer the owner ready access to multiple options.

Becoming a generator expert. One of the technical-support issues an owner faces is selection of an appropriate consultant (expert) for the job at hand. How does an "expert" become an expert? In my attempt to understand generators over a 70-yr career, I had the privilege of learning from a dozen incredibly talented industry engineers. Most of what I know I learned listening to these dozen men. Two diverse examples: Dean Harrington (deceased) from an OEM and Jim Timperley from a utility (see safety article later in this issue). Most capable experts have had similar experiences. But today most consultants will not have that privilege, nor in the future is it likely to be even available.

Depending on the properties of the mind of the individual, no amount of training may make a generator expert. Reason: The generator is a highly non-intuitive and extremely complex machine. Unless a person is gifted with a mind that deals well with the non-intuitive and complex, that individual may never become an expert.

As a consultant, 25 years ago I threw caution to the wind and wrote a book on generator design, duties, and deterioration. Using this book I conducted more than 30 two-and-a-half-day seminars for over 1000 attendees.

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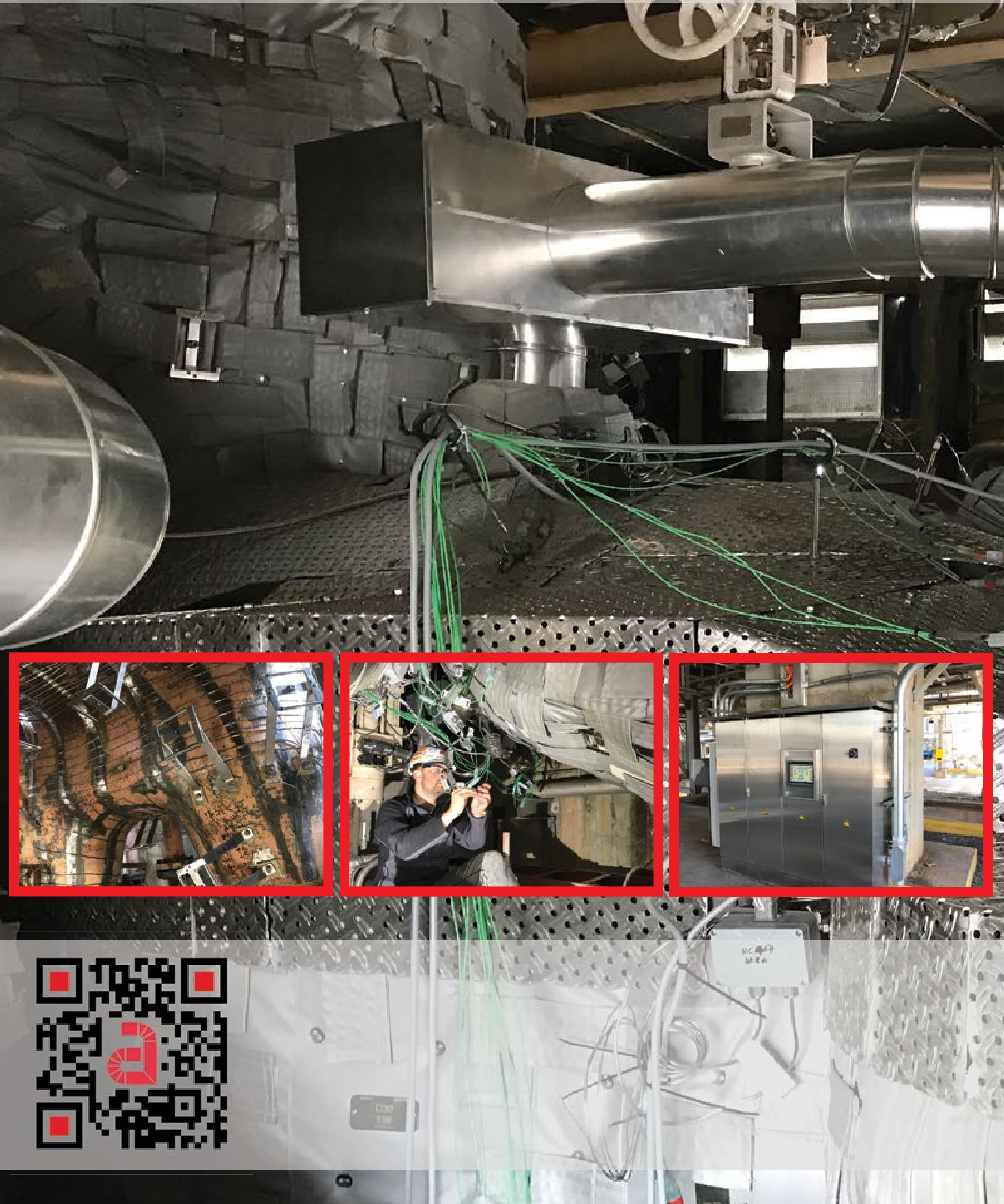
NEXT GENERATION



I hoped to provide sufficient information that the user participants would learn enough about the generator to differentiate between an expert and non-expert. I was not trying to make, nor could I make, experts of them in a training course.

The future. As the use and value of offsite support expands, there are several factors to consider, some of which are mentioned below:

Remuneration. The average cost for a site visit by a generator consultant today, including travel, hotel, meals,

What others think about the value of remote support

Engineers with experience in the operation and maintenance of electric generators recently shared their views on the value of remote support during an online forum. Roughly three dozen participants were involved. The editors extracted the thoughts below from what four highly experienced consultants said.

Consultant A completed a "desk review" of an instrument-transformer failure through remote support during the pandemic, which restricted travel. The owners provided onsite inspection observations and photographs. "We were able to coordinate activities by marking up photographs as supplied and requesting additional photographs of specific areas," he said. This extended the analysis process, but considering three days of travel time would have been required, the overall process was faster than going to the site. Project cost was reduced since there were no travel expenses and the fee for travel time was eliminated.

While larger projects will require onsite inspections, small, less involved, projects can be performed with the excellent communications available today. "We conducted daily conference calls," Consultant A stated, "but did not use live video since a good internet connection was not available at this location. A live video inspection would have saved time. That should always be considered. Even when travel to the site is required, starting with remote inspections of the conditions will save time overall."

Consultant B said that Covid-19 travel restrictions made it necessary to conduct rotor-out inspections and interpret EMI tests remotely. With that experience in hand, he believes offsite support may be a promising alternative to onsite visits in the future—at least for some tasks. He thinks OEMs already are moving in this direction to keep personnel safe in less-secure areas of the world.

Consultant B said that while a cell phone and camera are necessary for remote access, analytical success demands more sophisticated tools and proven solutions. Plus, power producers will have to adapt to not having the comfortable onsite presence of specialists. OEMs and third-party vendors will have to change as well, taking responsibilities without their physical presence in powerplants.

Consultant C, a metallurgist, typically is called when something is broken and plant personnel want to know what's wrong "with this thing." His work almost always starts out with phone calls, written communication, and photos, lots of photos. The technical process for failure analysis has not changed much in the last half century, he said, but the way you get to a successful conclusion is different in some respects.

What is different:

- Access to good cameras. Plant personnel generally can take the photos required for diagnosis and for explanation of the failure process. A bit of back-and-forth is involved, but it generally works.
- Much better computers. We can now put very clear graphics on photos and figures to explain a failure process or damage process.
- Remote meetings are possible and with a high-quality communications system for conducting meetings, effective tutorials can be presented on a given failure/damage condition. The big benefit is that people can leave the meeting with a clear an unambiguous understanding of what happened.
- Power generation has transitioned from a utility-dominated business with deep experience to one with assets owned by utilities and independent power producers typically having minimal (or no) central-office technical support.

What is not different:

- People on the user side are overloaded and have varying levels of experience—from high to low. This means consultants have to up their game to take less time to explain complicated processes.
- Consultants must make sure that a clear explanation of the analysis process and the basis of the final answers/conclusions/recommendations gets to the right people in the organization.

Consultant D has been involved in generator inspections, failure investigations, and root-cause analyses (RCAs) for nearly half a century. He said that while performing his work remotely is possible in some cases, most engagements require an experienced eye onsite to gather important details often overlooked by the owner/operator.

To perform a proper RCA, for example, one must look at many details not available via a video inspection. Touch and smell are important, too, he noted. Plus, potential problems with language and terminology may impact communications given the international nature of power generation, and clarification may be necessary. Onsite meetings can help in this regard. Remote review of operating data is possible—provided you trust the accuracy of monitoring equipment. You might not have the necessary confidence unless you had eyes on the instrumentation.

When a generator fails, he continued, "what I hear from an initial phone call and photos usually is well off-base with respect to determining the problem and the solution." A rule of thumb: A good failure investigation requires an extensive onsite inspection, possibly taking a day's time, to fully assess the failure and the associated unit condition.

A thorough inspection also is likely to find other issues. An example this consultant gave: While investigating a stator winding failure, you might expect to find additional stator problems, rotor problems, air-gap problems, frozen radial dowels, surge-ring cracks, and who knows what else. A video would fall short in fulfilling this mission.

Regarding testing, Consultant D said, "I have given explicit detailed testing procedures via email and phone and received strange results. Further discussions over a month-long period finally proved the directions were not followed and the test invalid."

On the topic of "becoming a generator expert" the consultant stressed the value of formal education, logical thinking, an innate and high degree of common sense, life-long dedication, and a love of the work. A degree in power engineering, Master's preferred, is the ideal foundation. No matter how much on-the-job training one has, he continued, knowing power basics, symmetrical components, machine design, dynamics, forces, thermodynamics, basic chemistry, etc, is crucial in developing first-class expertise. It allows one to fit together the pieces of the puzzle.

etc, probably is in the neighborhood of $15,000. That number might be reduced by one-third or more by opting for remote access.

Decision between onsite and remote support. I made about 450 onsite visits in my consulting career. Probably half could have been done well offsite with present technology. With better technology and a trained onsite owner's engineer, three-quarters, or more, of these jobs could have been done well remotely. There are many variables in this "equation" but certainly in the future many onsite visits can and will be replaced with remote assistance. The outcome of the onsite-to-offsite transition will depend a great deal on participation by all affected parties.

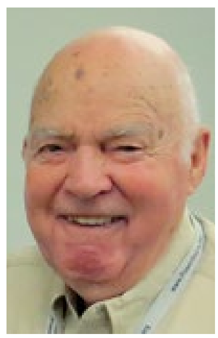
Owner support onsite. Remote technical support demands that the owner have a knowledgeable, capable individual onsite. Training for this assignment can be provided by seminars that teach the fundamentals of generator design, deterioration mechanisms, inspection, test, and maintenance—as described earlier.

Capability of consultants. In an offsite world, the true expert will be able to handle many more jobs. A way for owners to share their confidential assessments of individual consultants should be developed so the best engineers will be among those considered for a particular assignment. A secure user-only website, such as that hosted by the Generator Users Group, might be considered for this purpose.

Industry conferences. Online conferences, while not ideal, have major advantages. For example, rather than spending a week away from the plant, the participant spends a couple of days attending the conference from his/her office. Think of the time/cost saving. The reach of an online meeting also is much greater because of favorable economics and convenience. It's possible, for example, that a meeting of the Generator Users Group could attract a few hundred participants rather than the two or three score it typically hosts.

Technology advances. The ability to transmit high-resolution photographs to experts starting about 20 years ago made offsite analysis practical and jump-started the alternative to onsite evaluation. The same is true of today's video cameras and video chat systems for offsite support.

Summing up, the evolution in technical support toward offsite support is inevitable. For it to be done well to the maximum benefit of owners, plant and central-office personnel need to take a leadership position in the transition effort. CCJ



Clyde V Maughan retired from active consulting in July 2018 at the age of 92. Today he spends free time sharing unselfishly his extensive knowledge of generators with those seeking advice. The Clyde, as he has come to be known, spent 36 years with GE before "retiring" in 1986 to form his consultancy. Much of the knowledge Maughan acquired during his 70-yr career has been shared with the electric power industry through more than two-score technical papers, more than a dozen CCJ articles, several webinars, his handbook "Maintenance of Turbine-Driven Generators," dozens of seminars, and other avenues of communication. He also founded the Generator Users Group with help from a few industry associates and contributed significantly to the launch of the International Generator Technical Community.

Barry Worthington

July 24, 1954 – August 14, 2020

CCJ's editors mourn the passing of their colleague Barry Worthington, a loyal supporter of this journal's editorial mission. Few readers are likely aware of the United States Energy Association, fewer still would recall ever having heard Barry's name. That's because USEA focuses, in a broad sense, on the economics and politics of energy—electricity, coal, oil, gas, renewables—while your core responsibility is to produce electricity from gas turbines cleanly, efficiently, and reliably at the lowest-possible cost. This is important to USEA as well, as it supports the federal government's objective of bringing energy access to millions of global citizens without it.

Worthington, who started his career at Houston Lighting & Power Co after graduation from Penn State with an energy/environmental-centric degree, joined a floundering USEA in 1988. The nonpartisan, non-lobbying organization had two employees and revenues of $200,000; expenses were $250,000. Barry rolled up his sleeves and went to work. Today USEA has more than two-dozen employees and annual revenue in excess of $10 million.

This level of engagement is important to support the organization's worldwide activities. Key among its programs are the following:

- Energy Utility Partnership Program provides assistance to utilities and energy companies in developing countries to strengthen their ability to effectively manage, plan, and operate power systems, run financially viable businesses, and integrate different types of energy resources into their power grids. The power sectors of some three dozen countries have benefitted from this program.
- Energy Technology and Governance Program helps European and Eurasian countries improve their energy security and integrate energy markets on a regional basis.
- The annual Energy Supply Forum assesses the state of energy exploration and production, electricity generation, and energy fuel supply.
- Advanced Energy Technology Forum, introduced in 2019, explores the nexus between energy policy and technology development.

There's more, much more, that USEA does—a tribute to Barry's vision and incredible work ethic. Consider visiting www.usea.org.

Accomplishments are important, for sure, but perhaps more important is what the energy executives, government leaders, and others who knew Barry thought of the man, the leader, the doer. Hundreds of messages from around the world poured into USEA's Washington headquarters when word of his passing was announced. The following edited snippets testify to the enormity of the industry's loss.

- It is impossible to articulate the grief we feel about the loss of Barry Worthington. He was a remarkable leader.
- The most extraordinary ordinary man—unpretentious, self-effacing, decent to the extreme, casual, and abundantly capable.
- He was a diplomatic yet unapologetic pragmatist.
- Barry circumvented political polarity.
- He sought common ground among stakeholders, and he valued partnership.
- A class act, kind, and giving person; generous with his time, always gracious.
- Barry's contributions to the world of energy were meaningful and lasting.
- Well-respected in all facets of the US energy industry—and worldwide. His leadership brought USEA to be the pre-eminent organization that it is today.
- Barry's keen intellect, experience, and quick wit will be sorely missed.
- Barry's travels were the stuff of awe and legend: off to Beijing, Dubai, or Rio today, back tomorrow. Were there a prize for speed of travel turnaround, Barry would have won it over and over. He was the quintessential family man.
- The USEA's work on carbon capture, utilization, and storage has been pioneering.
- A tireless advocate for American energy and bringing infrastructure where it was needed most around the world.
- He traveled the globe in a nonstop search for consensus and innovation.
- Barry exemplified integrity.
- An energy-industry legend, incredibly knowledgeable.
- He walked with potentates and political savants from across the world and talked with them unaffectedly, as though he was leaning over a neighbor's fence.
- You might not talk to Barry for a couple of years, no matter, he was always available to answer your questions or provide needed advice—in the office, at home, or on the road.
- Unflappable.

—Bob Schwieger

Sheila Hollis, USEA chairman (center), was appointed acting executive director following the death of Barry Worthington (left); former USEA Chairman Vicky Bailey (right) was appointed executive chairperson

Herman Farrer Photography

Former Secretary of Energy Rick Perry (left) and Barry Worthington team-up for an open discussion session with attendees at the inaugural Advanced Energy Technology Forum in 2019. Perry delivered the keynote address

Frame 6 Users Group

What a difference a couple of years can make.

It wasn't long ago that the Frame 6 Users Group could be defined by the phrase "business as usual." The steering committee had remained the same for many years, as did the core attendee base and conference organizer. The meeting format essentially was "etched in stone."

So was the program content, to some degree, because the 6B is a familiar GE gas turbine in cogeneration systems at process plants where staff typically is challenged to keep legacy assets operating on a low O&M budget, often without the support of a corporate engineering staff. The presentations and discussions at annual meetings provided know-how and proven solutions to help achieve that goal.

In 2020, Jeff Gillis, a senior engineering advisor at ExxonMobil Research & Engineering Co, continues to chair the group, supported by veteran steering committee members J C Rawls, technology engineer in BASF-Geismar's utilities department; Mike Wenschlag, Chevron Global Power, El Segundo refinery; and Zahi Youwakim, utility plant engineer, Huntsman Petrochemical.

Robert B Chapman Sr, turbine repair engineer for Chevron Maintenance & Planning Execution, joined the committee two years ago. More recently, Kevin Campbell, a cogeneration specialist at the El Segundo refinery, and Kevin Bovia, a mechanical reliability engineer at BASF-Geismar, were added to the roster.

They replaced Geoff Kret of Total Petrochemicals USA, Sam Moots of Colorado Energy Management, and Brian Walker of Foster Wheeler Martinez Inc, whose corporate responsibilities had changed, plus Atlantic Power Corp's John Vermillion.

Wickey Elmo of Goose Creek Systems, who managed the user group's activities for several years, retired at the end of the 2016 conference and was replaced by the incumbent Greg Boland.

Perhaps the biggest hiccup in the group's three-decades-plus of service to the industry was the need to cancel the 2020 Conference and Vendor Fair because of the coronavirus pandemic. Some online sessions in the planning stage will help keep owner/operators current on fleet developments. Details will be posted at www.frame-6-users-group.org when they become available.

What follows is a report based on presentations and discussions conducted during the 2019 meeting at the Hilton Orange County in Costa Mesa, Calif, June 10-13, where Brian Walker received the 2019 John F D Peterson Award from Chairman Gillis, and the award's namesake, for his many years of outstanding service to the Frame 6 community.

Walker came up through the trades, accumulating more than two decades of experience in E/I&C work prior to his appointment as maintenance manager and HSSE coordinator at the Foster Wheeler Martinez combined-cycle cogeneration facility in Northern California.

Sean Bonato of Montana Dakota Utilities Co also accepted an award from Gillis, this one commemorating 40 years of operation by the industry's first Frame 6 (MS6431A), installed at MDU's Glendive Power Plant. Commissioning was July 15, 1979. The Glendive Frame 6, rated 41 MW according to Platts data, shares the site with a 43-MW LM6000. Both are dual-fuel capable, says Platts.

Workshop and schedule

Monday afternoon, June 10, the day before the 2019 conference began, Peterson, one of the user group's founders, conducted his highly regarded four-hour introductory course on the Frame 6B. This session is offered by the steering committee to acquaint new members on the (1) history of improvement in both thermal and mechanical performance since the engine's introduction in 1978, and (2) opportunities offered by the Frame 6 Users Conference for the best possible technical exchange and interaction with other owner/operators of the versatile engine, OEM engineers, and representatives of third-party products and services providers supporting the fleet.

The workshop is invaluable for first-timers and a welcome refresher for many veterans. It begins with a brief history of gas-turbine development (specifically the Frame 6) and moves quickly through Brayton Cycle basics. Key performance indicators are next, followed by an overview of engine components—compressor, combustion system, turbine, auxiliary equipment, and fundamental control concepts.

Common failure mechanisms and problems solved over the years (nozzle oxidation and creep, first-stage bucket life, etc) follow. The final segment of the program reviews resources available to users to enable better O&M decisions.

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

The formal meeting kicks off Tuesday morning at 8 a.m. and features several roundtable discussions and a vendor presentation before the opening of the vendor fair at 5 p.m. The roundtable topics last year (most years): safety, auxiliaries/generators/excitation, I&C, best practices, compressor, and combustion section. The featured presentation, by Jamie Clark of AGT Services, concerned case histories on a 6A3 field rewind and stator re-wedge.

Wednesday—so-called GE Day—

is reserved for OEM presentations (new/updated Technical Information Letters, rotor end of life, new technology offerings and updates, etc) and breakout discussion sessions. In 2019 the breakouts focused on the rotor, generator and engine accessories, FieldCore, combustion systems, I&C, and repair technology. A reception and GE product fair closed out the day.

Thursday, always a half-day at Frame 6 meetings, featured a roundtable discussion on the turbine section plus the second of two vendor presentations—this one by PSM on rotor repair and life extension.

Roundtables

Safety is the first discussion topic at Frame 6 meetings and most other user-group conferences. This roundtable is led by Gillis, whose position as gas-turbine technology lead for ExxonMobil's worldwide fleet of engines gives him a global perspective to share with attendees. OSHA is not global and America does not have all the answers.

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

General
- Life-saving rules.
- Compartment entry.

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

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

The first topic introduced concerned a unit trip on high oil temperature without alarm notification. Plus, recorded data did not indicate any change in temperature. The alarm for high oil pressure also was found faulty. The gremlin was a loose wire. Termination strip was repaired and the unit returned to service in the late afternoon. The user sharing the experience said termination strips can take just so much abuse and suggested that the person you assign to work on them should be someone you trust with a screwdriver.

An attendee shared his experience with a black-start unit brought up to full speed/no load (FSNL) that couldn't be synchronized. The safety issue was that the Mark VI auto-synch feature was not turned off and the breaker closed with electricians in the generator auxiliary cabinet. The group was polled to see how many attendees close the generator breaker with someone in the GAC. No hands were raised.

One outcome from this incident was a modified startup procedure that requires operators to confirm excitation at 50% speed on black-start units. Also, electricians must check the GAC to confirm there are no faults prior to startup. Finally, a warning sign was hung on the cabinet door and operators are required to issue stop-work permits to electricians during engine starts.

Another technicion mentioned that PPE safety boxes are located at strategic locations around his plant. They include PPE-use requirements for specific tasks and equipment. Tooling also is located throughout the plant. One example given was the placement of toolboxes on top of the HRSGs to reduce the need for technicians to travel back and forth to a central location, saving time and reducing the risk of injury.

One user offered an observation that safety procedures often are "ignored" between outages, when the safety "police" are not on duty.

Fire protection is discussed at every meeting. Last year a user mentioned that the CO_2 system at his plant discharged before the alarm activated. Having reliable alarms and external lighting to warn of a release is critical to personnel safety. One got the impression that controls for fire-suppression systems—water mist and CO_2—were not as reliable as they should be. Hard to find qualified vendors to maintain these safety systems, according to a few participants. One said he double-checks third-party certifications and any work done on the system.

Attendees were urged to check package integrity for leaks because if leakage persists—at louvers, for example—you can't maintain the inert atmosphere while the unit cools. Louver mechanisms on legacy units were identified as a problem area and characterized as being "rinky-dink."

Chairman Gillis noted several safety threads on the organization's online user forum—including experience with optical flame detectors, how to deal with ill-fitting compartment doors and hardware replacement to correct, functional tests to confirm proper operation of water-mist fire-suppression systems during unit commissioning, opening of compartment doors with the CO_2 system activated, and alternatives to IGD combustibles detectors.

He also listed in his presentation the Technical Information Letters (TILs) published by the OEM that should be reviewed by the safety manager at each plant (sidebar). If you don't have copies of the pertinent documents, request them from your plant's GE representative.

In the Auxiliaries Roundtable, discussions focused on sulfur buildup in stop/speed ratio valves that could prevent restarting after a unit trip, the value of a flash drum in the continuous blowdown line enabling beneficial use of the steam produced, the value of inlet bleed heat for deicing and unit turndown, and other topics of value.

An attendee reported a trip on low lube-oil pressure revealed that regulator valves had not been serviced in 32 years of service and the brittle diaphragms failed. The diaphragms on valves serving other units were replaced "just in time." Another user, who reported going 24 years before changing out diaphragms, warned, "Make sure you reinstall the orifice."

Other notes from the session illustrating the value of participating in the Frame 6 Users Group's annual meeting, included the following:

- Discussion of torque-converter orifice fitting issues.
- Upgrade of a jaw clutch to SSS clutch.
- Hardened coupling that led to hydraulic ratchet-pump failure.
- How to avoid coupling failures on your load gear and auxiliary lube-oil pump.
- Recommendation: Conduct accessory- and load-gear inspections during majors. Take the necessary precautions to avoid an oil spill.
- Pitting of load-gear tips or teeth was reported by several plant personnel. Consensus was that everywhere there is a nozzle, there's pitting at the tip of the tooth.
- Suggested inspection interval for AC auxiliary and DC emergency lube-oil pumps was five years.
- Failures of flexible hoses were reported between the reservoir and hydraulic pump.
- Checking of nitrogen pressure in the hydraulic oil accumulator was recommended during major inspections.
- Coupling issues in the shaft hydraulic oil pump were reported by several participants. Replacement intervals varied from annually to each hot-gas-path inspection to every major.
- Problems with an oil mist separator at one plant were traced to weak vacuum.

The I&C Roundtable included a debate on the pros and cons of upgrading control systems versus retaining/maintaining legacy controls. Several users supported the idea of sticking with legacy systems because there's a vibrant third-party supplier community available for support—including parts and knowledgeable technicians.

An operator with Mark VI controls said his plant upgraded to Mark VIe because of parts availability. Yet a recommendation from another participant was to keep spares of critical boards for Mark VIe and VIeS controls in-house because they are hard to find and lead times are long. Be prepared, he said.

Guidance offered to those considering new control systems included the following:

- When planning a rip-and-replace project, don't forget the wiring, instrumentation, and other equipment that may not be included in the contractor's scope of supply. And don't chintz on the contingency because you will have discoverables.
- Expect issues with lengths of wiring requiring junction boxes and other connections.
- Think about routing wires under the subfloor.
- Always say "yes" to a factory acceptance test (FAT). Rigorously run through all the logic, graphics, etc, with supplier personnel. You can't do this effectively in the field.
- Remember to double-check control constants after upgrading. Consider including this step in the FAT.
- All linear variable differential transformers (LVDTs), used for accurately measuring linear position or displacement, are not created equal. Check part numbers to be sure you have the correct spares. Also, install LVDTs in "friendly" locations to both minimize the potential for failures and to facilitate access.
- Servos impacted by varnish buildup is a perennial hot topic. A user said his plant came to expect trips because of varnish so they decided to change servos annually. Then they found the infant mortality rate was worse than expected so they went back to replacing servos when they fail.
- Dump-valve issues? Toggle the logic to be sure the valve is operating properly.
- Heads-up: Users say compressor bleed valves sent to shops for refurbishment sometimes are not reassembled correctly. Quality control should be stressed with suppliers and plant staff should verify correct assembly before the CBVs are transferred to your warehouse.
- Y&F 9500 combined stop/speed ratio and gas control valves were said to be robust, requiring little service. However, one attendee reported his experience with the OEM's field service team on one valve was not up to par and recommended using Young & Franklin for the inspection and overhaul of its valves. Also mentioned was the importance of following packing procedures to the letter to prevent leak-by.
- Attention to detail when filing permits was stressed. One user noted that DLN tuning required after an outage was not specified in its permit. Ouch.
- Kudos: PSM received "likes" from several attendees for its LEC III™ low-emissions combustion system.

Best Practices was introduced as a roundtable in 2019. Topics were varied. First was a fit-up test for first-stage nozzles and transition pieces (TPs) two to three weeks before the outage to avoid surprises. Other BPs included these:

- Do a proper repair spec and follow your parts through the shop for best results.
- Specify a full thermal barrier coating (TBC) for TPs. It will extend part life.
- Exhaust-gas thermocouple jumpering: Don't jumper to the adjacent T/C or to the one with the highest or lowest temperature. Use the

Safety TILs and Product Service Safety Bulletins affecting 6B gas turbines

TIL 2101, Modification of manual lever hoist for safe rotor removal.
2044, Dry flame sensor false flame indication while turbine is offline.
2028, Control settings for GE Reuter Stokes flame sensors.
2025, GE Reuter Stokes FTD325 dry flame sensors, false flame indication.
1986, Braid-lined flexible metal-hose failures.
1918, 6B Riverhawk load-coupling hardware and tooling safety concern.
1838, Environmentally induced catalytic-bead gas-leak sensor degradation.
1793, Arsenic and heavy-metal material handling guidelines.
1713, 6B, 6FA, 6FA+E, and 9E false-start drain system recommendations.
1709, 6B load-coupling recommendations.
1707, Outer-crossfire-tube packing-ring upgrade.
1700, Potential gas-leak hazard during offline water washes.
1633, Load-coupling pressure during disassembly.
1628, E- and B-class gas-turbine shell inspection.
1612, Temperature degradation of turbine-compartment light fixtures.
1585-R1, Proper use and care of flexible metal hoses.
1577, Precautions for air-inlet filter-house ladder hatches.
1576-R1, Gas-turbine rotor inspections.
1574, 6B standard combustion fuel-nozzle body cracking.
1573, Fire-protection-system wiring verification.
1566-R2, Hazardous-gas detection system recommendations.
1565, Safety precautions to follow while working on VGVs.
1557, Temperature-regulation valves containing methylene chloride.
1556, Security measures against logic forcing.
1554, Signage requirements for enclosures protected by CO_2 fire protection.
1537-1, High gas flow at startup—Lratiohy logic sequence.
1522-R1, Fire-protection-system upgrades for select gas turbines.
1520-1, High hydrogen purge recommendations.
1429-R1, Accessory and fuel-gas-module compression-fitting oil leaks.
1368-2, Recommended fire-prevention measures for air-inlet filter houses.
1275-1R2, Excessive fuel flow at startup.
1159-2, Precautions for working in or near the turbine compartment or fuel handling system of an operating gas turbine.

PSSBs

2018-1003, Online collector-maintenance awareness.
2018-0709-R2, Observation of hexavalent chromium on parts during outage.
2016-1220, GT upgrade—Impact on HRSG.
2016-1209, Gas-turbine water-cooled flame sensor false flame indication.
2016-1117, Lifting and rigging devices.
2016-1104, Gas-turbine operational safety GEK update.

algorithm in TIL 1524 to calculate the exhaust spread.

- Check T/Cs during startup for possible problems ahead. If you find a T/C lagging the others by about 100 deg F, and eventually catching up, consider replacement at your next opportunity.
- Replacement of wheel-space T/Cs can be challenging. Before *carefully* removing the defective T/C to avoid breakage, use a Sharpie® marker to indicate the proper depth of insertion and mark the replacement T/C accordingly so you know when it's fully inserted.
- Parts stocking strategies also generated meaningful discussion.

The sharing of best practices among owner/operators contributes to safer working conditions and increases in unit availability and reliability fleet-wide. The Frame 6 users have been proactive in this regard, contributing their experiences during the annual meetings, in the group's online forum, and via CCJ's Best Practices Awards program.

Two innovative entries recognized with awards last year, submitted by steering committee member J C Rawls of BASF-Geismar, are profiled later in this section. One discusses a home-grown boiler efficiency controller that improves performance through process automation, the second a performance dashboard that tells at a glance if a particular system or piece of equipment is meeting operational expectations.

The Compressor Roundtable included discussion of the following:

- HEPA hydrophobic filters. A user said his HEPA filters had been in service for two years and provided very dependable output over that time. Compressor remained clean.
- Some users touted the benefits of removing inlet silencers—including a lower delta p across the inlet system while mitigating compressor damage. One said the noise level didn't get much higher—except for one octave band that could be heard for miles, which was remedied. A few more users said they were planning to remove their silencers in the coming year.
- Dos and don'ts: Avoid compressor water washing before an outage to avoid corrosion; do perform an offline wash after an outage.
- A suggestion to the group: Clear the bellmouth drain after a compressor wash; you don't want a couple of feet of water accumulating at the compressor inlet where it can be sucked into the unit on restart.
- Inspection of the inlet bleed heat system was recommended during scheduled maintenance outages (TIL 1320).
- Alternatives for staking Row 1 compressor blades were discussed—including the biscuit mod.
- Move compressor bleed valves from inside the package to the outside for better reliability.

Presentations

There were three short presentations by owner/operators at the 2019 meeting—high wheel-space temperature issues, exhaust-plenum replacement, and rotor life extension—and two by vendors—generator minors that turned into majors and rotor lifetime evaluation.

High wheel-space temperature issues were discussed by an owner/operator with three 42-MW 6Bs (Model 6581B) that had been commissioned in 2003. Two units completed their second major inspections in 2018, the third in 2019. High temperatures were noticed in the second and third turbine stages of one machine during startup following the major inspection.

The root-cause analysis (RCA) by plant personnel was thorough. The investigation reviewed the following possible causes or contributors to the issue:

- People: T/C installation method, installation restriction, space restriction, air filtration, and filter house.
- Equipment: damaged T/C wiring, improper installation, functionality check (yes, no, results?), T/C integrity, broken T/Cs.
- Material (HGP components): T/C source (new, refurbished?), borescope, cooling, condition of nozzles, condition of buckets, repair history.
- Measurements and seal clearances: Shroud clearances, nozzle clear-

ances, bucket clearances, turbine clearances, diaphragms.

The findings:

- Wrong insertion. T/C was reading diaphragm temperature because the insertion length was incorrect. See fifth bullet in the Best Practices Roundtable summary above.
- Investigators found the T/C guide-tube cap was machined incorrectly, preventing the T/Cs from reaching the ends of their caps. When corrections were made the T/Cs installed smoothly to the correct insertion length.

Lessons learned:

- High wheel-space temperature is a common problem on 6Bs.
- During a major inspection, before installing the turbine casing, make sure the wheel-space T/Cs are installed correctly.
- Borescope T/C guide tubes.
- Apply heat on the T/C guide-tube caps and verify response via the control system.
- Teamwork involving all personnel with expertise to share is critical to rapid problem-solving.

The exhaust-plenum replacement case history had some twists and turns. One of the principal vendors being considered for this project emailed plant personnel the following message on a Monday morning in April 2019: Our company will be shutting its doors for business as of today. It is a Chapter 7 bankruptcy, not Chapter 11, which allows for a financial reorganization of the firm. Most employees were laid off on that day.

The week had to get better from that point forward.

Interestingly, another candidate vendor for this project, Shock Manufacturing, was formed about six years earlier by Gene Schockemoehl, who had been president of the company filing for bankruptcy. Turns out, Schock had a plenum design plant personnel believed more durable than that offered by the bankrupt company.

It features closely spaced, large-diameter Type-304 stainless steel pins to hold the insulation in place between the inner and outer shells of the plenum. Pins are welded directly to the outer casing where the temperature is between about 150F and 170F during operation.

Welds for the scallop-bar design offered by the bankrupt company, by contrast, are on the hot side of the exhaust casing where the temperature is more than 1000F. Frequent cycling is conducive to studs shearing off at the top of the bar and failure of the insulation system.

Rotor life extension is a topic on the minds of many 6B owner/operators because operating hours accumulate quickly in process plants that run continuously. Recall that the OEM requires inspections, refurbishment, and/or replacement of B- and E-technology rotors at 5000 factored starts or 200,000 factored hours, whichever comes first (to dig deeper, consult the latest versions of TIL-1576 and GER 3620). For most attendees at this user-group meeting, the hours limit is applicable.

The user presenting sees a 200,000-hour rotor lifetime evaluation (LTE) for his 6B without merit because the best you can do after spending all the money for the inspections, component refurbishments, new consumable parts, etc, is get approval to run another 100,000 hours (about eight years at his plant). The alternative he prefers is to bring the rotor into a qualified shop, replace all of its life-limiting components, and extend rotor lifetime by 200,000 hours.

He told the group that this course of action would involve the following at a minimum:

- Replace the last three or four stages of compressor wheels.
- Replace all compressor blades.
- Replace some turbine wheels and spacers.
- Replace all tie bolts and marriage bolts.

Case history: Effects of cyclic duty on air-cooled generators

Editor's note: This article is based on the presentation, "Frame 6/6A3 'minor' outages turned into majors with field rewinds," by Jamie Clark of AGT Services Inc at the 2019 meeting of the Frame 6 Users Group.

As production of renewable energy has grown so has cyclic duty on traditional turbine/generators increased. The adverse impacts of increased cycling are well illustrated by experience at a 1990s-vintage, Frame-6B-powered, 3 × 1 combined-cycle plant where each gas turbine drives a nominal 45-MVA, air-cooled 6A3 generator. The gas turbine/generators are arranged to also operate in simple-cycle mode.

A dozen inspections were conducted on GT generators at this plant from 2001 through 2019, allowing a meaningful assessment of deterioration rate. Engineers found that generators deteriorated at a greatly increased rate when cyclic duty changed from perhaps a half dozen cycles per month to a half dozen cycles per week (especially during the summertime) beginning about 2005-06. The damage primarily has appeared on the rotating fields, as experts expected.

Inspections conducted in 2001, 2002, and 2003 found problems primarily on the stators (Figs 1 and 2). Loose wedges also were observed. Stator rewedging was performed to replace the "camel-back" wedge systems, a system of rather poor design used for a few years by this OEM.

By 2007, field turn insulation migration was beginning to be noticed. By 2015, insulation migration was sufficient to schedule the first of the field rewinds; however, that work has yet to begin (Figs 3 and 4).

Load cycling causes the copper turns to have a tendency to move axially at the field body ends, and to assure the turn insulation lamination stays in place each lamination is bonded on one side to the adjacent copper turn.

The heavy cyclic duty combined with elevated temperatures over time may cause debonding and allow the turn insulation to migrate out of place. If the migration becomes severe, turn shorts begin to occur; the only repair is field rewind. This was the case on two of the generators at this site. Minor inspections resulted in finding gross turn insulation migration, forcing unplanned major outages for field rewinds.

In recent years, serious top turn distortion became apparent (Fig 5). This copper distortion is caused by a combination of insufficient copper hardness, endwinding blocking design, and cyclic duty—and is a fairly common problem on fields. By 2018, distortion had reached a level sufficient to require field rewind, and the first of the fields was rewound. The second field was rewound in 2019 because of nearly identical copper distortion.

Cycling of conventional powerplants will only increase as time passes. It is important that plant owners recognize this and plan maintenance accordingly. Inspection frequency will need to increase and qualified expert help should be available to assist in the decision process. When a rewind is to be performed, available cyclic-duty modifications should be incorporated in the new windings.

For stators this would include (1) an endwinding support structure that adequately allows for the always-present axial expansion of stator bars, (2) bonding or clamping of endwindings and connection rings to allow axial expansion while preventing vibration at contact points, and (3) proper stator wedge material selection and design to remain mechanically stable throughout the normal operating and cycling temperature ranges.

Field rewinds must incorporate proper copper hardness, especially in the slot portion of the coil. The

PSM's presentation, "F6B rotor repair and lifetime extension solutions for improved lifecycle costs," Thursday morning, offered an alternative to the OEM's LTE program, described on the previous day.

The presentation began with the requisite "who we are and what we can do for you," shop locations, international affiliations, numbers of LTE projects completed and the frames involved, availability of seed rotors for swaps to eliminate outage time, rotor-disk manufacturing experience, computer program and analysis capabilities for modeling, materials analysis, NDT capabilities (eddy current, ultrasonic, microstructural review, etc). You can access information of interest on the Frame 6 website.

What might have been the most interesting segment of this presentation for hands-on users came at the end—recent findings.

Example 1: 7EA compressor-rotor distress was identified in multiple locations—specifically pitting in disc webs and distress in blade slots previously blended and/or cracked. FCD was said to accelerate aft slot cracking; previously blended slots re-cracked during the subsequent interval.

Example 2: Rabbet-fit cracking was attributed to improper interference between disc snaps. The speaker said PSM reviewed critical specifications and ran calculations before shop personnel were allowed to "chase out" the crack. Re-contouring of the OEM's geometry was said to produce a life benefit.

Example 3: A 6B rotor (more than 5000 factored starts and about 40,000 factored hours) was found to have a flaw in the first turbine wheel, which was attributed to fast starting of the machine. Calculations and modeling conducted based on site data predicted the failure and suggested a material change and design refinements that would improve low-cycle fatigue life.

Example 4: Inspection of a 9E compressor revealed blade-slot cracks that had migrated through the rim. Multiple indications also were found on pumping vanes. Plus, cracking was found in the counterbore of the forward turbine stub shaft. This led engineers to believe in the possibility of component retirement during the upcoming LTE; they suggested the owner/operator develop a contingency plan.

AGT Services' presentation, "Frame 6/6A3 'minor' outages turned to majors with field rewinds," is summarized in the sidebar above.

GE Day

The first presentation after opening remarks reviewed how GE communicates with its customers and the value to plant personnel of the OEM's TILs, PSSBs, Product Service Information Bulletins (PSIBs), and GEKs covering installation, product specifications, troubleshooting, maintenance, technical recommendations, etc. There's much owner/operators can learn by becoming familiar with these resouces and reading thoroughly sections pertinent to tasks at hand.

The speaker selected one TIL (2122) and one PSBB (20180709) for detailed coverage. The first focused on replacement recommendations for threaded fasteners; the latter, hexavalent chromium concerns, which had been covered during the Safety Roundtable the previous day.

slot armor insulation system must have a robust slip plane to accommodate winding expansion and contraction, as well as stress relief of the slot armor at the field body slot exits.

The best available turn insulation materials are required, with proper thickness and high-quality adhesion to an adjacent turn. Blocking under the retaining rings must allow for the small but important copper expansions that always occur, and have proper restraints implemented to eliminate blocking migration and assure blocking that will stay in place. Finally, the retaining-ring insulation material must ensure thickness stability and have a robust slip plane to allow for copper end turn expansion and contraction.

As asset owners are increasingly challenged to run these older units a "bit harder" than historically, and are pressured to reduce maintenance costs, a decision must be faced—that is, weighing the immediate benefits of minor inspections only or facing the cost of major inspections. The decision should consider the unit's history, fleet experience of similar units and planned changes in duty. Cost savings from "minor inspections only" may likely be lost many times over if they turn into costly unplanned major outages.

Acknowledgement: Clyde V Maughan contributed to this article.

1, 2. Inspections in the early 2000s found problems primarily on the stators—such as connection-ring vibration (left) and stator bar vibration (right)

3, 4. Field turn insulation migration—end turn at left, slot turn at right—came into view in 2007

5. Serious top turn distortion has been evident for the last several years

The motivation for TIL-2122 was the liberation of a stud in a combustion assembly that caused damage in the hot gas path. The process used in fastener manufacturing was identified as the primary contributing factor and the OEM conducted a risk assessment for all parts supplied by the negligent vendor, which was disqualified based on findings.

A fleet-wide program was initiated to address high-risk applications, with low-risk applications managed through TIL-2122. It advises the replacement of questionable components that are accessible at the next interval; fasteners that are part of an assembly would be replaced in the normal repair process.

Attendees then were reminded of some important older TILs, in particular 1585 and 1986, also mentioned during the Safety Roundtable and listed in the sidebar. Focusing on the combustor for a moment, the speaker advised a review of the following:

1377-3, Extendorized combustion liners, revised stop locations.

1437-2, DLN1 liquid-fuel operation recommendations.

1770, DLN1/1+ tuning requirements.

1952, Modified repair process for 6B standard combustor fuel nozzles.

1991, 6B transition piece to S1N floating seal engagement.

2041-R2, 6B secondary fuel-nozzle inspection and repair guidelines.

Plus, 1574 and 1713, which also were called out during the Safety Roundtable.

Next, the speaker suggested attendees review these GEKs and GERs and to build the reviews into the plant's O&M policy:

- GEK111694, Flex hoses.
- 229A6027, Pressure testing of flexible metal hose. Note: All parts are tested by the OEM's suppliers before shipment.
- GEK121358, DLN1+ gas-only electrically actuated GCV and SSRV.
- GEK 111331, O&M recommendations for media-type gas-turbine inlet-air evap coolers.
- GEK 111787, Combined hydraulic- and lift-oil system.
- GEK 116736, Water-mist fire protection system.
- GER 3620, the OEM's O&M guidebook. Note: The editors recommend this be read cover to cover by all plant O&M personnel.
- GER 4217, a helpful guide to 6A/6B history and upgrades.

Final slide highlighted the value of registering for and using MyDashboard, the OEM's 24/7 connection (https://registration.gepower.com/registration) for technical, performance, and planning information on your assets. Use it to file warranty claims, view manuals and technical documents, search GE's solutions database, get outage reports, and much more.

Rotor. The following speaker updated the group on rotor end-of-life (EOL) initiatives. He began with a review of GER 3620 (revision N) and the factoring methodology for hours and starts used in establishing maintenance intervals. Next came a series of highlight slides discussing (1) rotor life and the failure methods and mechanisms that influence it, (2) rotor life management and the inspection-based analytical modeling and analysis used to gauge remaining life, and (3) service-center observations and findings related to 6B rotors. Explanations and impacts of creep, fatigue, and fracture were summed up in a couple of slides on mechanical design and metallurgy.

The presentation's value to users is familiarization with technologies, concepts, methods, calculations, etc, used in rotor EOL determinations and subject matter they should have a good understanding of.

Improvements. This presentation focused primarily on experience with the Advanced Gas Path (AGP) mod on 6Bs and compressor improvements to extract greater value from your assets. Perhaps you recall that the first AGP for a 6B engine went into service two days before the group's June 2018 meeting. This speaker reported that as of the 2019 conference five AGP sets had been delivered, with the fleet leader (the first unit) at more than 8000 factored fired hours (FFH). Also mentioned was that beginning this year (2020) all new Frame 6Bs would be AGP-equipped.

The AGP enhancements for a 6B, it was said, typically can deliver from 2% to 15% more power, a heat-rate improvement of up to 4%, an HGP interval of 32k FFH, higher firing temperature, and 2% to 7% more exhaust energy. The exact benefit for a given unit depends an engine's operating history and component profile.

Regarding the interval extension to 32k FFH, the value is quite significant, going from four major inspections, 16 combustion inspections, and four HGP inspections, for a 200,000-hr lifecycle, to three majors and three HGP inspections. Run a back-of-the-envelope calculation for your 6Bs to get an idea of the benefit for your plant.

A supporting case history (favorable to the OEM), was for an original 6541B coming up on an HGP inspection with a need for new replacement-in-kind parts. The unit, equipped with Mark VI controls and DLN1 Advanced Extendor, operates baseload 8000 hr/yr on natural gas. Assumptions were $50/MWh for power, steam revenue at $5 per 1000 lb/hr, and a fuel cost of $5/million Btu. With a 15% increase in power output, heat-rate improvement of 5.1%, and an increase in exhaust energy of 7.6%, the annual benefit was calculated at $2.3 million in round numbers.

Architectural changes to the compressor and turbine sections are key to the AGP engine's performance improvements. Advanced airfoil design, use of materials and coatings with greater tolerance to corrosion and erosion, implementation of blade-health monitoring, and use of stainless-steel stator vane segments for the first four compressor stages are among the many beneficial changes. Get more specifics from the presentation posted on the Frame 6 website.

BASF Geismar

Boiler efficiency controller improves performance through process automation

BASF Geismar

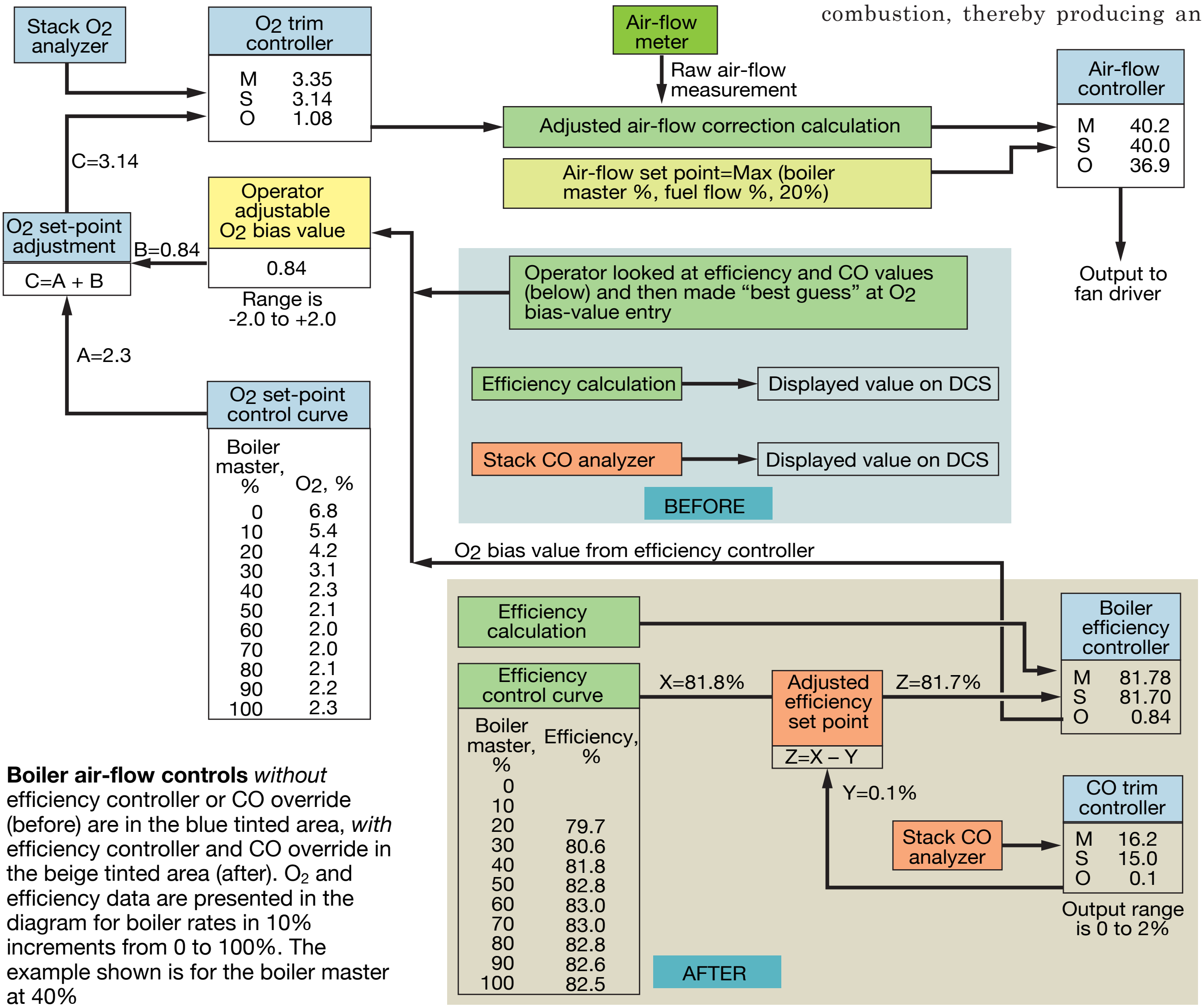
BASF Chemical Co

160-MW, gas-fired, 2 × 1 combined-cycle cogeneration facility located in Geismar, La.

Plant manager: Jerry Lebold

Challenge. Boiler combustion controls are designed to optimize the air flow to the fuel flow rate such that sufficient air (oxygen) is available for complete combustion and the amount of performance-robbing excess air is minimized. Recall that insufficient air results in the formation of excess carbon monoxide, a regulated parameter, as well as a loss in efficiency because of incomplete combustion.

Part of the air-flow controls programming at BASF Geismar allowed for operator adjustment of the stack O_2 set point value—an O_2 bias value. An operator could enter a negative bias in an attempt to lower stack O_2, thereby increasing boiler efficiency. But if the O_2 value were reduced too much, insufficient air would be available for combustion, thereby producing an



Boiler air-flow controls *without* efficiency controller or CO override (before) are in the blue tinted area, *with* efficiency controller and CO override in the beige tinted area (after). O_2 and efficiency data are presented in the diagram for boiler rates in 10% increments from 0 to 100%. The example shown is for the boiler master at 40%

excessive amount of CO. By contrast, if the O_2 bias value was set too high, an excessive amount of air would be used, leading to inefficient combustion.

Powerplant board operators have many duties and do not have the time to babysit the O_2/air controllers to fine-tune the O_2 bias value and to make adjustments each time boiler load or fuel composition changes. To avoid nuisance CO alarms, operators typically would set the O_2 bias to a high value, contributing to inefficient operation.

Solution. Initial solutions revolved around trying to give operators target efficiencies to hit, thus letting them know at about what point the CO would "break-through." This was only moderately effective because the target efficiency varied with boiler load and fuel composition, and occasionally CO break-through would occur before the target efficiency could be reached—for one or more of several minor reasons.

Plant personnel ended up modeling boiler efficiency over a wide range of operating conditions and fuel compositions and created characterization tables that could calculate an accurate efficiency target for the given operating conditions. This model was used to generate a set point for an *efficiency controller*, which when in automatic, would compare the actual boiler efficiency to the efficiency target (set point) and adjust the O_2 bias automatically.

The efficiency controller automatically lowers the O_2 bias value until (1) the target efficiency is reached, (2) the CO level starts rising (at which time the efficiency set point is adjusted lower, thereby increasing the O_2 bias value), or (3) the minimum O_2 bias value limit is reached. In essence, the new efficiency controller automatically adjusts the O_2 bias value to achieve the target boiler efficiency, and the CO controller is configured to adjust the efficiency set point on the efficiency controller should CO emissions rise too high.

Control schemes, before and after the staff effort, are illustrated in the diagram.

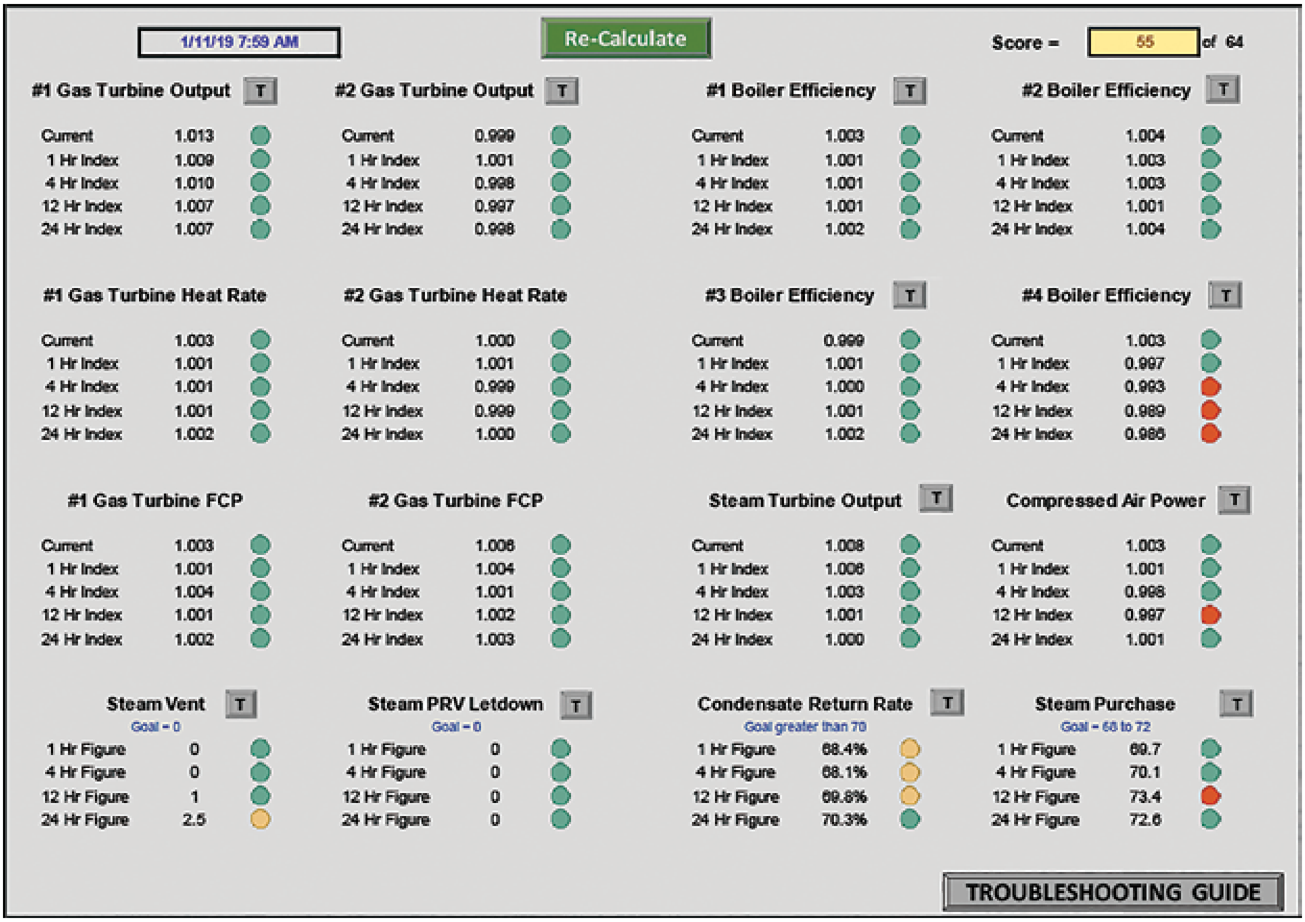
Results. the efficiency controller and CO override controller have worked very well. Operators no longer have to adjust the O_2 bias value as it now is generated automatically. The boilers operate at the targeted values and any CO excursions are handled automatically without operator intervention.

Project participant:
J C Rawls, BASF-Geismar Utilities Dept Technology Engineer

Plant equipment meeting expectations? Check the performance dashboard

Challenge. Develop a tool for the operations staff that provides a simple and intuitive display of the performance of various systems and equipment and is easy to use. Critical to the development of a user-friendly performance dashboard are the following:

- Identify the proper key performance



Performance dashboard enables operators to tell at a glance if a particular system or piece of equipment is meeting operational expectations by the color of its indicator light. The data shown account for changes in the performance target as operating conditions vary. The "score" at the upper right reflects the number of green lights among the 64 calculations presented. A troubleshooting button at the bottom right provides operators methodology for bringing off-normal conditions back into spec

indicators (KPI) to monitor.
- Model equipment/system performance accurately to provide appropriate target values under varying operating conditions.

Solution. The KPIs selected for monitoring included gas-turbine output and heat rate, boiler efficiency, steam venting, steam letdown through PRVs, specific power consumption for compressed air, and purchased steam.

Some KPI target values were a constant value—such as zero for steam venting and 70,000 lb/hr as the target for purchased steam. However, many KPI targets vary with operating conditions. For instance, the expected efficiency of a boiler is not a constant value but varies based on boiler load, changes in fuel composition, etc. Similarly, gas-turbine output varies considerably with ambient-air temperature.

Equipment and system performance models were developed for a wide range of operating conditions. At BASF-Geismar Utilities, most of the modeling was based on real-life operating data collected when the equipment was known to be operating well. Thus, the operational targets are proven performance metrics and not necessarily based on new equipment design data, which in some cases may not be appropriate.

Because of the varying targets for different operating conditions, performance indices were developed for many of the KPIs. A *performance index* is a calculation to gauge how well a piece of equipment, or process, is meeting its defined expectation—or more simply, its target performance. A performance index of 1.0 indicates the equipment/process is exactly meeting its goal; a higher score, exceeding expectations; a lower score, not meeting expectations.

For processes measured by a value that *increases* with improved performance, the performance index is the actual performance divided by the target performance. To illustrate, if at a given condition boiler efficiency is expected to be 82.0% but the actual performance is 82.4%, that performance index would be 82.4÷82.0 = 1.005. The result is greater than 1.0, indicating satisfactory performance.

For processes measured by a value that *decreases* with improved performance, the performance index is the target value divided by the actual performance. An example is gas-turbine heat rate, a measurement of fuel consumption divided by the unit output. If the expected heat rate of a gas turbine is 12.0 million Btu/MW and the measured (actual) performance is 12.25 million Btu/MW, the performance index would be 12.0÷12.25 = 0.9796. The result, being less than 1.0, indicates poor performance.

The performance index is not useful for comparing the performance of two unlike pieces of equipment. For instance, if equipment A, which normally produces 80 units per day instead produces 85 units is compared to equipment B which normally produces 100 units per day but instead produces 95 units, the performance index score for equipment A would be higher yet equipment B still produced more units. But if one does not look at the performance index value, one might think equipment B is doing well because it is out-producing equipment A while in fact it is underperforming its expectations.

Results. The dashboard created (figure) shows the KPI data together with a green, yellow, or red indicator light—to provide an instant indication of performance. An Excel spreadsheet was used to download the necessary process data from AspenTech Explorer and perform the necessary calculations.

The performance data displayed shows average values for periods of one, four, 12, and 24 hours along with the current performance. Providing data in this format allows performance trending.

Note that the small button with the "T" is a quick link that opens a trend graph for that particular parameter. Another quick link at the bottom of the dashboard opens a troubleshooting file which can be used as a guide to correct poor performance.

To create some competitive spirit among operators and shifts, there's a "score" in the top right-hand corner showing the number of green lights compared to the maximum possible number of green lights. Current performance data are not included in this score as it changes on a minute-to-minute basis.

For the dashboard shown, the first three rows of performance data are KPIs monitored using performance indices with target values that vary with operating conditions; the bottom row of data are KPIs that have fixed target values.

From this display you can see boiler No. 4's efficiency performance was unsatisfactory but improved. Similarly, steam was vented hours ago but the vent is now closed. Condensate return rates dropped and are still marginally low and should be investigated/addressed.

Data displayed in this manner do not tell, for instance, which boiler is operating most efficiently, but rather indicates how the actual boiler efficiency compares to the expected performance.

Project participant:
J C Rawls, BASF-Geismar Utilities Dept Technology Engineer

Alstom Owners Group Third Annual Meeting

The Alstom Owners Group, born of necessity to help owner/operators navigate the O&M challenges that came with GE's purchase of Alstom in November 2015, looks ahead to its fourth annual meeting sometime in 2021—face-to-face, pandemic permitting. Additionally, in place of their scheduled February conference, AOG will provide users and vendors the chance to share information and meet up at a virtual conference hosted in conjunction with CCJ. Details forthcoming. AOG was one of only three gas-turbine user groups on CCJ's calendar able to conduct traditional live meetings in 2020—the 501F and 501G organizations were the others.

This proved to be a "breakout" year for AOG with nearly two dozen equipment/services providers and 50-plus users participating in a four-day program that included presentations on a wide range of subjects, a shop tour, and several four-hour training sessions plus one full-day session.

The group's steering committee has three user representatives—Brian Vokal of Midland Cogeneration Venture, Chris Hutson of Georgia Power, and Robert Bell of Tenaska Berkshire Power—and two vendor reps—Pierre Ansmann of ARNOLD Group and Jeff Chapin of Liburdi Turbine Services. Chapin, one of the organization's founders, manages the group's day-to-day operations.

If you want to dig deeper on topics of interest, contact Chapin at jchapin@aogusers.com to gain access to the relevant presentations. This service is offered only to verified users.

Keynote: CSEF steels

The odd man out at AOG 2020 was Keynote Speaker Jeff Henry, a well-respected global expert on boiler and piping materials who presented "Grade 91 and the Creep-Strength-Enhanced Ferritic Steels: What 35 Years of Use Has Taught Us." He was the only person on the program focused on heat-recovery steam generators; most everyone else spoke about gas turbines, steam turbines, and/or electrical generators.

With many of the attendees responsible for the operation and maintenance of combined-cycle plants, Henry's message was particularly important—many in the industry taking materials for granted. After all, boilers, piping, and other high-pressure components are designed, built, and operated according to the *ASME Boiler & Pressure Vessel Code*—aren't they? And the Code is always correct—isn't it? He provided participants a much-needed dose of reality.

Henry, president of Chattanooga-based Applied Thermal Coatings-Combustion Engineering Solutions (ATC-CES), has had a career-long concentration on the service performance of powerplant materials—including the manufacture, welding, and behavior of CSEF steels. The ASME Fellow is active on several Code technical committees. He is the former chair of Code Section II, the Materials Standards Committee, and currently chairs the Working Group on CSEF steels.

Henry began with a brief backgrounder on Grade 91, moving quickly into an overview of the metallurgy of Grade 91 and other CSEF steels. He next identified problems associated with the use of Grade 91 and closed with the eye-popping fact that the latest version of the Code (July 2019) shows allowable stress values for Grade 91 that are *lower* than those published previously.

CSEF steels, the materials expert said, are a class of alloys that offer crucial engineering advantages over so-called traditional ferritic alloys (T/P11 and 22, for example)—including superior elevated-temperature strength and thermal-physical properties that provide improved resistance to thermal-fatigue damage. Compared to P22, these advantages translate to a 40% reduction in pipe-wall thickness for the same creep life and 12 times the fatigue life.

However, Henry continued, the track record on the use of CSEF steels reveals some blemishes:

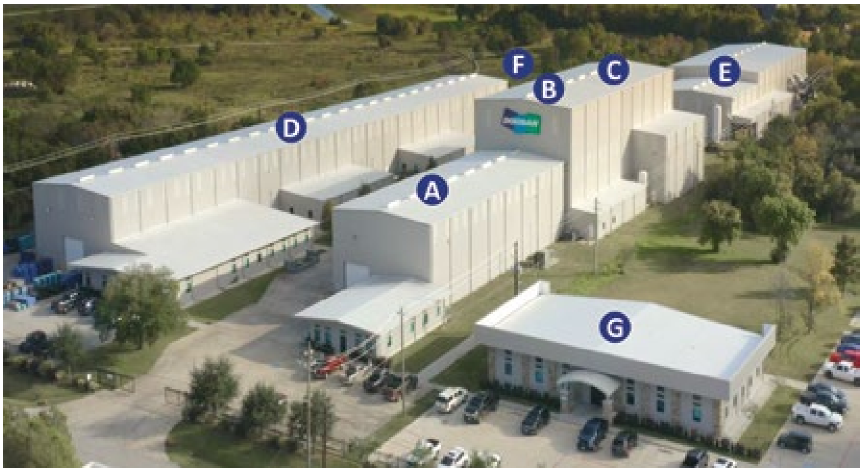
- Many costly errors have been made both in design and in processing of the material—and, very concerning, all the errors have not yet been identified.
- Problems have extended even to the analysis of material properties by the Code.

The degree of technical control required during all phases of design, production, manufacturing, and erection involving CSEF steels is substantially greater than it is with traditional alloys. Improper heat treatment, Henry stated, has been the single greatest cause of unnecessary failures, repairs, and replacements involving these materials—particularly Grade 91.

Such improper practices have cost the industry hundreds of millions of dollars, and will continue to do so as poorly heat-treated components that have not been properly inspected continue to fail prematurely. Verification of quality only can be achieved through rigorous up-front process control.

An aggressive quality-control program can ensure that the material in each component has the desired properties. The results of the inspections and testing conducted as part of the QC program become the basis for the assessments that monitor the condition of the components as service life is accumulated. The best advice is to keep good records of everything you can.

Moving on to the revised allowable stress values for Grade 91 mate-



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

rial published in the July 2019 Code update, Henry assured attendees that the lower numbers do not mean operating equipment is suddenly at risk. He considers the following response appropriate for users:

- Review design limits for your plant to determine if a change in stress values raises concerns regarding the operating life of specific pressure parts.
- If there are concerns based on review of design limits, compare the limits to actual operating conditions to determine if concerns persist.
- If concerns do persist, initiate a comprehensive condition-assessment program, including stress analyses and NDE, to identify areas of greatest concern.
- If results indicate problems assuming minimum material properties, conduct a destructive testing program to characterize the heat-specific strength in problem areas as a basis for establishing the need for any repair/replacement actions that may be appropriate and for determining rational re-inspection intervals.

For new HRSGs and high-pressure piping systems, Henry predicted designers will look to stronger CSEF grades, particularly Grade 92 or Grade 93—a risky strategy, he believes. There is limited operating experience with Grade 92, questions remain over the poor damage tolerance of Grade 92, and there is less experience with Grade 93, even in Japan.

Coupled with increasingly demanding operating conditions in response to expanding deployment of renewables, he continued, operators likely will face very difficult challenges in the coming years at a time when the resources available to successfully handle those challenges are more limited than perhaps at any time in the industry's history.

Henry explained that we now have the loss of OEM metallurgy expertise, which is a "game changer," along with elimination of support engineering functions within the utilities and non-utility operators. For the OEMs, this added expense was (in the past) in their own best interest because they stood behind their designs and products.

Unfortunately, he added, there are some relatively small engineering firms that, although good, might not know how to address complex material interactions. In other words, they might not know what they don't know.

Shop tour

Doosan Turbomachinery Services (DTS) was the "high-profile" vendor at the January 27-31 meeting in the Magnolia Hotel in Houston, sponsoring a tour of its extensive, relatively new shop in nearby La Porte with capability for F-class inspection, overhaul, repairs, and new parts manufacturing (Fig 1).

The company's 2020 presentation to Alstom users focused on the development of repair processes for the GT24. It began with a step-by-step review of how its highly experienced and flexible team (80% of Doosan's employees have been in the business for more than 20 years) goes about tailoring repair solutions for customers—including verification/validation.

The company's first-article qualification process was described for coatings. Next came summaries of inspection, quoting, repair, and quality-control processes. The last included quality checks on coatings, heat treatments, and the final product. The presentation was a perfect segue for the tour to follow—you came to know how all the pieces/processes you would see on the shop floor fit together.

However, the tour did not focus on the GT24, as the montage shows. Work on other Alstom machines (such as the 11NM), plus GE and Siemens engines, was ongoing. The variety of shop work in progress was a bonus for visitors because many had responsibilities for GE and/or Siemens machines in addition to their Alstom units. A bit of history: Doosan's gas-turbine manufacturing history dates back to 1991, when it was licensed by GE to make its Frame 6B. In 2007, Mitsubishi Hitachi Power Systems licensed the company to produce M501F and M501G gas turbines.

Doosan is recognized today for its world-class capabilities across a broad spectrum of machines manufactured by GE (Frames 3, 5, 6, 7, and 9) and by Siemens (W91/W92/W101; W171/W191, W251, W501, W701, V series). The company's F-class work is enabled by La Porte's modern infrastructure—including two rotor-bay cranes with a 52-ft hook height and rated capacity of 100 tons, low-speed balancing of rotors to 90 tons, unstack/restack tooling and fixturing, etc.

Regarding steam turbines, Doosan says it offers some of the most comprehensive and technologically advanced repairs in the market. Services include nozzle/diaphragm/valve/case repairs, plus rotor inspection, balancing, machining, welding, and blading services, for Siemens/Westinghouse, ABB/Alstom, GE, Elliott, Dresser Rand, Mitsubishi, and Toshiba, among others.

Examples of recent gas-turbine work follows:

Alstom 11N rotor assessment and overhaul. The GT11 is predominately a peaking machine with more than 85 of these engines installed in North America alone. Basic configuration: 18 compressor stages (more than 1250 blades) and five turbine stages (more than 400 blades). Doosan touts its comprehensive program to inspect, evaluate, and repair or replace 11N rotor in a true partnership with its customers.

Its onsite inspection and evaluation process is as follows:

- Hand-clean critical zones for assessment.
- Perform local NDE using phased-

array ultrasonic testing, mag particle, and/or eddy current.

- Take metallurgical replicas.
- Measure critical dimensions.
- Assess findings and make recommendations.

A shop inspection is conducted this way:

- Blast-clean rotor.
- Take full dimensional inspections—diameters and runouts.
- Perform balance check.
- Conduct a full range of NDE tests—including white light, mag particle, eddy current, ultrasonic.

Rotor life evaluation is supported by a sophisticated methodology that relies on NDE inspections mentioned above, plus a hardness traverse, and materials analyses. The hoped-for outcome: Confirmation that the rotor's condition supports continued operation.

Where indications are found, models are created to validate recommended repairs. The proposed repairs are run through life-assessment simulations to estimate remaining life and assure repairs are not life-limiting. Where work is required, Doosan has the capabilities in-house to execute repairs.

New rotor required? No problem. The company has the reverse engineering and 3D modeling tools necessary to design the new rotor, plus the forgings and welding, heat-treatment, and machining capabilities to make it.

501F aftermarket support. Doosan has earned respect among 501F owner/operators for its work in that fleet. For example, its repair/upgrade solution developed for the 501F two-piece exhaust system six years ago has been adopted by several plants. More recently, it completed the in-kind replacement of the torque tube and air separator for a W501FC during a major maintenance interval.

Reverse engineering for that project began immediately after de-stack at Doosan's La Porte shop. White-light 3D scanning and metallurgical analysis of the existing torque tube and air separator started the process. Note that neither component had failed but the owner decided to replace both given fleet history and unit age. Risk management!

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

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

7F aftermarket support. Doosan's progress in developing products and services for the 7F were in evidence on the tour. Its DART (Doosan Advanced Re-engineered Turbine) program's upgrades for the 7FA.03 (compressor, combustor, turbine) were of interest to several attendees. Combustion hardware improvements include fuel nozzles and the combustion assembly; plus, the company's auto-tuning solution. Upgraded designs of buckets, nozzles, and shroud blocks are part of the DART promise to deliver power and efficiency equal to or better than the 7FA.04 AGP turbine components provided by the OEM.

Doosan recently unveiled a new rotor disc for the 7FA; work on commercializing an Inconel disc is progressing. New rotor discs are available for the 7EA and 501FC, in addition to the GT11NM mentioned earlier. The company has performed major inspections on 7FA rotors in its shop, although this work was not in progress when the tour was conducted.

Training workshops

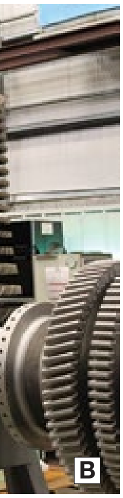
There's pent-up demand for engine-

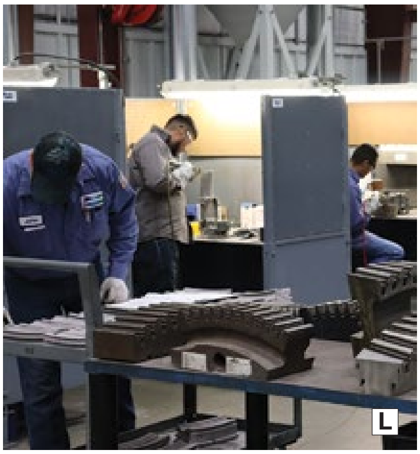
Doosan Turbomachinery Services shop

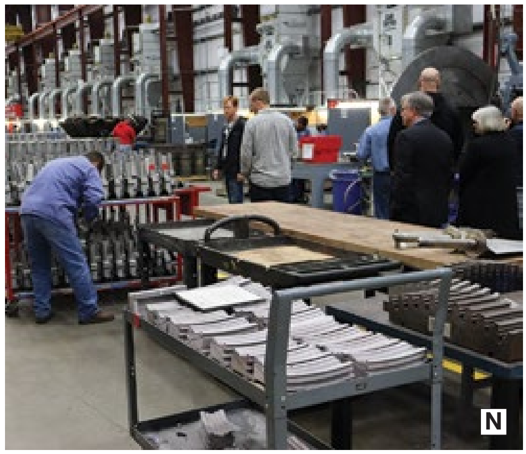
The third Alstom 11NM rotor manufactured by Doosan Turbomachinery Services (DTS) at its La Porte (Tex) shop is in the queue for blading, partially exposed for viewing purposes in Fig **A**. Newly manufactured 7EA turbine wheels in **B** are wrapped and secured on pallets (foreground) adjacent to new turbine stub shafts. In the background are used Frame 7 compressor rotors displayed for sale.

In the foreground of **C** are 7EA compressor wheels, turbine spacers, and stub shafts manufactured by DTS. A double-flow steam-turbine rotor is in the background. Rotor technicians in **D** install locking hardware on an 11NM rotor produced in La Porte.

The second Alstom 11NM rotor







made by DTS is undergoing a progressive balance run in **E,** while technicians are using the shop's scissor lift stacking pit in **F** to assemble a 7EA compressor rotor. In **G**, a 7FA turbine rotor is ready for shipping. In **H**, two W501F exhaust cylinder cases undergo DTS's "zero-hour" repair process. It includes the shop's baffle-seal mod, upgraded saddle and strut shields, alignment mod, and atmospheric vent mod.

Visitors examine La Porte's in-house coating facility in **I**. It features three large acoustic thermal spray booths with eight-axis CNC robots, HVOF spray systems, high-energy plasma systems, two-axis CNC turntables, and a SmartArc metal spray system.

AOG attendees examine the 11NM rotor in **J** acquired to fully characterize and model the internal and external geometries used by DTS in its new-rotor and lifetime evaluation programs. DTS inspectors in **K** perform incoming, in-process, and final inspections.

The shop's rotating-component repair facilities are shown in **L**. In the background, certified bucket and blade repair specialists do weld prep prior to re-establishing tip heights in DTS's inert-chamber welding booths. Multiple dovetail-root simulators are in the foreground for fitment and rock checks.

Moment-weigh equipment in **M** ensures all rotating components have optimized sequencing with the highest accuracy and repeatability. Batch carts in **N** are designed to maintain component security and accountability. Each cart carries a shop-floor router with detailed work instructions.

DTS personnel present the new 11NM gas-turbine rotor shown in **O** to key personnel from the customer, Midland Cogeneration Venture (MCV). From l to r, Sanjoo Lee, DTS performance excellence director; Bryan May, DTS account manager; Adam Johnson, MCV staff engineer and gas-turbine SME; Kristi Gledhill, MCV's supply chain manager; Brian Vokal, VP operations for MCV; Dan Tenbusch, MCV's maintenance manager; Sean Choi, DTS CSO; Glenn Turner, VP engineering for DTS; and Alex Ford, DTS rotating equipment engineer.

specific knowledge among Alstom gas- and steam-turbine owner/operators given the OEM's flagging efforts in customer training as its commercial activities wound down before the sale to GE, and in the months that followed the transfer in ownership. Both users and vendors recognized this and collaborated to develop a conference agenda to meet the needs of the AOG community.

Integrated into a fast-moving program of nominal half-hour supplier and user presentations, and closed discussion sessions for owners, were five four-hour training sessions, three Tuesday (January 28) and two Thursday, each running the full afternoon (1 to 5 pm). Plus, there was an exclusive full-day workshop on Friday.

Highlights of the workshops follow:

MD&A

Mark Crittendon, MD&A's engineering manager, reviewed basic generator design and electrical and mechanical testing of both generator fields and stators, before diving into key issues affecting Alston's legacy gas-turbine fleet. He noted that this fleet of air- and hydrogen-cooled generators is comprised of many different arrangements, some with unique designs manufactured by legacy companies.

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

Pole-to-pole cracking issues can be identified with a borescope during a generator minor or major inspection. Crittendon said the company's solution can be implemented immediately when cracking is found. If no indications are in evidence, he suggested the solution be implemented during a future outage as a preventive measure.

Slot-armor cracking. One of the field components impacted by cycling is the slot armor, which insulates field coils from the rotor forging. If armor cracking is found during a borescope inspection and the condition is not addressed, serious damage to the generator can occur. MD&A's solution involves a field rewind, including replacement of the original slot armor and armor caps.

Bar corona protection. Crittendon said the legacy Topair WX/Y23Z generator fleet has experienced quality issues conducive to corona activity in the endwinding region where the stator bar exits the slot. Specifically, damage to the grading tape has been observed. Failure to correct can lead to damage of ground-wall insulation. The speaker explained MD&A's solutions to address corona activity in both the slot and endwinding regions.

Phase connection lugs. Phase connection failures in the WX/Y21Z fleet have exposed quality issues with the lugs. MD&A offers a redesigned replacement to correct the problem.

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

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

C C Jensen

Technical Manager Axel Wegner, an expert on the care and treatment of lube and hydraulic oils, and well respected by turbine users, began the C C Jensen-sponsored workshop with a short discussion on the basics of oil contamination and

analysis (use QR code to access additional content). He followed that with introductory remarks on what varnish is and why you don't want it in your lube oil system.

Then Wegner dug into the details: oil analysis, what the data mean, and how to remove varnish from your oil and evaluate the effectiveness of your treatment solution. When looking at the overall health of your fluid, many parameters must be analyzed, he said. However, Wegner continued, a few can be focused on when the goal is to prevent or remove varnish.

Preventing varnish by maintaining the health of your anti-oxidant additive package requires the tests identified below, in Wegner's opinion. Those benefiting most from this segment of the presentation were first-timers and those new to the industry—typically about one-third of the attendees.

- RPVOT accelerates the oxidation process to evaluate the oil's remaining ability to resist oxidation.
- FTIR monitors base-stock degradation, oxidation, and additive depletion in lubricants.
- RULER accurately measures the remaining active antioxidants in the lubricant.
- TAN is an indicator of oil health. A sharp increase in acid number can mean the oil is approaching the end of its useful life.
- Water content. Water is considered the most destructive of contaminants, causing accelerated degradation of the fluid and corrosion of system components.
- Metals content. Metals can act as an oxidation catalyst.

The tests recommended for focusing on parameters for varnish removal:

- Ultra centrifuge or UC test, Wegner's personal favorite, enables you extract insoluble contaminants so small that they cannot be detected by normal particle counting but could plate out in the turbine system.
- MPC or Membrane Patch Colorimetry test involves making a patch that isolates and agglomerates insoluble byproducts associated with varnish. Patch color is indicative of varnish potential. Results of the well-defined and repeatable test process can be compared among different labs.
- ISO particle count of soft and hard insolubles.

The next segment of Wegner's workshop focused on choosing the proper oil conditioner for a riven application. He told the users, "Today we know the following three methods for removing varnish:

- Physical filtration, including absorption and adsorption, removes insoluble varnish. You can select from depth or surface filters, he said, with or without preconditioning step—such as electrostatic, balanced charge agglomeration, etc.
- Chemical filtration removes both soluble and insoluble varnish. In use are cartridges with chemical bead compositions of different mixtures which can be adjusted to achieve better performance on different oil brands and machine types.
- Depth filter absorption/adsorption with advanced agglomeration. In use are systems that effectively precondition the oil in a manner that soft contaminants fall out of solution (without chemical aids), agglomerate, and are removed by depth filter inserts with high dirt-holding capacity.

The obvious question from a user: Which method should I choose? Wegner said, "That entirely depends on the efficiencies of alternative systems in your specific application." He offered these general criteria:

- Systems with oil operating temperatures up to about 100F can be treated by any one of the three options identified above; many brands are available.
- In systems where lube-oil temperatures alternate from less than about 100F to more than 100F (such as daily-start engines), all three options generally work as well. However, the physical filtration method might prove less effective at higher temperatures unless the filter medium is upgraded, because more varnish will be in solution.

Pioneer Motor Bearing

Engineering Manager Dr Lyle Branagan returned to AOG in 2020 to lead another Pioneer training workshop—this one entitled "Elements of Successful Operation of Alstom Bearings." Given the number of presentations he makes annually at user-group meetings, you have to think of Branagan as the industry's "go-to guy" when questions arise on fluid-film radial and thrust bearings (use QR code to access additional content).

Note that authorized repairs of bearings in Alstom equipment are available from GE for both steam and gas turbines and from Pioneer for steam turbines. Also, that Pioneer is the exclusive US licensee of Alstom intellectual property for the servicing and repair of steam-turbine bearings.

The workshop covered the full range of elements required for successful operation of Alstom bearings, answering each of the questions below based on an in-depth technical understanding of Alstom bearing design and operation developed over several decades.

- Are my bearings healthy?
- What's the impact on bearing performance/life of extended time on turning gear?
- What will be the impact of more frequent starts and stops?
- What should an owner look for in a visual inspection? In his presentations, Branagan stresses the importance of a careful visual examination of bearings after their removal from a machine because of the opportunity if affords the owner/operator to identify any of several potential conditions of distress. Because the Babbitt (white metal) lining of a bearing is deliberately a renewable, sacrificial layer, refurbishment often is possible to restore the bearing for long-term operation.

  Such refurbishment generally is cost effective even for simple bearings with bore sizes above about 12 in. Of course, if a spare or new bearing from the OEM is not readily available on a timely basis, repair and refurbishment become a necessity no matter what the size.
- What should O&M personnel look for in an oil analysis? See the C C Jensen workshop overview immediately above.
- What information is needed to decide on refurbishment and what planning is necessary?
- What are the important aspects of a successful refurbishment?
- Are there upgrades to our turbine instrumentation that we should consider to improve bearing reliability?

Hughes Technical Services

The four-hour class was conducted by Tom Douglas, senior systems engineer, for operators, engineers, and managers who wanted to learn more about the P13/BlueLine system. Hardware and software used to work with the system were covered. Examples explained how to follow signals through the system and the logic blocks used. Additional details discussed included speed modules, Modbus communications (serial and TCP), and fiberoptic data transfer.

HTS specializes in legacy ABB/Alstom gas turbines, controls and electrical systems commissioning, maintenance, troubleshooting and upgrades, mechanical gas- and steam-turbine commissioning and maintenance, EV and standard combustor tuning and adjustments.

Emerson

Emerson conducted a training module on gas turbine controls. Laurence O'Toole began the workshop with a history of gas turbines and related technology developments, and an overview of control systems and control principles. Lorcan Roche then dug into the subject of gas-turbine frequency response and control-system modeling for MOD 027 compliance; he explained the GGOV1DU model commonly used for gas turbines. Lastly, Nicolas Demougeot reviewed the finer points of tuning on DLN machines, including examples of practical field problems on gas turbines that can affect tuning.

Liburdi Turbine Services

A full-day training course on Friday, "Basic GT Metallurgy, Repair Technology, and Condition Assessment," was conducted by Liburdi's Doug Nagy. This non-commercial session explained superalloy metallurgy as it applies to gas-turbine components, focusing on component damage experienced from GT service exposure as well as the techniques used to determine the remaining lives of critical hot parts. Protective coatings, advancements in component repair technologies, and repair quality-assurance techniques were included in the syllabus.

Plus, attendees were exposed to several case-study examples and got to participate in an interactive wrap-up session where they developed real-world repair solutions.

Nagy, who has decades of experience in the repair of gas-turbine components, explained that he designed this course for professionals involved with the technology or business of gas turbines in the oil and gas and power-generation industries—in particular, those with the following responsibilities:

- Plant, engineering, asset, technical, maintenance, and/or operations manager.
- Plant, mechanical, production, and/or reliability engineer.

Here's the course outline:

- Introduction: Why repair and refurbish parts?
- Nomenclature: Review of typical GT components and the respective environments they withstand.
- Materials and metallurgy: GT materials and their properties.
- Coatings typically used in gas turbines—such as anti-corrosion, wear surface, and thermal barrier.
- Degradation characteristics of GT components—including creep, low-cycle fatigue, etc, and their effects on GT components.
- Evaluation of used compoents and how to determine the appropriate repair/refurbishment process.
- Refurbishment and repair processes: Procedures and techniques used to restore components to industry standards.
- Quality assurance: Methods and procedures to verify components meet industry standards.
- Vendor selection and verification.
- Case studies were presented to illustrate component repair and refurbishment processes. The class then was divided into teams and given components for which they determined the best repair/refurbishment process.

The workshop concluded with a roundtable discussion on the latest repair trends and Q&A with the user participants.

Vendor presentations

Insulation systems for Alstom gas and steam turbines, *ARNOLD Group.*

Pierre Ansmann, global head of marketing, told the assembly of owner/operators that his company's single-layer insulation system was state-of-the-art technology and capable of solving all known insulation-related problems associated with gas- and steam-turbine O&M.

He opened the presentation by describing issues users may face with conventional insulation—such as:

- Replacement lagging not made to the correct specification.
- Insulation blankets that require repair or replacement at each outage.
- Hot spots on the insulation surface conducive to handling and maintenance problems.
- Turbine trips caused by overheated auxiliary equipment.
- High noise level inside the enclosure.
- Loose fibers and dust from calcium fiber blocks that can cause health and safety issues.

Loss of earnings results from poor design/installation of turbine insulation and/or premature wear and tear of blankets. The balance sheet can be impacted negatively by reduced power production, contractual penalties, damage to mechanical and electrical equipment and instrumentation, and shorter outage intervals.

Ansmann said ARNOLD's insulation avoids the stated problems because of interlocking high-performance blankets which conform perfectly to the turbine surface, high-quality materials and manufacturing, and long-term high-temperature resistance. The company guarantees reuse of its insulation system for 15 outages without a decrease in efficiency.

Highlights of the well-illustrated presentation (more than 100 high-quality photos showing details important to users) included blanket construction, design of the support structure, ease of access to inspection points, step protection for longer life, piping and flange insulation, insulation for inside the exhaust system, insulation system designs for the GT24, GT26, 11N, and 13D gas turbines and the KA26 steam turbine, as well as for steam-turbine warming systems.

2. Step protection is a clearly visible component in the GT24/26 single-layer insulation system

3. Old-design piping insulation with sheet-metal cover is at left; new flexible insulation design is at right. Time for dismantling/reassembly for the old design was about seven hours, with flexible insulation only 20 minutes

4. Inner insulation at the exhaust diffuser consists of a 4 × 1 in. layer of needled silicate fiber mats held in place securely with washers on the pins

5. Removable heating blankets on the split line and above it facilitate maintenance and minimize insulation wear and tear

Digging into the details, Ansmann spent about one-quarter of his time at the podium describing the features of single-layer insulation system for the GT24/26 (Fig 2), including its support structure, step protection, access to inspection ports, new-design flexible insulation for piping, and C-MAS insulation (Fig 3), etc. If you're not familiar with the last feature, C-MAS is a secondary sheet-metal casing wrapped around the combustor/turbine section. Low-pressure air flows in the annulus between C-MAS and the primary casing to help the latter expand uniformly.

For the GT11N, Ansmann focused on the exhaust diffuser—especially inner-insulation installation considerations (Fig 4). For the KA26, emphasis was on turbine warming blankets and the removable heating segments above and on the split line (Fig 5). Closing comments covered the company's capabilities for onsite machining of turbine components (including shafts), auxiliary equipment, and valves. Low-speed

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6-8. Inspection results: Field pole crossover cracking (left), phase-to-phase failure (center), bottom-bar insulation damage

balancing also can be done onsite.

Unplanned generator repairs resulting from increasing start/stop duties, *GT Services Inc.*

Jamie Clark is a frequent presenter at industry meetings focusing on frame gas turbines. He opened his AOG 2020 presentation thusly:

- Industry-wide, increasing start/stop counts are the primary causes of generator forced outages and increased emergent scope during planned outages.
- Thermal and mechanical stresses suffered when units are cycled elevate what had been low-cycle fatigue issues to high-cycle ones.
- In addition to fatigue-related issues attributed to cycling, human errors may increase as well. Synchronizing out of phase, motoring, etc, are some of the results that have been experienced.

9. Capital parts repair exceeded expectations with a 98.3% yield for all repairs (left)

10. Service interval was extended from 24k to 32k EOH with no new parts needed (below)

Clark compared the maintenance histories of two groups of 7FH2 gas turbine/generators to illustrate the penalties associated with cycling. One group had 12 baseload generators arranged in 2 × 1 combined cycles; the other group 11 simple-cycle peaking units. The combined cycles averaged 272 starts and 30k to 90k equivalent operating hours, the peakers 1835 starts and 12.3k to 54.9k EOH.

Here's the status of baseload generators in combined-cycle service:

- Excellent wedge tightness.
- Acceptable EL CID results.
- Passed knife check/building bolt torque.
- Minor greasing in endwindings.
- Good machine health overall.

The scorecard for generators in peaking service (Figs 6-8):

- Three forced outages attributed to J-straps.
- J-strap cracking identified in two inspections.
- Slot liner delamination found.
- Pole/pole and coil/coil crossover deficiencies found during J-strap repairs.
- Two units required a second rewind because of poor initial rewinds.
- Eight machines required core tightening.
- Keybar rattling attributed to loose belly bands.
- All machines required a full re-wedge.
- Connection-ring dusting/movement identified.
- Eight generators required endwinding/series connection blocking and re-tie.

Clark supported the summary findings by way of well-illustrated case histories. Recent findings, he said, confirm that the most involved repairs were required on cycling units.

Clark urged attendees to get a baseline condition assessment of their generators as soon as possible and to fix what's required to assure reliable service—even if it takes a major to do it. He suggested consideration of robotic inspections in lieu of field removal where possible and offered the pros and cons of using robots.

Clark also recommended a re-evaluation of the timeline for future inspections where there have been significant changes in operating duty. Shorter outage intervals, he said, might be a good decision for units that have transitioned to peaking service in the last few years. Of course, baseload and seldom-run units may enjoy longer intervals.

Finally, be aware that generators made by the same manufacturer, and having comparable operating profiles, are prone to suffer common problems. It behooves you to attend user group meeting to become knowledgeable on fleet-wide issues.

Catalyst improvements and case studies, *Groome Industrial Services Group.*

Steve Houghton quickly reviewed Groom's capabilities given most attendees had gas- and steam-turbine responsibilities and might not be famil-

iar with the firm. Here's what he said Groome does:

- Cleaning of SCR (selective catalytic reduction), CO, AIG (ammonia injection grid), and steam recovery tubes.
- SCR, CO catalyst supply and disposal.
- Catalyst framework supply and install.
- Acid washing of CO catalyst.
- Install of permanent sampling grids.
- New-catalyst install.
- Gas flow-seal replacement and maintenance.
- New AIG install.
- AIG tuning.

The company is respected for its ability to recoup lost performance at the exhaust end of combined- and simple-cycle plants (use QR code to access additional content). Some examples:

- Restore catalyst performance by effectively addressing chemical contamination issues.
- Increase NO_x conversion efficiency.
- Eliminate catalyst plugging/fouling.
- Reduce ammonia slip and reagent consumption.
- Reduce turbine backpressure to increase power production and efficiency.
- Extend catalyst life.

Houghton presented a couple of case histories to illustrate the benefits of Groome's services. At one plant, stack NO_x was lowered by 0.5 ppm, reducing ammonia consumption from 192 to 144 lb/hr. At another, Groome was able to reduce ammonia slip from just less than 9 ppm to 5.3, cutting ammonia consumption from 511 lb/hr to 471. After tuning, ammonia slip dropped to 4.3 ppm, ammonia consumption to 461 lb/hr.

11. Extended coating protection made parts more durable, reduced fallout

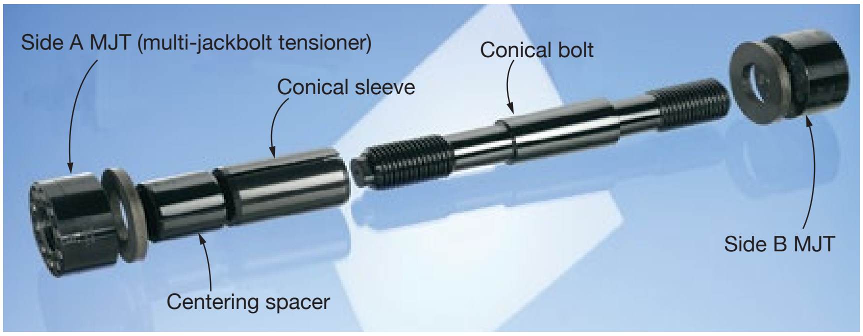
Another GT24 plant reported that Groome's work increased steam-turbine output from 100 to 106 MW.

Ten-year aftermarket LTSA observations and results, *Liburdi Turbine Services.*

Liburdi's Doug Nagy illustrated the O&M saving possible by performing advanced-technology component repairs to extend the lives of critical gas-turbine components rather than mitigating risk with an insurance policy, a/k/a LTSA.

The case history presented involved a 2 × 1 GT11N2-powered combined cycle with a load-following service profile, occasional shutdowns, and 60k equivalent operating hours on natural gas. The user had never signed up for an LTSA and dealt with the OEM on a transactional basis for critical parts, inspections, etc. The owner/operator preferred this approach because it offered flexibility in supplier choice and scheduling, access to engineering and technical support, more favorable terms and conditions and pricing, etc.

The stated success was $7.5-million in net saving over the 10-yr period studied. The saving was calculated as the avoided cost of new parts minus the cost of the advanced repairs performed by Liburdi. Parts previously



12, 13. EzFit coupling bolt avoids fitted-bolt seizure issues (left), eliminates slippage during operation (right)

14. Major Tool has considerable machining capability in its extensive shop

had been declared at the life limit, or unrepairable by conventional methods/procedures.

Major accomplishments claimed by Liburdi are the following:

- Capital parts repair yield exceeded expectations with a 98.3% yield for all repairs, including third-cycle repairs; no new program parts were needed (Fig 9).
- Service interval was extended from 24k to 32k EOH; no new program parts were needed (Fig 10).
- Innovative EV burner inventory management; no new program parts were needed.

Minor accomplishments were these:

- Compressor erosion remediation avoided replacement of functional parts.
- Innovative foreign-object control protocol implemented.
- Extended coating protection made parts more durable and reduced fallout (Fig 11).

Improved air inlet system for six GT24s, *Camfil.*

Principal Engineer Jim Benson presented on the upgrade of air inlet systems serving a combined-cycle plant in central Texas. Its six 1 × 1 power blocks are each powered by a GT24. The original V-panel self-cleaning filters dating back to the millennium were not meeting expectations. Such filters are best suited for a high-dust desert environment, which was not the case here. The plant was dogged by inlet-related performance issues since COD: compressor fouling requiring a minimum of two offline washes annually, high pressure drop across the inlet filters, and short filter life.

The owner/operator received dozens of proposals. The alternative selected involved modifying the filter house to accommodate a two-stage barrier style filter. However, concept validation was required. That assignment fell to Camfil's mobile air filter test lab, which was parked conveniently near the air inlets for the units being tested. The lab was onsite four months to benchmark the existing filters against proposed alternatives.

The two-stage, V-bank-style filtration arrangement selected for validation had a lower pressure drop than the original pulse filter and a much higher filtration efficiency—98% versus 32%. The first stage (pre-filter) has an F8 efficiency rating on 0.4-µm particles. Initial efficiency was 55% minimum; average, 90%-95%. The second stage has an E10 efficiency rating: 85% on 0.17-µm particles (the most penetrating particle size), 98% on 0.4-µm particles.

The project involved removing the existing V-panel pulse module and installing the new barrier filter module, a task that took a standard install crew of eight about 15 days per unit. Note that the pre- and final filters were installed back-to-back to save space and allow the use of one mounting grid instead of two. Weather hoods, service walkway, ducting downstream of the filters, and structural member all were reused. Project completion was April 2015.

The results:

- Offline compressor washes have been reduced from two annually to one every three to four years. Inspections revealed the compressors were "much cleaner than before" or "very clean."
- Pressure drop through the filter house is lower.
- The first set of pre-filters remained in service about four and a half years; the final filters still have service life remaining based on pressure-drop measurements.

When turbine/generator coupling bolts seize up, *Superbolt, Nord-Lock Group.*

Mike Manno explained the EzFit coupling bolt to attendees and how it has proven effective in critical power-generation applications by eliminating the costly, time-consuming challenge presented by seizure-prone fitted coupling bolts during outages. He noted recent cases that demonstrate the technology's value in the field. Manno also reviewed the principles of mechanical expansion bolts—what they are, how they work, and how they mitigate the problems associated with conventional bolts (use QR code to access additional content).

OEM support for Alstom equipment, *GE Gas Power.*

Richard Dudding, Alan Davala, Ricky Turner, and Ryan Richard, together representing more than six decades of ABB/Alstom experience, presented on flexibility solutions to optimize gas-turbine performance and integrated outage planning. Attendees were most interested in direct interaction and Q&A with the GE team; productive discussion ensued.

The critical nature of advance, integrated planning for "C" inspections was discussed with the importance of configuration engineering and FSI reviews conducted at least 24 months in advance and follow-on discussions at six-month intervals with the local GE service team.

The OEM's global repair capabilities and support for the GT11 and GT24 fleets were reviewed. This included mention of investing in an acquisition/auction of the assets of Dominion's Bellemeade Power Station, providing reconditioned options to meet future customer requirements. GE also has made available unfired parts from an 11N2 in storage.

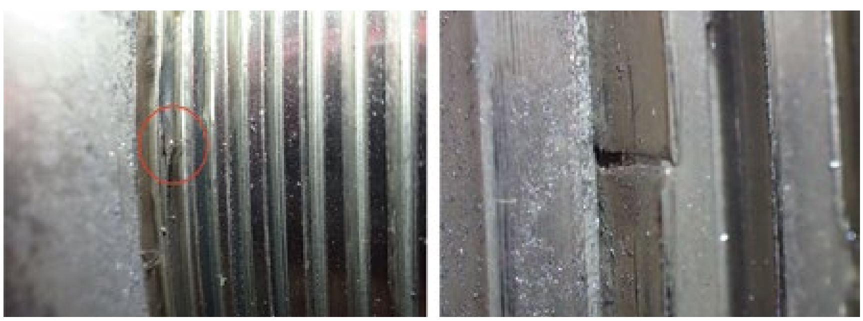
The OEM team's takeaway from the presentation was that GE's continued investment and support for the Alstom fleet was well received by the AOG.

Alternative source for repair and replacement parts—stationary gas-turbine components, *Major Tool and Machine.*

Hans Lissman and Mark Sweeney introduced their company to users, many of whom were not familiar with the privately owned non-union company and its considerable fabrication and machining capabilities in more than 600.000 ft² of environmentally controlled shop space. The Indianapolis-based firm employs more than 375 personnel, many highly skilled.

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

The company has participated from concept to design to manufacture of stationary components for several Alstom gas turbines—including the GT11 series of high interest to AOG attendees. Regarding the vari-



15. J-seal installation tip: Butt-gap overlap at left is not acceptable; gap overlap of 0.010 to 0.020 in. at right is acceptable ous GT11 models, it has fabricated pressed parts, collars, and other components for hot-gas casings; liners for the lower combustor; tile carriers for Rows A through D; swirlers; shield cones; air mixing nozzles, and other parts. Plus, it has experience in a wide range of repairs.

A shop tour reveals tooling and fixtures in place for the Alstom type 8, 9, 11, and 13 gas turbines, among others (Fig 14). Also, dies for pressed parts in place for Alstom type 8, 9, 11, and 13E2 machines.

INPIRIO products and services.

INPIRIO® may be new to owner/operators outside the AOG community. The company was founded only 26 years ago by former ABB/Alstom engineers with gas-turbine and combined-cycle expertise. It is a global firm with certifications outside the US from SGS Switzerland and TUV Germany. Among INPIRIO's capabilities are the following: in-house production of new/repaired components, lifetime evaluation of parts, optimization of components based on customer-specific issues, field service support for outages, etc.

Major components repaired/manufactured by the firm include hot-gas casings, turbine vane carriers, exhaust-gas casings, mixing chambers, U-duct liners, and many others.

The company also operates an online ecommerce platform for asset optimization called Spares Gate. It offers a variety of parts ranging from individual customized spares packages to structural and strategic comments.

Claimed advantages over the OEM are these:

- Supply of own manufactured parts.
- Faster lead times.
- Troubleshooting and generic problem-solving.

Repair planning: Mitigating risk to outage durations—finger dovetails and J seals, *Advanced Turbine Support*.

Bryan Grant, Advanced Turbine Support's resident expert on steam turbines (Fig , spoke to turbine repair risk mitigation. Here's an outline of his presentation:

- Tips on planning repairs to assure success.
- Blade replacement quality assurance.
- J-seal installation and inspection tips (Fig 15).
- Final inspection best practices.
- The importance of final FME (foreign material exclusion) close-out inspections prior to unit closure.

This heavily illustrated presentation is a valuable addition to the notebook of any O&M technician with steam-turbine responsibilities. Practical tips on finger dovetail repair; cover assembly; J-seal caulking-wire fit-up, straightness and crush checks, installation, field damage and failure checks; L-0 midspan inspections; steam-path cleanliness; balance-weight inspections; diaphragm repair versus replace, etc,

Steam solutions and redesigns, *EthosEnergy Group*.

This presentation opened with a review of the company's considerable capabilities in the overhaul, repair, spare parts, field service, etc, for gas and steam turbines, and generators, manufactured by all OEMs.

Featured in the remainder were Alstom steam-turbine solutions for shim migration, case re-rounding and HP case machining, and redesign of seals and blades.

The shim migration solution was simple in concept: Eliminate the shims. But this required detailed engineering and machining—for example:

- Undercut radius replaced with a compound fillet.
- Rounded edges of the contact surface to reduce peak stress.
- Reduced the skew angle.
- Replace austenitic blade material with high-temperature martensitic stainless steel.

Case re-rounding was illustrated by way of photos. The mechanical repair solution developed included finite-element analysis; rounding bar material, design, and manufacturing specs; straightening and assembly procedure; and heating procedure for stress relief and straightening.

Seal redesign also was described with several photos.

Notable findings from steam- and gas-turbine projects in 2019, *PSG-Power Services Group*.

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

The presentation focused on jobs completed in 2019 that would be of interest to this group, including these:

- In-situ replacement of the seat on a fast-acting valve. Increased vibration and other factors created significant operational challenges for the valve's seat components leading to delamination of the cobalt-chromium layer from the high-chromium base material. Particulates liberated during seat delamination caused downstream damage to the steam path. An RCA identified different rates of expansion for the base metal and the overlay, plus HAZ-related issues, as the chief causes of the problem.

  Seat machining with a special boring bar and deep-hole weld machine with remote video control contributed to success. The valve seat face is now Inconel with improved bonding capabilities to reduce the risk of liberation during operation.
- Best practice. GE steam turbines retrofitted with Alstom components have HP and IP diaphragms with tip seal holders. Experience indicated that steam flow around the tip seal holders can cause erosion conducive to a forced outage. A proven solution is to remove the seals and deepen the seal grooves, then weld the erosion and seal holder to the diaphragm.
- Case cracking caused by steam-turbine cycling was addressed by grinding out the crack and weld repair. Photos illustrated the procedure.

GT11NM hot-section component assessment, *TEServices*.

If you have never participated in an independent third-party metallurgical evaluation of a gas turbine to determine the condition of the machine's major components, the presentation by Hans van Esch provides a great opportunity to learn what to look for during a "C" inspection, what you may find depending on service duty, and what you might do to maximize the productive life of your unit.

When it comes to shop audits, vendor verification, metallurgical evaluations and failure analyses, component assessments and lifetime extension, van Esch is among the industry's elite. This presentation walks you through condition assessments for 11NM stator and rotor heat shields, vanes, and blades to illustrate wear, fretting, erosion, oxidation, corrosion, tip rubs and other damage. You'll learn how to gauge the degree of wear and tear, what can be repaired, and what should be replaced.

Capabilities on Alstom legacy technologies, *Ansaldo Energia*.

Ansaldo, the OEM of record for the GT26 and GT36, was not well known to many attendees. But Harald Moehlig, global product manager for GT26/36 service, filled the information gap by bringing the users up to date on virtually everything you might want to know about the company concerning its organization, business units, facilities, engineering and manufacturing capabilities, and product offerings for the 50- and 60-Hz markets.

GT26 outage plan and technical support manual overview, *EPRI.*

Technical Executive Leonard Angello, well known to US generation professionals, presented the research organization's GT26 overhaul plan, much of which is applicable to the GT24 as well. This was a follow-on to a presentation on the same topic last year, but in 2020 focusing on Volume 6 of the manual, Assessment and Inspection.

The seven-volume work is designed to help owner/operators plan, manage, and document major overhauls, and incorporates custom-built databases with details on the numerous maintenance tasks necessary to complete a gas-turbine major inspection.

Volume 6 features 44 Inspection Assessment Data Sheets (IADS forms in EPRI lingo) arranged in four parts categories: combustion, rotating, stationary, and structural. Examples of forms in the rotating category are LPT blade row 1, HPT blades, and HPC blade row 20. A similar format is used for all IADS forms, which are unique to specific component features, issues, and inspection criteria.

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

OEM quality parts for the power generation industry, *Energy Parts, Div of HEMAG Balgach AG.*

Energy Parts is the power-generation division of HEMAG, founded in 1977 to produce high precision parts for the energy and aviation industries, among others. The company's first power-industry order came from Brown, Boveri & Cie in 1985.

The presentation describes the company's facilities and equipment used to produce nearly 5000 parts for the following BBC/ABB/Alstom engines: GT8, 9, 10, 11, 13, 24, 26, and 36.

Parts manufactured include blade-carrier segments, locking-piece assemblies, sealing rings, heat shields, fuel nozzles, and associated hardware. CCJ

Crete Energy Venture

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

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

Fifty plants participated in the 2020 Best Practices Awards program with eight selected by industry experts for Best of the Best honors profiled here. Details of the Best Practices submitted by the remaining entrants will be published in future issues.

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

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

Green Country Energy, owned by J-Power USA and operated by NAES Corp, is an 801-MW generating plant in Jenks, Okla, equipped with three gas-fired 1 × 1 combined cycles powered by GE 7FAs. Plant Manager Danny Parish and station personnel shared these best practices:

- Replacement of the Kato Engineering brushless exciter on a 9A4 generator.
- Safe entry into gas-turbine compartments protected by CO_2 fire protection systems.

Hermiston Generating Plant, owned by Perennial Power Holdings and PacifiCorp and operated by the former, is a 500-MW gas-fired combined cycle in Hermiston, Ore, powered by two GE 7FAs. Best practices submitted by Plant Manager Brad Knight and his staff:

- Hydrogen purge remote activation.
- Personal ownership leads to 25 years of no lost-time accidents.

River Road Generating Plant, owned by Clark Public Utilities and operated by GE, is a 250-MW, 7FA-powered, 1 × 1 combined cycle in Vancouver, Wash. Plant Manager Robert Mash and his team shared these experiences:

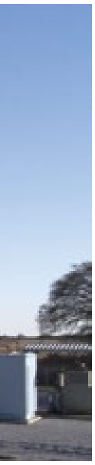
- Non-chemical algae control.
- Combining JSAs and operating procedures.
- Lube-oil conditioning and real-time monitoring.
- Hydrogen-detection flange tape.

- Cooling-tower oil boom.

Klamath Energy LLC, owned and operated by Avangrid Renewables, is a 536-MW, gas-fired, combined-cycle cogeneration plant in Klamath Falls, Ore, equipped with two Siemens 501FD3s. Plant Manager Dennis Winn and his staff submitted three best practices:

- Evaporative-cooler improvements.
- Gas-turbine fire-suppression upgrade.
- Cooling-tower cell platforms.

Milford Power LLC, owned by Starwood Energy Group and JERA Co, and operated by NAES Corp, is a 204-MW, gas-fired 1 × 1 combined cycle in Milford, Mass, powered by a Siemens 501D5. The best practice submitted by Plant Manager William Vogel and his staff describe the additions and enhancements—such as wet compression, duct burners and SCR catalyst, HP steam turbine—made to increase plant output by more than 50 MW. Note that JERA is a joint venture between two Japa-



Hermiston Generating Plant


Green Country Energy


Klamath Energy LLC

nese generating companies, TEPCO Fuel & Power Inc and Chubu Electric Power Co.

Crete Energy Venture, owned by Crete Energy Venture LLC and operated by Consolidated Asset Management Services (CAMS), is a 330-MW peaking facility located in Crete, Ill, equipped with four simple-cycle GE 7EAs. Plant Manager Brad Keaton provided these three best practices:

- Instrument-air reliability upgrades.
- Generator PT relocation.
- Demin-water-tank insulation.

PSEG Peakers, owned and operated by PSEG Fossil LLC, is the name given to the simple-cycle units at Kearney (10 GE LM6000PCs), Burlington (four LM6000PCs), Linden (four GE 7EAs), and Essex (one 7EA) Generating Stations, together rated more than 1050 MW. Plant Manager Clint Bogan and his staff manage these assets efficiently using the "Maintenance and outage share file" described in their best practice.

St. Charles Energy Center, owned by Competitive Power Ventures (CPV) and operated by Consolidated Asset Management Services (CAMS), is a 745-MW, gas-fired combined cycle in Waldorf, Md, powered by two GE 7FAs. Plant Manager Nick Bohl and his staff submitted these best practices:

- Brush maintenance program leads to increased generator reliability.
- Job status board helps keep staff informed and safe during maintenance events.
- Vision screen promotes operational excellence.
- Improving visitor tracking and management, and internal cyber controls, in complying with CIP-003-7.
- Cooling-tower fan-gearbox mod aids in monthly oil sampling and oil changes.

Other plants submitting best practices that will be shared with users are the following:

7FAs
Barney Davis Energy Center
Bastrop Energy Center
Calhoun Power Co
Central Eléctrica Pesquería
Effingham County Power
Essential Power Newington
Hunterstown Generating Station
Marcus Hook Energy Center
MEAG Wansley Unit 9
Plant Rowan
Rathdrum Power
Woodbridge Energy Center

Aeroderivatives
Energía del Valle de Mexico I (EVM I)
Exira Station
Greater Toronto Airport Authority Cogen
Lawrence County Generating Station
Nesharim Leading Energy
Nevada Cogeneration Associates No. 1
Orange Cogen
Orange Grove Energy
Pinelawn Power
Worthington Generating Station

501F
CCC Tuxpan II & V
CPV Valley Energy Center
Dogwood Energy Facility
Lea Power Partners
Monroe Power Co

501G
New Athens Generating
Middletown Energy Center
New Harquahala Generating
Shepard Energy Centre

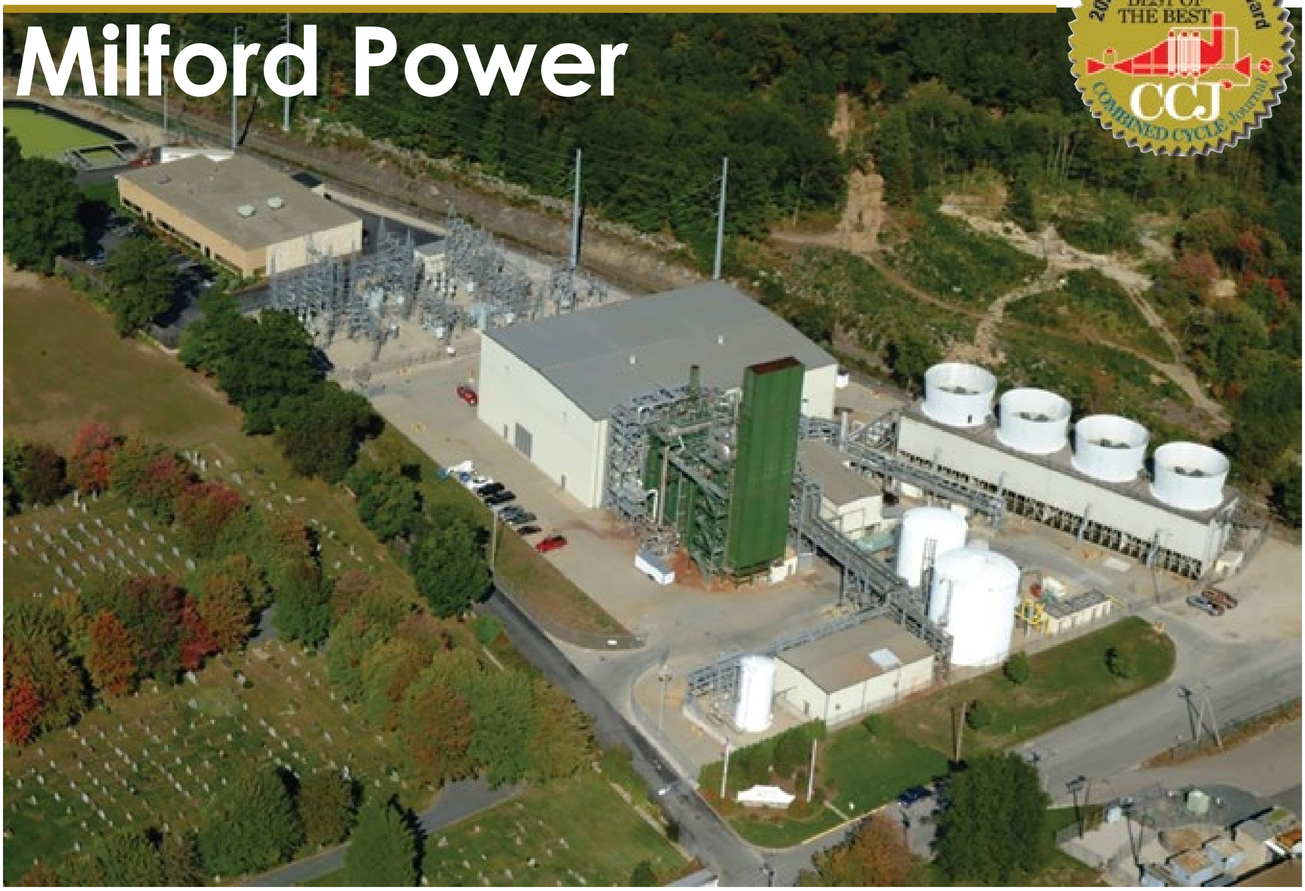
7EA
Doyle Energy Facility
Elwood Energy
Lincoln Generating Facility
Mulberry Cogen

501D5A
Blackhawk Station

SGT-800
Holland Energy Park

Diesel
AES Levant Holdings BV

Milford Power



Uprate project boosts plant output by one-third

Challenge. More power was needed from Milford Power LLC, which began commercial operation in 1993 as a nominal 150-MW (90F day), W501D5-powered, 1 × 1 combined cycle equipped with an unfired heat-recovery steam generator and SCR catalyst for NO_x control. The steam generated today powers a Siemens (ABB) SST-700 HP/VAX LP turbine. The generator coupled to the gas turbine is hydrogen-cooled, the generator serving the steam turbine is air-cooled.

Cycle cooling is by a surface condenser and four-cell wet cooling tower. Cycle makeup is produced by a system using reverse osmosis and continuous electrodeionization in series. Grey water from the local wastewater treatment plant provides tower makeup.

Solution. To increase output, the owner proposed modifying the as-built plant by adding a wet compression system at the gas-turbine (GT) air inlet and duct-firing capability to the HRSG, and upgrading the steam turbine.

Wet compression. When used in conjunction with the existing evaporative coolers, the wet-compression phase of the project increases GT output by 13 MW—when the ambient temperature is between 60F and 90F. Wet compression works by injecting demineralized water into GT inlet air to increase mass flow, hence gas-turbine output. Unit efficiency increases as well: A 10% boost in output is achieved with an 8.5% increase in heat input. Use of wet compression at Milford increases demin-water consumption by 80 gpm.

Equipment required for the wet-compression project included a spray-water delivery system (tubes and nozzles installed in the inlet air duct); a water transfer skid with pumps, piping, and controls (Fig 1); and interconnecting tubing between the skid and nozzle array. The nozzles are located downstream of the inlet silencers and are sized to achieve a uniform spray pattern and to prevent droplet formation to the degree possible. A drain line in the air inlet duct was increased to prevent accumulation of the additional water required. This drain was piped to a collection sump for use as cooling-tower makeup.

An observation window was installed on the inlet scroll, positioned opposite of the spray array to monitor the spray pattern.

Note that the wet-compression system does not increase pollutant emissions. Maximum emissions rates still occur at cold ambient temperatures (wintertime conditions) when wet compression does not operate.

Milford Power LLC

Owned by Starwood Energy Group and JERA Co

Operated by NAES Corp

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

Plant manager: William Vogel

Duct burners added a nominal 500-million Btu/hr at the front end of the existing HRSG within an existing lined burner cavity (Figs 2 and 3). The seven new natural-gas burner assemblies, each equipped with pilot and flame scanner, doubles the HP steam flow to the turbine, thereby doubling electric production of the steamer.

Equipment added to support the duct-burner system, and the additional steam flow, included the following: new HP-superheater manifold piping; new trim for the HP steam and feedwater control valves; replacement of nine existing 1-in. HP-superheater drains with 2-in. valves; access platforms for each duct-burner assembly (one on each side of the HRSG), new fuel-gas piping, manifolds, and distribution

1. Wet compression skid includes high-pressure pumps, PLC panel, and tubing for delivering water to the gas-turbine air inlet duct

2, 3. Fuel-gas skid and distribution manifold for the duct burners are at left, burner platforms at multiple elevations at right

skid; air blower for cooling air to the flame scanners; and a new compressed-air supply receiver for purge air.

An air-flow model study was conducted by the HRSG OEM "to define the minimum air-flow distribution devices required to ensure acceptable velocity distributions at the entrance planes of the duct burner, and to determine from model measurements the change in the system pressure loss due to the installation of flow-distribution devices." This modeling guided modification of the HRSG exhaust-gas inlet distribution grid: Half of the holes in the lower 8 ft of the perforated plate were covered to redirect a larger volume of air flow upward.

The existing SCR catalyst was replaced with a multi-function catalyst to control emissions of NO_x, CO, and VOCs in accordance with proposed limits of 2 ppm for NO_x, CO, and ammonia slip (Fig 4). The new catalyst combines the catalytic function of SCR NO_x reduction and CO/VOC oxidation into a single catalyst layer.

4. New catalyst controls emissions of multiple pollutants simultaneously

Note that use of the duct burner is limited by the current ambient air plan to the heat-input equivalent of 2000 hr/yr. The pressure drop across the catalyst is 1.5 in. H_2O.

The existing ammonia delivery system and injection grid were reused. The grid manifold and piping were vacuumed and the nozzle openings cleared of any blockages. With the existing catalyst removed, it became necessary to repair the upper support bracing and locking mechanisms used to secure the catalyst frames on the downstream side.

CEMS equipment and its companion data acquisition system were reused, but reprogrammed to address the new lower emissions limits and air-permit obligations.

The steam turbine was uprated to 93 MW from 42. The new HP cylinder features a more robust blade-path design using the existing casing and inlet control valves to address the higher steam flow (Fig 5). The new LP turbine also was designed with a robust blade path, as well as other improvements (Fig 6).

The original mechanical overspeed trip was disabled and a new hydraulic

5, 6. New HP steam turbine rotor and barrel assembly is at left, new LP section at right trip block with speed probes to support integration of the replacement electronic trip system within the Emerson DCS was installed. Additional monitoring and performance measurement instrumentation was added to both the HP and LP turbines in support of the project's final testing.

Steam admission and extraction valves were disassembled and inspected, with some suggested OEM service-bulletin betterments applied. The HP casing was inspected where indications were found in the area of the HP inner gland and valve seat areas. These were removed as recommended by the OEM with no further corrective action.

New thrust-bearing shoes and liners were installed along with the inspection and reuse of existing journal bearings. An internal alignment of the new LP diaphragms required elevation changes to both the diaphragms and bearing pedestals.

Miscellaneous notes. Milford Power was designed as a 2 × 1 combined cycle, but the second GT was never installed. Thus, the existing generators for the steam and gas turbines were sized accordingly. The reduction-gear assembly between the HP turbine and generator was inspected and confirmed as suitable for the increased loading.

Existing step-up transformers, surface condenser, condensate pumps, circulating-water pumps, and cooling tower also were adequate for the uprate. While more demineralized water, and grey-water makeup to the cooling tower, were needed to implement the uprate, no changes to the existing treatment systems were required.

The additional control requirements dictated changes to the DCS. However, the PLCs for the wet-compression and duct-burner systems were connected to the DCS to provide status only; control of both systems remained with their respective PLCs.

Results. The uprate modifications were located within the existing infrastructure of the facility and increased plant output by approximately 53 MW. Some of the takeaways and lessons learned from the project are summarized below:

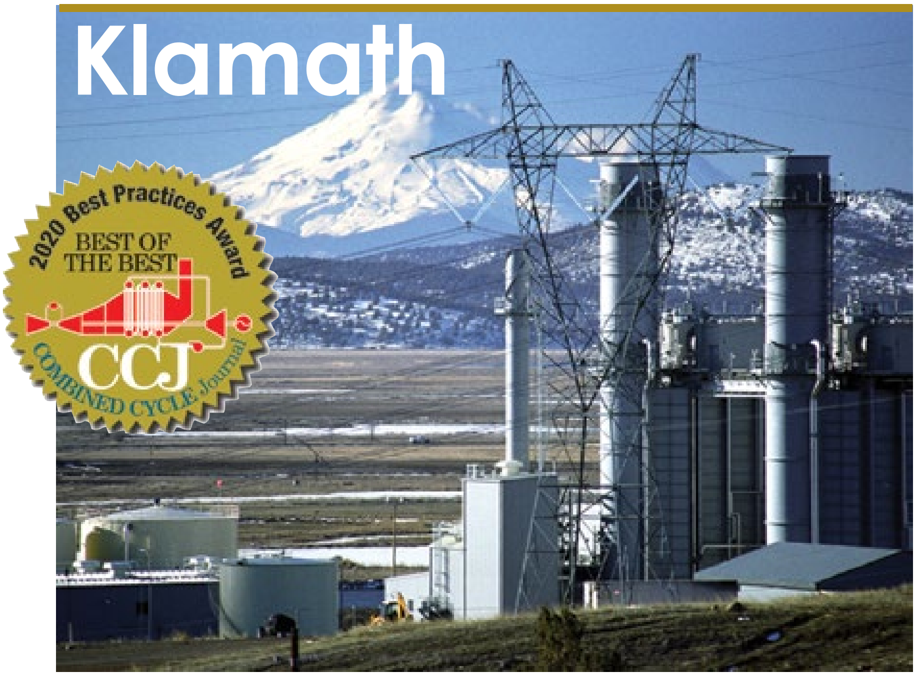
- The overall project took four years to complete and involved three different owners.
- Operational information on the GT exhaust communicated by a former owner, although not completely accurate, was used as a basis for design of the upgrades. A new GT exhaust NO_x analyzer was installed to better define emissions values at the different load ranges.
- Local building permits were required, making it necessary to work with town employees most familiar with occupational type buildings and not utility facilities.
- On projects like this, it is important to have an effective cost-management program in place for time-and-materials type contracts and emergent work discovered that is outside the base scope.
- Working with three different major contractors resulted in a fragmented project schedule. It took the effort of plant personnel to finalize an overall project schedule that clearly identified project milestones.
- Piping supports were pre-designed based on known pipe runs; field-run piping was not considered.
- The existing 50%-capacity boiler-feed pumps that each provided 100% of the plant's capacity without duct burners now provide only 50% capacity with the burners in service. Thus, it is necessary to operate both pumps to achieve the higher output with no backup available.
- High noise levels from the fuel-gas skid for the duct burners was discussed in the planning process but no solution was provided for mitigation.
- Compressed air from the GT air inlet compressor extraction point now contains more moisture with wet compression in service than previously.
- Steam-turbine output was believed limited to 93 MW prior to operation; engineering review showed it was 96 MW based on steam conditions.
- Electrical/control drawings. A pre-review of available onsite drawings indicated they had to be updated to the actual configuration of the existing circuitry so the engineering contractor could issue correct field drawings for installation.
- A second flow model for ammonia flow from the AIG across the new catalyst should be done to better understand any inefficiencies. Also, operational flow measurements should be taken to validate the effectiveness of new catalyst.

Notable accomplishments:

- Experienced no OSHA recordable injuries, no lost-time accidents, no environmental events.
- Achieved an additional 13 MW with wet compression in service.
- Achieved the performance guarantee of 90-MW output from the steam turbine.
- Demonstrated 204-MW plant output to ISO New England.

Project participants: William Vogel, Chris Tea, Kris Buckman, Kevin Collins

Klamath



Water mist replaces obsolete fire protection system

Challenge. The original Westinghouse (now Siemens) gas turbines at Klamath were furnished with FM-200 fire extinguishing agent in the engine enclosure and in the electrical and mechanical packages. Obsolescence of the electronic portions of the fire protection system mandated an upgrade of the two-decades-old equipment.

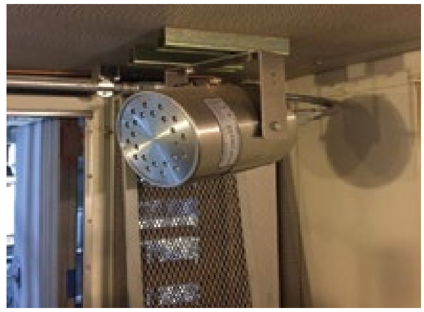
> **Klamath Energy LLC**
>
> *Avangrid Renewables*
>
> This 536-MW, gas-fired, 2 × 1 combined-cycle cogeneration plant, powered by 501FD3/6 gas turbines, is located in Klamath Falls, Ore
>
> **Plant manager:** Dennis Winn

Solution. The size of the turbine enclosure encouraged replacement with the Victaulic Vortex Hybrid Water Mist Suppression System (Figs 1 and 2). Features: Water droplets smaller than 10 microns (100 times smaller than water particles from traditional water-mist systems) and nitrogen are discharged from nozzles located throughout the enclosure.

This system provides for nearly zero wetting, no costly cleanup or equipment replacement, quick recharge, no need for assurance of tight room integrity, and, finally, a green design safe for people and the environment.

Suppression capabilities are

3. Novec™ 1230, which leaves no residue and is nonconductive, replaced FM-200 as the fire extinguishant in the electrical package. It uses piping and nozzles similar to that for the FM-200 system. The GWP of Novec 1230 has a rating of 1



4. The Stat-X® condensed aerosol fire suppression system replaced the FM-200 system in the mechanical package, which provides conditioned oil to the gas turbine. Here's how the system works: Potassium radicals from the Stat-X dispenser chemically join with combustion free radicals, interrupting the fire's reaction pathway and creating stable molecules. This common Halon substitute has a GWP rating of zero: Halon's GWP is 1301

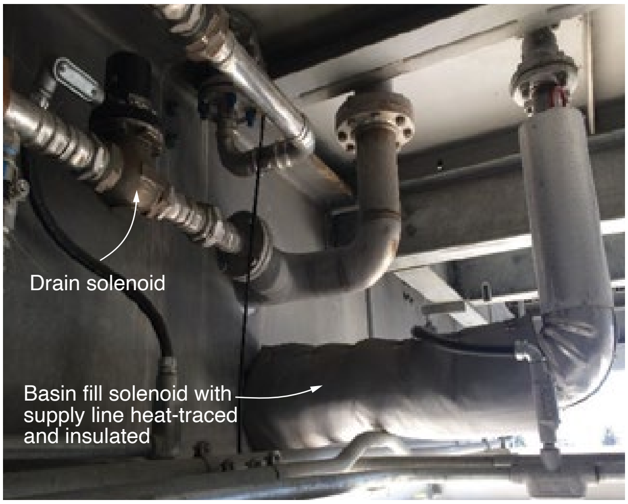
1. Nitrogen storage is sufficient to provide two releases to both gas-turbine enclosures. Operating pressure is 2100 psig (above)

2. Water storage tank, 100-gal capacity, sits alongside the initial and extended discharge control boxes for the Victaulic Vortex system. Nitrogen provides the motive force to drive water to the spray nozzles and resultant droplets (fog) into the enclosure (right) improved by providing significant thermal cooling as well as a prolonged period of inert atmosphere while the turbine spools down and temperatures fall below the autoignition temperatures for oil and natural gas. Importantly, the fire-suppression atmosphere created is capable of sustaining life while activated.

Alternative solutions for the electrical and mechanical packages are described in Figs 3 and 4.

Results. Installing the systems described allowed the site to remove the existing FM-200 systems that are less safe and contribute more substantially to global warming. FM-200 has a Global Warming Potential (GWP) of 3220, considerably higher than that of the Victaulic Vortex™, which incorporates nitrogen and water-mist extinguishing agents.

Project participants: Scott Nelson, Mark Mayers, Greg Dolezal, Dennis Winn, Chris Volk, Bruce Willard, Alan Scales, Joy Corner



5, 6. Evap-cooler basin as seen from the outside with solenoid valves installed (left); basin level transmitter is at right

Evap-cooler improvements save water, extend media life

Challenge. This site's gas-turbine air inlets are mounted on the roof of the generation building, which totally encloses both engines; inlets are located 50 ft above ground level. The air intakes are horizontal and equipped with a self-cleaning pulse-type filtration system plus evaporative cooling.

In the evap coolers, pumps continually circulate water from a lower reservoir to the top of each module and evenly distribute it over the media. A percentage of the circulating water is blown down continually to reduce the concentration of minerals and other waterborne contaminates that over time would leave deposits on the media. Water lost to evaporation and blowdown is replaced with service (potable) water.

Personnel regularly checked the evap coolers to verify their proper operation—specifically, that basins were not overflowing or at levels so low as to cause circulating pumps to trip. Frequent adjustments to, and maintenance of, the floats in the level-control systems were required.

A goal of the operations team was to reduce the number of times personnel had to visit the evap coolers on rounds.

The solution was to add solenoid valves for filling and draining the basins (Fig 5) and level detectors that could be monitored remotely in the control room (Fig 6). Both features were incorporated into the Siemens T3000 DCS. Advantages of automating the evap coolers are the following:

- Fewer visits by O&M personnel to the roof to adjust/fix the fill valve and float.
- Reduced cycling of the circulating pumps when low water levels in the basins would activate the cutout switches.
- Known basin levels that could be trended.
- Automated filling when ambient temperatures and baseload operation require evaporative cooling.
- Each fill valve received independent commands for filling and draining, allowing a water system already at its limits to be more capable of filling the basins.
- Automated draining of the basins during cold weather to prevent nighttime freezing.
- Ability to dump and fill the water basins from the control room when high conductivity so dictates.
- Tighter control of basin levels is possible. The old float was located near the man-door of the basin and the incoming air flow would cause turbulence in the float area. The new level indicator was relocated to the pump suction bay and placed in a stilling chamber, allowing much tighter control tolerances.

Results. Feedback from the operators has been positive. The media has had less calcium/magnesium buildup than in previous summers because of the ability to dump and refresh the basins' cycled-up fluids. This is predicted to add approximately three years to the life of the media.

Additionally, potable-water loss has been virtually eliminated. Reason: The basin no longer overflows. Gas-turbine performance also has improved because the evap coolers are more reliable. The total financial impact of the improvements will be monitored over the next couple of summers to evaluate project effectiveness. Stay tuned to CCJ for updates.

Project participants: Scott Nelson, Mark Mayers, Doug Hudson, Spencer Greer, Bruce Willard, Dennis Winn

Cooling-tower cell platforms reduce cost, promote personnel safety

Challenge. Klamath's counterflow mechanical-draft cooling tower is equipped with 200-hp, two-speed motors in each of its eight cells. Their one-piece, fully floating, composite horizontal drive shafts transmit motor torque to the right-angle gearboxes connected to each fan. Because no permanent work platforms were installed in each cell, maintenance was time-consuming and personnel safety was called into question.

Solution. Quotes for permanent work platforms were requested from several companies. The alternative, temporary platforms, was expensive. Each time personnel entered a cell it cost about $5000 in materials and labor to erect and remove scaffolding. Plus, there were performance impacts. For example, a loss of 0.4 in. Hg in condenser backpressure was experienced during a single-cell lockout, which typically lasted four hours. This amount of backpressure loss equates to a 0.8% decrease in plant output and 0.8% increase in heat rate.

The platform design selected covers 152 ft² and its FRP panels have a net free opening of 83% (Fig 7). This means the panels reduce the airflow area in the 30-ft-diam cells from 707 ft² to 681 ft². The 83% of net free opening was considered essential to avoid a disruption of air flow.

During this same outage, the plant installed new blades and bolting hardware on the fans. To minimize the effect of the air-flow restriction, the amperage of each fan motor was checked before the outage began. The average horsepower was calculated to be 183. The angle of each new blade was adjusted to maximize the horsepower output to 200.

Re-blading required a re-torqueing of the new hardware after 50 hours of fan operation. Thus, the new platforms started their return-on-investment shortly after re-start with a saving of $40,000.

7. Permanent work platforms, made of FRP, have a net free opening of 83%. Photo left is looking in at fan, looking out at right

Finally, the site purchased new cooling-tower fill and drift eliminators. The original fill had 1-in. openings because designers feared the use of secondary effluent from a nearby treatment facility would foul the fill. Years of operation showed this did not occur and the new fill has openings of 0.75 in., allowing for more contact surface area with no effect on air flow.

Results. All of the above items help to reduce the impact of the new safety platforms. Now personnel can access gearbox heaters, vibration probes, and perform alignments without have to engage a scaffolding company and crew.

Project participants: Greg Dolezal, Doug Hudson, Spencer Greer, Dennis Winn

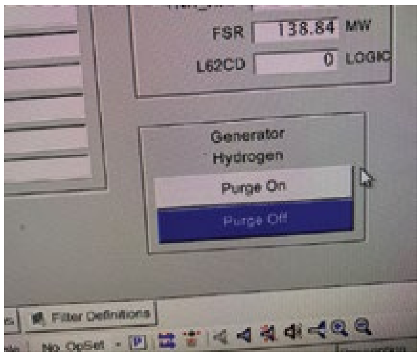
Hermiston

Hydrogen purge remote activation helps keep employees safe

Challenge: Provide an automatic remote means to purge a hydrogen-cooled generator without dispatching employees to the area.

Many 1990s-era 7FH2 generators were equipped with an automatic purge system that activated when hydrogen purity at the seals dropped below a specified setpoint. However, the controls were located in the collector compartment and could not be safely accessed if a hydrogen leak in that compartment was suspected. In the event seal oil was lost it would be unsafe to approach the collector compartment to activate the purge. If the controls were left in maintenance for any reason there would be no way to activate the purge without endangering an employee.

Solution. Since the automation was already in place along with solenoid-activated hydrogen shutoff valves, hydrogen vent valve, and CO_2 admission valve, all that was needed was to move the controls to the Mark V. Employees of Hermiston and TTS Energy Services, Orlando, Fla, modified control wiring and re-routed it to the Mark V. Because of the significant safety and liability concerns associated with hydrogen, a controls consultant was engaged to modify the Mark V logic and create a purge button to activate the purge from the Mark V HMI (photo).



Results. Now control room operators can monitor hydrogen purity remotely and perform a preemptive purge in the event they lose seal oil, without putting employees or equipment at risk. The total cost of the project was less than $10,000.

Project participants: Scott Rose, Tim Key, Jason Gefre

Personal ownership leads to 25 years of no lost-time accidents

Challenge: Provide a working environment where all employees can go home safely each night, without sacrificing plant reliability.

Solution. Instill a culture with a sense of ownership for the plant and for the safety of the people around them. Hermiston Generating Plant as been owner-operated by Hermiston Operations Co since COD. The facility's 50/50 co-owners, PacifiCorp and Perennial Power, are heavily invested in providing a safe working environment. HOC has been successful in inspiring employee ownership by doing the following:

- Investing $75,000 annually in employee safety and technical training.
- Developing safe work habits by hiring locally and training employees from the ground up.
- Handling significant decisions concerning safety, maintenance, operations, and accounting at the plant level.
- Spending time as a team—including team members' families—at company-sponsored barbeques, safety events, and gatherings.
- Maintaining a highly active safety committee, managed and operated at the plant level.
- Empowering employees to stop any job, at any time, if they feel it is unsafe.
- Recognition from the owners through emails and awards.
- Investing in engineering controls, such as these:
  - Automating the air-ejector skid to minimize ladder usage.
  - Relocating local instrumentation to ground level.
  - Automating the hydrogen purge skid to be activated from the control room.
  - Building safe working platforms.

Results. Hermiston Operations Co has achieved the following:

- Started its 25th year Nov 1, 2019 with no lost-time accidents.
- Was recognized as a SHARP graduate in 2005.
- Has a five-year average EFOR of 0.86%.

Project participants: All plant personnel

Hermiston Generating Plant

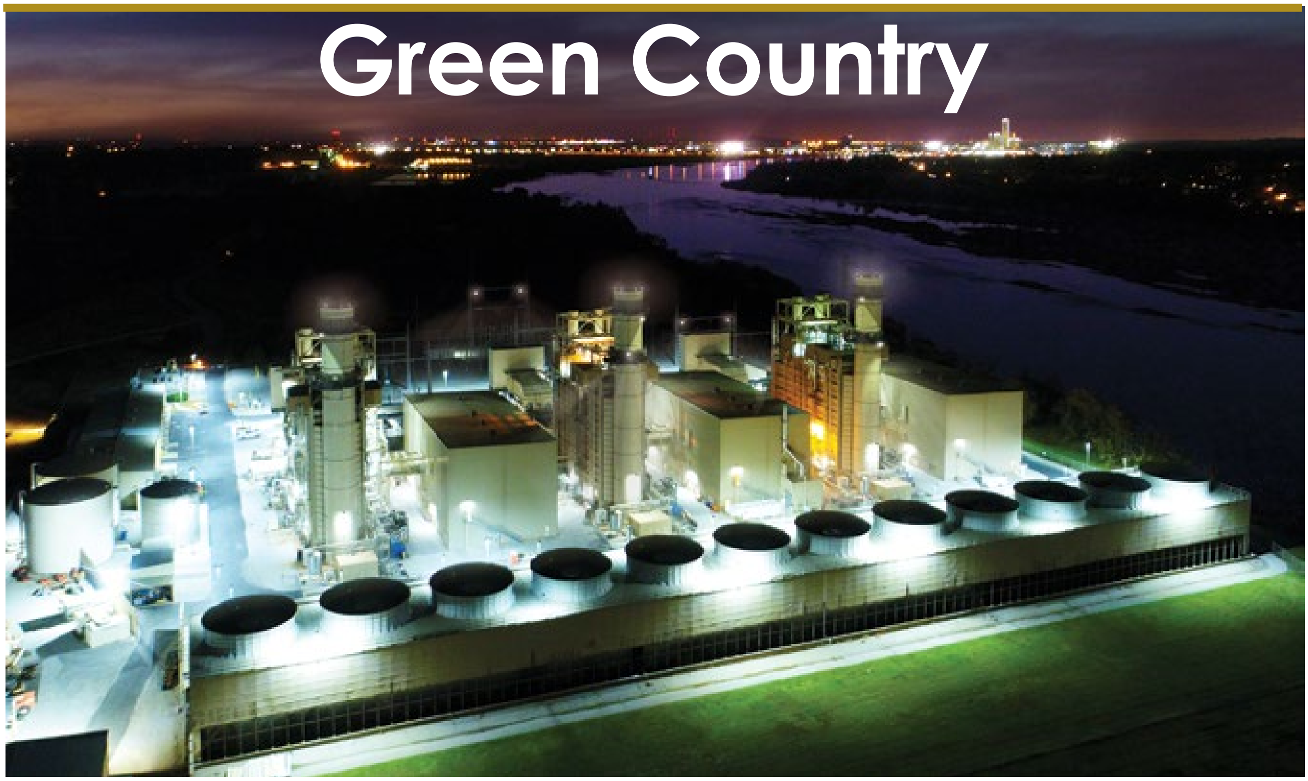
Owned by Perennial Power Holdings and PacifiCorp

Operated by Hermiston Operations Co

500-MW, gas-fired, 2 × 1 7FA-powered combined cycle located in Hermiston, Ore

Plant manager: Brad Knight

Green Country



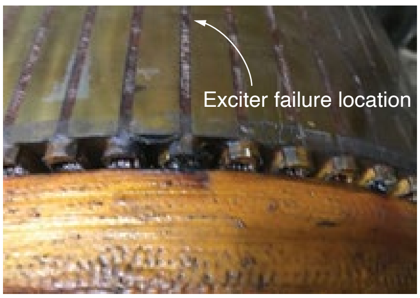
How to replace a Kato brushless exciter on a 9A4 generator

Green Country Energy
Owned by J-Power USA
Operated by NAES Corp
801-MW, three gas-fired 1 × 1 7FA-powered combined cycles located in Jenks, Okla
Plant manager: Danny Parish

Challenge: Removing and replacing an exciter during peak demand period while limiting financial impact.

The GE 9A4 generator married to one of Green Country Energy's three steam turbines experienced a ground-fault trip in August 2019, placing it into a forced outage. After removing the exciter stator, staff determined visually, and through testing, that the rotating field winding had shorted to ground (Fig 1).

Locating documentation, specialty parts and tooling, and qualified field technical advisors on short notice for removal of the rotating field was a daunting task. Although inspection and maintenance of the plant's Kato exciters had been performed routinely (including removal of exciter stator), removal of the rotating field was not something GCE personnel had done previously.



1. Common failure location on a Kato exciter field

Solution. Staff contacted other facilities to discuss exciter rotating-field removal/replacement experiences. While some plants had successfully removed the exciter rotor in the field, others had experienced complications that led to complete generator field

2. Specialty tooling required to replace the exciter field was made in-house (left)

3. Generator rotor is cooled by dryice retained in a modified ice chest (right) removal and offsite repairs. GCE staff knew that pulling the complete generator field would result in a minimum of three weeks of lost generation and forced-outage hours, as well as additional risk to the generator.

Upon reviewing the Kato documentation, drawings, and specialty tooling requirements, GCE's maintenance, IC&E, and operations teams were confident this was a task they could perform onsite. After careful review with plant management, the owners (J-Power USA), and the NAES engineering department, GCE opted to manufacture its own specialty tooling for exciter-field removal and installation. This in-house-produced tooling (Fig 2), together with unique work processes, allowed plant personnel to remove the rotating field in less time than possible with a vendor-supported effort.

The 9A4 Kato brushless exciter historically had performed well at GCE with only minor issues. Because of the component's long-term dependability, the plant did not maintain a spare. Kato no longer manufactures these brushless exciters and finding a replacement on short notice proved very challenging. While GE did locate a new old-stock replacement overseas, it would have taken weeks to deliver it to the site.

During the tooling manufacturing process, GCE's management team reached out to other facilities with similar exciter arrangements. It located a new old-stock replacement at a partner facility that had experienced similar problems with its exciters and had purchased a spare. The partner facility sold GCE its spare exciter.

The extended lead time required to purchase a new exciter from the OEM (more than three months) encouraged GCE to have its original exciter rewound and shipped to the partnering facility. This gave both plants relatively quick access to a spare if needed. GCE then purchased a new exciter and had it shipped to the partnering facility; the rewound spare was returned to GCE.

Upon receiving the new exciter from the partnering facility, technicians verified its fit to the generator rotor and devised a system to shrink the rotor while expanding the exciter field. This enabled an appropriate "slip-fit" of the exciter field on the generator rotor.

Technicians retrofitted a very large ice chest to hold both the generator rotor end and dry ice to facilitate fit-up (Fig 3). The rotor was left on ice for around six hours. During rotor icing, the exciter field was heated with an external source. Technicians finalized the fabrication of an installation plate and extended deep sockets needed for the all-thread that was used for pressing the exciter field onto generator rotor.

Results. A successful exciter-field replacement (Fig 4) was performed completely in-house in a relatively short period of time. In-house technical skills together with support from owner J-Power USA, operator NAES, and GCE management enabled timely project completion. The GCE team came together with a "We've got this" attitude and was able to gather the information needed through manuals, drawings, and collaboration with other facilities to fabricate everything required to remove and reinstall the exciter field.

In addition to the in-house technical skills, the relationships that GCE has cultivated through the years with other facilities allowed for productive and quick information exchange. These relationships also have led to equipment-sharing support. It was this support, along with the in-house technical "can do" attitude that took a potential three-week-plus outage, during peak season, and reduced it to six days. The positive impact to availability and generation was substantial.

Project participants: The Green Country Energy O&M staffs

Safe entry into gas-turbine compartments equipped with CO_2 fire protection systems

Challenge: Safety is a core value at Green Country Energy and identifying opportunities for safety improvement projects is a big part of what GCE employees do daily. Entering gas-turbine packages protected by CO_2 fire suppression systems has always had inherent risks: The potential exists for an employee to enter a compartment and be present during a CO_2 release. Technicians routinely enter GT compartments for inspections and other tasks.

During the early years of operation, CO_2 fire suppression was not a requirement and was not installed in the exciter and/or load compartments. Through discussion with the insurance provider and other facilities, it was determined that adding CO_2 fire suppression to these areas would be an industry best practice. This project was completed several years ago.

While addition of CO_2 fire suppression in the exciter and load compartments provided needed protection against fire, bringing the extinguishing systems up to NFPA 12-2018 standards required manual isolation valves with supervisory indication for each zone. These valves were not installed at GCE because system isolation was not standard practice except in times of unit outages and individual zone isolation was not something that could be done easily (Fig 5). Therefore, past practice allowed employees to enter exciter compartments and accessory modules for routine tasks without isolating the CO_2 system.

The belief was that the audible and visual alarms, coupled with the time delay of the CO_2 discharge, would give an employee ample time to evacuate the area. Although true, this left room for error and required complete system functionality to work. GCE technicians needed a way to safely perform routine rounds and readings in exciter compartments or accessory modules without the risk of asphyxiation from a CO_2 release.

Solution. In 2019, GCE completed all GT CO_2 fire suppression upgrades. The upgrades consist of CO_2 manifolds with manual isolation valves for both initial and extended discharges to each zone (Fig 6). Valve supervisory switches also are used for remote valve position indication. Addition of manual isolation valves and super-

4. New exciter field is installed

5. Automatic solenoid zone valves were not easily disabled or isolated (left)

6. New valve manifold has individual zone isolation capability and supervisory switches. Note labeling for each station (right)

visory switches, brought GCE's CO_2 fire suppression system up to current NFPA standards.

Labeling was added to the valves and piping to ensure correct zone isolation when used. Technicians can now easily isolate one zone (five total) without sacrificing the protection to other critical gas-turbine areas. Although not required by NFPA on systems with audible/visual alarms, odorizers were used in the high-exposure areas of the exciter and load compartments (Fig 7). Signage also was upgraded to current NFPA standards (Fig 8).

In addition to the equipment upgrades, a standard operating procedure was developed for all employees. The SOP does not replace tasks that would require a LOTO, but covers entries for readings and inspection. The procedure includes control room notification for isolation, restoration, and logging requirements.

7. In-line odorizers are installed in high-exposure areas

8. NFPA signage was upgraded

Results. The system and procedure have only been in place a short time but are working extremely well (Fig 9). The valve manifold allows for effective and easy isolation of fire protection zones. Technicians are now safely entering exciter compartments daily for readings and inspections. Although used daily for exciter compartments, this same process allows for quick access to accessory modules and gas compartments.

Project participants: The Green Country Energy O&M staffs

9. Upgraded CO_2 fire suppression system is meeting all expectations

River Road

River Road Generating Plant

Owned by Clark Public Utilities

Operated by General Electric

250-MW, gas-fired, 1 × 1 7FA-powered combined cycle located in Vancouver, Wash

Plant manager: Robert Mash

Non-chemical alternatives control algae in cooling tower

Challenge: After five years of operation, River Road Generating Plant was compelled by the Washington Dept of Ecology to eliminate use of chlorine for biological control in its cooling tower. Instead, the plant was instructed to use bromine. Several years after the switch to bromine, River Road began to experience a resilient and chemically resistant form of filamentous blue-green algae. Its growth in spring and summer got out of control.

Expensive and toxic algaecide treatment was required to limit algae growth. The plant discharges tower blowdown to the Columbia River under a NPDES permit with strict discharge limits. One consequence: Blowdown was not permitted for up to 12 hours following this treatment process to assure dissipation of residual algaecide and to maintain permit compliance. That led to high cycles of silica.

During the peak of algae growth, accumulation at the forebay trash screens upstream of the circulating-water pump suction became so great the screens had to be pulled and manually cleaned every three days to prevent collapse (Fig 1). Removal of the trash screens required a crane and crane operator at a cost of $4500 per event.

Solution. These combined factors prompted staff to seek out new technologies to control algae. In 2013, plant personnel located a company that provided algae control using floating ultrasonic devices (Fig 2). They were procured and installed in various locations and orientations in the tower basin. Algae growth was reduced substantially, but not eliminated during the summer.

The search continued for an effective non-chemical technology; reverse osmosis, flocculation, ozone, UV treatment, and electrodeionization were among the technologies investigated.

Because sunlight is required for algae to grow, nursery shade screens were installed around the tower perimeter. They reduced the light required for photosynthesis and did help to reduce the algae more than the ultrasonic devices did on their own. However, the algae problem was not eliminated entirely during the summer.

During the search for a solution, staff located a company, Flow-Tech Industrial Water Treatment Systems, Milwaukee, Wis, that had developed a product used in small-to-medium size HVAC applications for many years, with well-documented success.

The vendor proposed creating and using its patented non-chemical devices on an industrial scale at River Road. The relatively small components are mounted on circulating- and service-water system pipe flanges in strategic locations (Fig 3). Each unit transmits AM radio frequency into the water systems and cooling tower basin.

The theory of design is that the radio frequency disrupts the lifecycle of the algae in its single-cell haploidic form and kills it, before it forms viable colonies. Plant personnel worked with the vendor to develop and implement an industrial-scale test plan for the devices at River Road.

Results. Application of the new devices has measurably reduced the plant's biological and algae count within the cooling tower. Chemical treatment has been reduced to an algaecide injection once every three weeks rather than every other day (Fig 4). Benefits identified thus far include the following:

- A nearly complete elimination of algae in the cooling tower.
- Lower micro-bio counts on weekly

1. Before using non-chemical means, algae control was an ongoing battle (left)

2. Ultrasonic devices rupture algae cells, preventing them from rising to the water's surface and absorbing the sunlight needed for photosynthesis (right)

3. Radio-frequency device installed on circulating-water pipe disrupts the lifecycle of algae shortly after their creation

4. The impact of non-chemical treatment on biological and algae counts over a five-week period was impressive (left)

5. Hydrogen tape turns a dark color in the presence of that gas (above)

dip-slides.

- A significant reduction in chemical consumption for biological control.
- Elimination of crane costs for in-service screen cleaning.
- Reduction in chemical discharges to the river.
- Reduction in the handling of toxic chemicals by plant personnel.

Project participants: Sid Roy, Terry Toland

Hydrogen-detection flange tape promotes safety, facilitates inspection

Challenge: Following each generator maintenance activity, the system supplying the machine with hydrogen for cooling was restored and leak-checked using a soapy water product that bubbled or foamed if a leak existed.

A team member who attended the 2019 conference of the 7F Users Group saw a demonstration by Nitto Inc, Teaneck, NJ, promoting a pipe flange tape that changes color in the presence of hydrogen (Fig 5). Thus, it provides a visual indication of a leak because it will not return to its original color once hydrogen gas flow is stopped. Even though a soap test indicated no leaks, the team thought it would be a good practice to use the color-changing tape.

Solution. The team member presented this idea as a proactive safety practice to the safety committee. The tape was purchased and installed on every hydrogen flange. Leaks were found.

Results. Thirty-eight flanges were taped. All had been soap-checked prior to using the tape. Once installed, four flanges changed color within two days. Where leaks were indicated, tape was removed from the flanges, and the joints were soap-checked again. Only one of the leaks was large enough to cause bubbling visible to the eye.

The hydrogen-detection flange tape worked well as a pre-emptive safety check and has stimulated proactive thinking about previously unrecognized problems. This fits in well with the long-established plant safety culture at this VPP Star site. Use of the tape is now part of the hydrogen-system restoration procedure.

Project participants: Terry Toland, Micah Wild, Margie Brice

Real-time monitoring of lube-oil condition

Challenge: River Road relies on one lube-oil tank to supply the bearings of the single-shaft plant's gas turbine, steam turbine, and generator. The original oil conditioning unit supplied by the OEM was grossly undersized for the 10,000-gal sump and was removed from service shortly after commissioning.

In 2000, the plant purchased a portable conditioning unit to filter the lube oil. It was functional and cleaned the oil fairly well. As that unit reached the end of its useful life, and the sophistication of the plant team grew, a replacement was sought.

Solution. Plant personnel worked with a small, local oil-filtration company to design, construct, and install a new conditioning system—one that would fit in the same physical space as the original unit, have a higher throughput, and include online particulate and moisture analyzers.

Following a water-intrusion experience, plant personnel learned the importance of obtaining oil-quality test results quickly. Relying on sample results from a third party to determine moisture content and particle count had put the staff in a reactive mode instead of a proactive one. The new conditioning system provides real-time monitoring of 4-, 6-, and 14-micron particles (Fig 6). The dew-point monitor and associated instrumentation assure instantaneous detection of moisture in the oil.

Results. The new unit increased the oil conditioning rate from 13 to 38 gpm. Third-party analysis for 4/6/14-micron particulates prior to installation of the new system was 22/20/16; two weeks after installation it was 18/16/12.

Moisture in oil was not tracked regularly before the new system was installed. The data available showed the Karl Fisher number for entrained water averaged around 600 ppm. That number has been reduced to 25 with the new system.

The new conditioning/monitoring system has dramatically improved

6. Oil conditioning system provides real-time monitoring of 4-, 6-, and 14-micron particles

lube-oil quality. The expected benefit is less bearing wear between maintenance outages.

Project participants: Ken Roach, Mike Buhman, Jack Blair, Daniel Bartholomew

Oil boom protects environment against leakage from cooling-tower gearboxes

Challenge: River Road's cooling tower has five gearboxes, each containing about 20 gal of lube oil. The catastrophic failure of a gearbox poses the risk of releasing oil into the cooling-tower basin. From there it could migrate into the natural environment—more specifically, into the Columbia River—and result in a water-permit discharge violation.

Solution was to install a boom upstream of the cooling-tower circulating-water-pump trash screens to collect any oil that might be spilled, preventing it from reaching the effluent discharge piping (Fig 7).

Oil collected in the basin can be removed by absorbent pads or skimming equipment.

7. Boom captures oil that might leak into the cooling-tower basin

Results. The oil boom installed continues to provide a reliable way of preemptively capturing any oil that might leak into the cooling-tower basin. The boom is easy to handle and is cleaned during annual outages.

Project participants: Sid Roy, Jacob Sanderson

Benefits accrue from combining JSAs and operating procedures

Challenge. At River Road, work instructions historically included two separate documents—a job safety analysis (JSA) and an operating procedure. Personnel using the work instructions had to review these documents side-by-side to understand the risks associated with each step of the process.

Moreover, since the facility maintains work instructions for many its processes, reviewing documents and keeping them updated required considerable time commitment for the onsite team on a regular basis.

Solution: Incorporate the JSAs into the operating procedures, providing a job safety analysis for the task at the beginning of the document. New format also includes more pictures pertaining to the process steps.

Results:

- Having the job safety analysis for the given task at the beginning of the document simplifies work instructions. Additional pictures are included for more clarity regarding steps involved.
- Alleviates the need to review multiple documents while performing a task and increasing awareness of the hazards associated with the task.
- Reduces number of documents to be reviewed and updated by half, reducing the time required to keep the documents current and updated.

Project participants: Margie Brice, Sid Roy

St. Charles

Cooling-tower fan gearbox mod facilitates oil sampling, recharge

St. Charles Energy Center

Owned by Competitive Power Ventures

Operated by Consolidated Asset Management Services

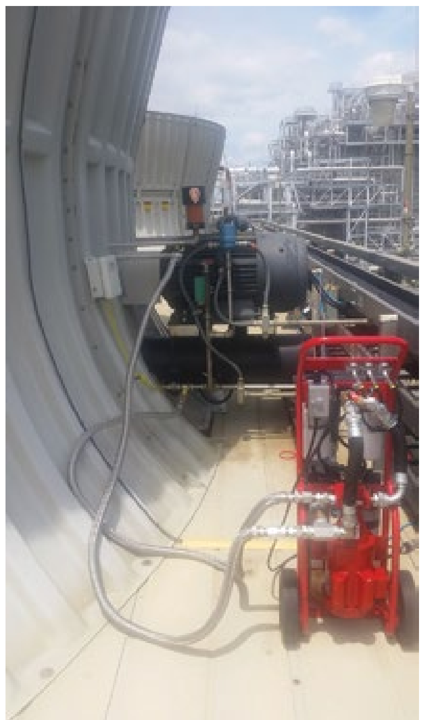
745-MW, gas-fired, 2 × 1 combined cycle located in Waldorf, Md

Plant manager: Nick Bohl

Challenge: Oil in cooling-tower fan gearboxes is sampled/tested monthly. When the tower was built, safe and easy access to facilitate sampling was not a priority (Fig 1). Some personnel considered the sampling process dangerous and time-consuming. It involved (1) LOTO of the necessary breaker and circ-water valves for the affected cell, (2) unbolting of part of the fan shroud, (3) installing a walkway to reach the gearbox, (4) locking the fan to prevent its rotation, (5) putting on a fall protection harness, (6) walking to the gearbox, (7) tying off to an anchor point, and, finally, (8) removing the filler plug and drawing an oil sample.

After the oil sample was retrieved, the entire process was reversed to return the tower cell to service. Weather permitting, this evolution would take at least two hours to complete. Multiplying that by 10 fans means a minimum of 20 man-hours was required monthly to pull oil samples from the cooling tower.

The same process was followed for gearbox oil changes. The time it took to drain and fill each gearbox made this job difficult to plan and perform.



1. Easy access to cooling-tower fan gearboxes for sampling lube oil was not a priority when the plant was designed (above)

2. Portable oil pump/filter cart facilitates sampling and oil changes (right)

Solution. Develop/implement a safer, more efficient way of obtaining oil samples, and of performing oil changes. Staff decided the best method would be to modify the equipment so sampling and oil changes could be done without entering the tower cell. Piping was connected to the gearbox and routed outside the fan shroud, and hoses and quick couplings were installed on the piping near the fan motor to allow easy access to the sample/fill line. Lastly, plant purchased a portable oil pump/filter cart to facilitate sampling and oil changes (Fig 2).

Today, all a technician has to do is hook up the oil cart, turn on the pump to circulate the oil, and retrieve the sample from the sample port. During oil changes, the cart allows for quick draining/filling of gearbox oil and provides the option to valve-in filters to remove particulates and moisture.

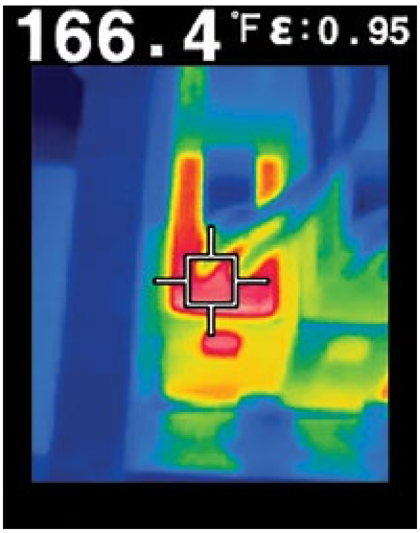
Results. Oil sampling and changes can be done in minutes versus the hours previously. Most importantly, these tasks can be performed without putting employee safety at risk: All work is performed on the cooling-tower deck outside the fan shroud. Added benefit: When the piping was being modified, staff ran an additional line from the gearbox vent port outside the fan shroud. A desiccant filter was added to that to decrease the moisture level in the oil and increase its useful life.

Project participant: Frank Katzenberger

Brush maintenance program improves generator reliability

Challenge. Less than a year after commissioning, St. Charles experienced a ring-to-ring fault causing a collector flashover on the steam turbine/generator. After this event, plant staff established daily and weekly criteria for brush and collector inspections and maintenance going forward.

Staff initially adopted a procedure for weekly generator field brush checks involving use of a clamp-style ammeter, plus a visual check for discoloration of shunts, chipped brushes, excessive wear, contamination, hung up brushes, etc. The action of taking current readings by clamping the ammeter around the shunt pigtails of a running machine is a dangerous evolution even with the required arc-flash PPE—especially given the number of brushes per unit.



3. Thermal scans of generator brushes help O&M personnel decide when brushes should be changed

Solution. Mindful of the safety concerns related to online amp readings, staff incorporated infrared technology into the weekly brush inspections. An IR imager is now used to perform a thermal scan of each brush while the machine is online (Fig 3). The temperature of each brush is recorded on a spreadsheet and used to track performance over time.

Staff can now determine which brushes are carrying the most load and which are not carrying current as they should be, based on the running temperatures. Data are evaluated weekly and compared to prior results to establish a priority level for the replacement of each brush and/or holder.

Results. Use of IR technology has minimized the safety risk of placing hands and equipment inside of a running machine along with eliminating the shock and flash risk associated with those actions. Staff is now able to schedule brush changes based upon the temperature profile of the given brush over time and assign priority to those that need immediate attention.

Using this technology along with normal wear-indicator inspections has greatly increased generator reliability, mitigating the detrimental effects of brush selectivity and the potential for flashover. However, the most important benefit is personnel safety.

Project participants: Bill Bates, Jimi James, Frank Katzenberger, Chris Higgs

4. Job status board helps staff follow changes during outage

Job status board helps keep staff informed, safe

Challenge. During planned maintenance outages it can be difficult for staff to track what and where work is being performed. A plant could have hundreds of contractors on site with many different lock-out/tag-out (LOTO) clearances, confined-space permits, and hot-work permits. In addition to permits and clearances it is particularly important for personnel to be informed of major evolutions—such as lifts involving cranes, foreign material exclusion (FME) zones, excavation areas, and the occasional x-ray zones.

Outages can be ever-changing events so keeping personnel up to date on the status of these items is an extremely important safety concern. Staff needed to find an easy, effective way to communicate the status of these items to all personnel.

Solution. Staff created a status board for mounting in the control room that was simple to read and allowed personnel to make changes easily as the status of jobs evolved (Fig 4). Instead of using a standard LOTO station or outage board, plant staff wanted something visually attractive with

5. LOTO boxes hold keys associated with clearance isolation locks. Labeling matches up with notations on the job status board

pictures, and understandable by the least experienced personnel.

The staff commissioned Powergen Publications Inc to create an artistic rendering of the entire facility using actual plant drawings. This drawing contained all equipment onsite—including piping and proper flow paths. It then was imprinted on a 4 × 8-ft metal whiteboard, allowing technicians to write on the drawing with erasable markers as well as to place magnets onto the surface. Individual magnets were custom designed by the facility to represent LOTO's, confined space, hot work, crane, excavator, x-ray zones, areas of isolated power, and emergency power locations.

The LOTO boxes used by the facility to hold the keys associated with clearance isolation locks were individually labeled to match the LOTO magnets on the outage board (Fig 5). With the LOTO magnets matching the LOTO cabinets, personnel can easily see where each LOTO is hung and can sign on to the corresponding paperwork. The magnets are easily removed or added as the job status changes.

Results. The outage board has been an huge success and become a focal point during the outage. Before an outage even starts the board is used to help in the planning where LOTOs must be hung for the jobs being performed. During the first stage of the outage, the board is used by the staff to see what LOTOs have been hung, allowing them to plan work and decide where the next LOTOs would be needed.

During the outage, the board is used to identify where all work is being performed in the facility. Near the end of the outage, the board helps staff quickly determine what equipment has been cleared and what is still under a LOTO—thereby allowing for a better and more efficient plant restoration process.

Besides being used for outage work, the board is a primary tool for training technicians—because it is a huge one-line drawing of the entire plant. Staff also has used the board during plant upsets to direct personnel response and identify equipment to check.

Project participants: Nick Bohl, Jonathan Bennett

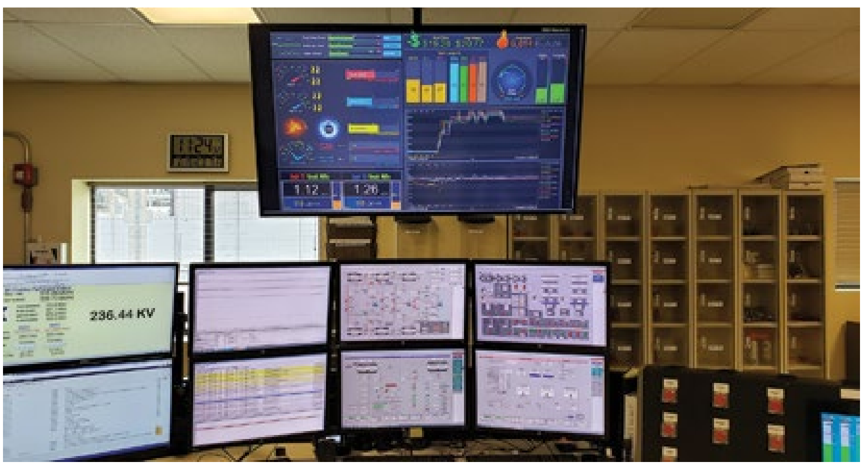
Vision Screen promotes operational excellence

Challenge. With staff changes following the assignment of a new O&M company to the facility, familiarity with the plant and its nuances raised some challenges for the fresh faces—for example, frequent connection loss with the gas-turbine flame scanners, irregular fuel-gas or plant-air pressure performance, and chemical tanks not being replenished in a timely manner.

Accessing and readily monitoring these factors while learning a new facility and trying to troubleshoot operational challenges led to an unnecessarily convoluted shift. Adding additional screens to the control room seemed to treat the symptom and not the problem.

Solution. The historian PI server captures all the parameters of interest so the complimentary software tool, PI Vision, was used to build the platform that would later be named SCEC Vision (Fig 6). A large screen display was ceiling-mounted and outfitted with a 4.5-in. Intel mini-computer specifically optimized for 4K UHD resolution with a high refresh rate. Internal cyber controls and NERC guidelines were followed when implementing this concept, segregating the device from the controls network.

6. SCEC Vision displays parameters of interest to operators and management



7. Large-screen display is the centerpiece of the control room

Screen layout required significant effort. PI Vision inherently has a very limited design toolset, so it was up to the staff to create custom images and data equations. Every icon, animation, and formula has been designed in-house. Once the initial layout was completed, a survey was taken of all data points considered important to plant health so they could be implemented.

The result was a simple but aesthetically pleasing display anchored as the centerpiece of the control room (Fig 7). The historian PI server now feeds data, in real time, to this centralized display, complete with visual cues to keep operators alerted of detrimental change.

Results. Since implementation of SCEC Vision, there has been a dramatic improvement in voltage-schedule adherence. Plus, chemical-tank provisions are ordered without delay, and flame-scanner faults are detected quickly and corrected. The fuel-gas and plant-air pressures now are tweaked to near perfection. A quick look back at the previous eight hours trends the plant's generation and drum level controls to scan for unusual operation.

There also have been unforeseen benefits. Whether it is during the morning staff meeting, or simply passing through the control room, SCEC Vision had become a conversation piece that helps inspire new ideas and constructive criticism. As the staff overcame many of the above-mentioned obstacles, the mindset moved to improving efficiency and reliability. SCEC Vision became so valuable that screens were placed in the offices of the plant manager and plant engineer for monitoring purposes.

The importance of plant efficiency led to operator training and heat-rate monitoring on SCEC Vision. Condenser vacuum, fuel-gas metering, and vivid palettes featuring the CEMS and HRSG duct burner behavior are all contributions from operator feedback.

There was virtually no cost associated with the development and implementation of this tool—other than a $150 annual licensing fee. Use of SCEC Vision continues to grow to serve the needs of the plant and its personnel.

Project participants: Jonathan Bennett

Keep up with NERC requirements on visitor tracking, control of transient cyber assets

Challenge. With NERC CIP-003-7 introducing additional requirements for cybersecurity and controls, one particularly polarizing topic had become visitor tracking and management. With St. Charles located just outside Washington DC, the plant often hosts guests from government agencies and nearby engineering colleges. The industry-standard visitor sign-in sheet did not meet the latest regulatory standards.

Revision of the NERC standard introduced strict governing of transient cyber assets (TCA) and removable media. Whether it be an OEM sales consultant, electrical relay technician, or GE technical advisor, all too common are devices such as laptops and USB thumb drives allowed to connect freely to what should be controlled digital environments.

Rarely were these devices scanned for malicious code that would contain malware designed to execute immediately upon contact. All of this further highlighted the necessity for more intuitive, and modern access monitoring and control tools.

Solution. Staff decided a digital kiosk would allow the facility to eliminate most of the shortcomings of a pen, paper, and clipboard setup. This would require an easily accessible interface with security against physical theft.

The kiosk design selected was a slim Android tablet and complimentary stand, complete with the security option of a lock and key. Unnecessary applications were stripped upon installation, user access was limited, and an "Always Awake" application was installed with enhanced brightness. LobbyTrack ended up being the visitor management software of choice, configured with a "self-sign-in" lock code to prevent misuse. A placard was affixed above the station to guide visitors to sign in.

Another digital kiosk was implemented to manage the TCA and removable-media concerns. A Windows-based device was chosen this time with security again being the focal point for the choice of stand. The intention of this station is to allow all outside devices and media to be scanned within a sandbox environment where a report can be generated and logged without risk of malicious code—that is, malware or ransomware—compromising the plant network.

The control room houses the HMIs for the plant's DCS and has a connecting door to the business servers. Previously, guests would sign in at the lobby and have unchecked access to the control room and, arguably, the server room, if not for the CRO monitoring them. Now, biometric smart locks have replaced the original door latches for both control-room and server-room access.

All personnel have their fingerprints coded. Different security levels are assigned to staff based upon specific need—that is, very limited access is granted to the server room to reduce unnecessary foot traffic and threat potential opportunity. Should the fingerprint have trouble for whatever reason the faceplate of the smart lock allows a numerical code to be entered. The digits on the faceplate strategically rotate with every press to eliminate any third party recording the code.

Results. Plant management received immediate positive feedback when the digital sign-in kiosk went live. New visitors simply enter their name and company on the touch screen, select their host, and the rest is done for them—including notifying the host that their guest has arrived.

Visitors can be scheduled, to reduce sign-in time to near-instant, and returning visitors can simply type in a few characters from their name to be presented with a suggestion box for a quick autocompletion. This has dramatically improved visitor accuracy and participation. There is also a web-based control panel where monthly reports can be generated, which ended up providing an unforeseen benefit in our accounting department with monthly accruals.

Part of the initial concern in implementing the security kiosk for scanning TCA and removable media was that the process might be expensive and cumbersome. Rather than use a full workstation plant opted for a two-in-one tablet which reduced the cost dramatically while still being able to manage Windows media quickly and efficiently. The anti-viral/malware software has been configured to scan connected devices immediately, place threats found in a secure vault, and generate a report without any prompts or interaction. The additional security measure has been painless, generally requiring less than 60 seconds for a complete scan.

Upon first installation of the biometric smart locks it took less than an hour in total to add and configure each onsite employee with his/her own unique fingerprint key. The fingerprint scanner has been quick, reliable, requiring zero maintenance, and alleviating the need of metal keys or plastic keycards. These biometric smart locks are also configured with their own independent roster. Universal access is not allowed, everything is on an as-needed basis.

Contractors also can be granted a temporary access PIN, prior to arrival, with an expiration time and/or date. This allows unimpeded workflow with a trusted vendor. The lock also has short-range Bluetooth communication providing a full-access log complete with timestamp for incident recall. There was a period of culture shock with repeat contractors, but the message is loud and clear that the plant is taking security very seriously all while complying with the updated NERC CIP-003-7 standard.

Project participants: Jonathan Bennett, Kelly Swann, Javier Gomez

Crete

Unit trips stop after relocating generator PTs

Crete Energy Venture

Owned by Crete Energy Venture LLC

Operated by Consolidated Asset Management Services (CAMS)

330-MW, four-unit, 7EA-powered peaking facility located in Crete, Ill

Plant Manager: Brad Keaton

Challenge. Since 2008, perhaps earlier, Crete had been experiencing generator circuit-breaker trips and grid separation because of PT (potential transformer) fuse failures. Between 2008 and 2009, Unit 1 suffered eight PT fuse-failure events (nine total among the plant's four 7EA peakers) resulting in 9.95 hours of forced-outage time and lost generation. Plant personnel noted during the investigation of, and recovery from, these events that the PT fuses were migrating out of their clips, and interrupting the circuit (Fig 1).

In October 2009, a third-party contractor was hired to measure vibration on the Unit 1 generator, higher-than-normal readings having been observed on the exciter end of the machine. The contractor found that the second balance resonance vibration was high and vibration energy was being transmitted to the casing and extremities of the generator. The issue was resolved, so staff believed, by using a dynamic weight correction to the generator field (two planes). No PT fuse failures occurred in 2010.

In 2011 and 2012 the PT fuse-failure trips returned, with Units 2 and 4 having three failures contributing 1.74 hours of forced-outage (FOH) time. Site technicians attempted to zip-tie the fuses into the clips, given migration was noted on multiple fuses at the time of failure (Fig 2). This proved ineffective: Fuse migration was still observed during the 2012 fall outage.

Site personnel fabricated a new style of fuse clip with a latching bale mechanism and upgraded the fuses from 15 kV-0.5E amp to a more robust 15.5 kV-1E amp fuse with a protruding lip on the ferrule to prevent axial movement (Fig 3).

At this point the failures were so common that staff had developed a recovery procedure using the MCB terminal blocks in the generator compartment and moving the failed fuse lead over to the second PT terminal of the affected phase to limit forced-outage time. Resistance was measured on all fuses during the spring and fall outages to see if fuse degradation could be tracked; fuses were proactively replaced. Only one failure was noted in 2013 on Unit 4 (1.27 FOH).

In 2014 three PT fuses failed—one on Unit 1 (0.35 FOH) and two on Unit 2 (1.42 FOH). A contractor was brought onsite in summer 2014 and the generator exciter end was balanced on Units 2, 3, and 4, where high seismic vibrations were identified during gas-turbine operation. After balancing, no fuse failures were noted for the remainder of 2014 or 2015.

In 2016 the fuse failures returned, this time exclusively on Unit 1. Over the course of a month, five more fuse failures occurred, resulting 4.49 FOH and significant lost revenue. Staff contracted a generator specialty group to collect flux-probe and vibration data during unit operation at varying real and reactive power conditions. A four-day maintenance outage was taken to disassemble both ends of the generator and perform visual inspections for possible mechanical issues.

1-3. PT fuses migrating out of their clips (left), holding fuses in place with zip ties was not successful (center), new style of fuse clip at right eliminated fuse migration

Multiple test runs were performed with varying balance shots until vibration was reduced. Data were collected for the remainder of the summer peak season and sent for third-party review. There were no recurrences of PT fuse failures in 2016. The same vendor returned in March 2017 and performed a borescope inspection of the Unit 1 generator rotor. No issues were identified.

Two months later, Unit 1 experienced a PT fuse-failure event: Two of the six PT fuses failed while the unit was at base load, resulting in 4.4 FOH. Unit vibrations were low during this event and, having exhausted balancing and mechanical inspection efforts on the generator itself, staff shifted its focus to the line-side cabinet where the PTs were mounted.

An engineering firm conducted impact/resonance tests on the fuses, fuse clips, PTs, and cubicle. Transfer functions from the impact-response data were computed to determine the response as a function of frequency. Based on data taken during the resonance testing, three fuses had natural frequencies that were in close enough proximity to 60 Hz as to amplify their response to any generator vibration that might be present. A recommendation to install vibration dampening material under the PTs was implemented on Units 1 and 2.

Unit 3 experienced another fuse failure during the summer peak period. During the fall outage, plant personnel found the fuse resistances on all four units still shifted from 61 ohms new to 25 to 30 ohms at the time of inspection, with no difference noted in the units with dampening material installed. This was indicative of imminent failure based on prior experience; management determined a drastic change of approach was required.

Solution. In fall 2017, staff and a contractor worked on a plan to physically relocate the PTs from the line-side cubicle to another compartment where vibration would not be an issue. After considering multiple locations, the parties determined that the back side of the PACS generator circuit-breaker package would be an ideal location.

The vendor's engineering and design department calculated there would be enough room to move the PTs to the new cubicle and maintain electrical clearances from phase-to-phase and phase-to-ground. The project was approved by the owner and the full scope for Units 1 and 2 was planned for the outage in spring 2018. The relocation process began in April and was completed in nine days.

Next, primary injection testing was performed using the system back-feed as the source, with the GCBs closed and the generators for Units 1 and 2 completely isolated by removing a section of the non-seg bus between the GCB and the generator terminals. All voltages had the proper amplitude and phase angle at both the primary and secondary generator protective relays and controls system.

Results. In summer 2018, Units 1 and 2 had 125 combined starts with no PT fuse failures. Unit 3 experienced three PT fuse failures during the same period, re-enforcing the thought that the PT relocation had permanently resolved the issue. Plant management budgeted for and completed this project on Units 3 and 4 in spring 2019. Prior to relocating the PTs, there had been a total of 26 fuse-failure events totaling 25.09 FOH. In a total of 325 starts since project implementation, there have been no PT fuse failures.

Project participants: Brad Keaton, Joe Albers, Mike Viater

Instrument-air system upgrades boost reliability

Challenge. Crete battled issues with its instrument-air system and pneumatically actuated equipment for several years. Each of the plant's 7EAs was supplied with an air compressor and dryer capable of producing only about 8 scfm of instrument-quality air. In addition to inadequate output, dryer operation was unreliable.

Performance issues also were identified with the inlet-bleed-heat (IBH) valve and the 11th-stage compressor bleed valves during cold weather. On multiple occasions the IBH air regulator (located on the turbine-compartment roof) malfunctioned because of moisture accumulation and its subsequent freeze-up on the diaphragm. This caused multiple runbacks and lost production.

The compressor bleed valves had caused several gas-turbine trips on shutdown. The trips were attributed to slower-than-expected operation of the valves, or a complete failure to actuate, because the porestone filter under the inlet section accumulated moisture which froze and restricted air flow to the actuators.

Solution. Staff determined multiple phases of improvement were required to adequately address the issues with pneumatic systems. In order to resolve cold-weather reliability issues, the IBH regulator was relocated into the accessory compartment. Necessary tubing modifications also were made—including vendor-provided heat tracing and insulation of the instrument-air tubing downstream of the regulator on the turbine-compartment roof.

The 11th-stage compressor bleed valve air-supply issue was resolved by piping instrument air to the solenoid-valve supply and removing the compressor discharge air and porestone filter from the system—thereby reducing the risk of freeze issues.

To complete the project and ensure an adequate supply of instrument air, four larger compressors and dryers were installed. The new, so-called AirCenter has more than three times the capacity of the original equipment (Fig 4) and is equipped with an internal PLC, which is linked to the Mark V control system to provide alarm status.

Plant personnel then repurposed the old air compressors and dryers as a backup system which starts automatically when system pressure drops below a setpoint. All cable pulls, terminations, and tubing modifications were performed by plant personnel to minimize cost.

Results. Since project completion, the site has not experienced bleed-valve actuation issues, purge-valve failure-to-close runback events, and/or IBH air-supply issues over the course of 558 starts. On the two occasions where the new AirCenter malfunctioned, the backup compressed-air system took over and provided an adequate supply of air to operate all necessary pneumatic equipment reliably.

The man-hour commitment required to maintain a functioning instrument-air system has been reduced signifi-

4. AirCenter replacement air compressors had more than three times the capacity of the original equipment

5. Demin storage tank as installed is at left, insulated at right

cantly because of the AirCenter's high reliability. Staff continues to monitor and actuate air-operated devices at a greater frequency during cold weather to ensure proper operation.

Project participants: Brad Keaton, Joe Albers, Mike Viater, Jeff Haun, Kevin Pomykala, Jeremy Escolar, Kevin Bray

Tank insulation saves demin water

Challenge. Crete consumes from about 500,000 to 900,000 gal/yr of demineralized water for power augmentation (fogging) and compressor water washes. City water is demineralized onsite to 0.5 µS by a trailer-mounted system and stored in a 150,000-gal stainless-steel tank.

However, the tank was not insulated, requiring that it be drained before winter for freeze protection. Water remaining was considered "process water" and because Crete does not have a discharge permit it cannot be dumped to ground or a stormwater sewer. Disposal cost the plant was between $10,000 and $20,000 annually, plus an additional $10,000 in the spring to replenish the demin water supply.

Solution. Staff and a contractor developed a plan to insulate the storage tank with 2-in.-thick polyisocyanurate foam protected by an outer metal shell (Fig 5) and to install two 7.5-kW direct immersion heaters to maintain the desired water temperature.

Another vendor provided heat tracing and insulation on system piping and instrumentation outside the tank. Plant personnel pulled cable for the heater power feed from a spare 480-Vac bucket in the Unit 1 electrical control compartment and replaced the previously installed junction boxes and cable trays to accommodate the heater elements and heat tracing. The entire project was completed for $100,000.

Results. This project allows Crete to hold demin water in the tank year-round. During the two winters since project completion, 167,000 gal of process water that would have required offsite disposal was retained in the insulated tank, saving nearly $60,000. Breakeven is expected after the 2021/2022 winter.

Project participants: Brad Keaton, Joe Albers, Mike Viater, Kevin Bray, Mike Yankovich

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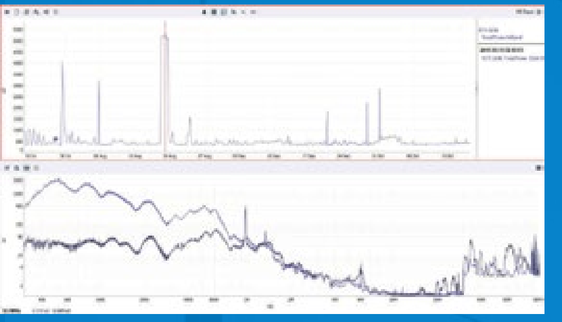

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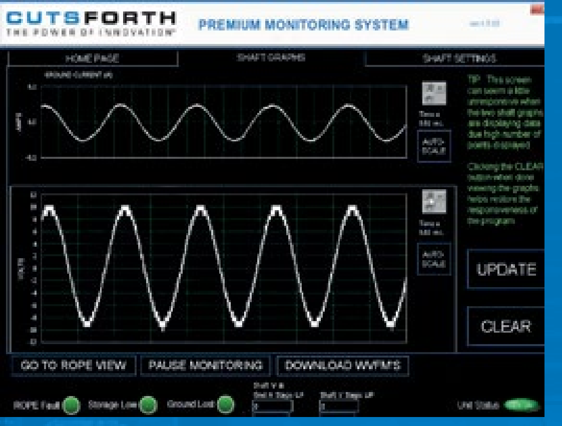

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- The system reduces frequent walk-down inspections by operators.
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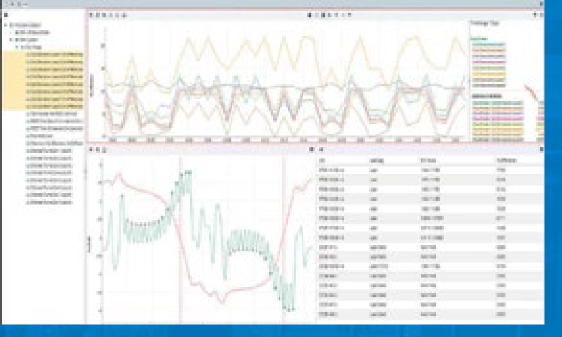

ROTOR FLUX MONITORING

- High speed flux signals identify shorted turns and severity
- Flux waveforms displayed on easy to use interface, and archived
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PSEG Peakers

Maintenance, outage file-sharing boosts productivity at four peaking plants

Challenges:
- Downsizing of planning staff created a backlog of outage/maintenance planning and scheduling tasks.
- Personnel at the Kearny, Burlington, Linden, and Essex peaking sites had to communicate together in real time.
- Needed a way to consolidate all reference materials, procedures, IPBs, drawings, and schedules for use by O&M personnel in real time. The existing system relied on multiple platforms and computers and was not user friendly, causing delays in the completion of tasks.
- Transition from hard-copy and paper to a digital platform, but retain the capability to use both.
- The cost for a contractor to build the desired platform, and consolidate the necessary files, was prohibitive.

Solution. Use off-the-shelf software, OneNote, included free with Microsoft Windows already installed on PSEG's computers. Training was free as well, and fast: It took only about two hours to become proficient on OneNote using a YouTube program.

The software runs on and uses PSEG's shared drive, located behind the company firewall, so everything is safe and secure.

Results. OneNote has been well-received by staff. Its capabilities are summarized in the illustrations.

Project participants: Al Van Hart, Ron Eilers, Clint Bogan

PSEG Peakers

Kearny Generating Station: 456-MW, dual-fuel, 10-unit simple-cycle peaking facility located in Kearny, NJ, and powered by GE LM6000 PCs

Burlington Generating Station: 168-MW, dual-fuel, four-unit simple-cycle peaking facility located in Burlington, NJ, and powered by GE LM6000 PCs

Linden Generating Station: 350-MW, dual-fuel, four-unit simple-cycle peaking facility located in Linden, NJ, and powered by GE 7EAs

Essex Generating Station: 81-MW, dual-fuel, one-unit simple-cycle peaking facility located in Essex, NJ, and powered by a GE 7EA

Plant manager: Clint Bogan

1. Snapshot of the PM outage desktop which all qualified personnel can see live and make updates in real time. Starting from the top, each green tab is assigned to a given peaker to keep unit-specific information and PM history organized. The hyperlinked quick REF links below are mostly to provide supervisors quick access to the Pre Job Brief (PJB), JHA, hot work, confined space, FME, etc.

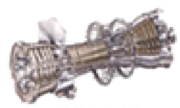
In the Operations PM section, the blue hyperlinks in the "Task Sheet" column take you directly to the procedure, GEK, or reference material for that task. The files highlighted in the "Comments" column and attached are BSI reports, contractor inspection reports, calibration reports, vibration, oil analysis, pre-start checklist, etc. Comments in red are the real-time notes entered by the operations team

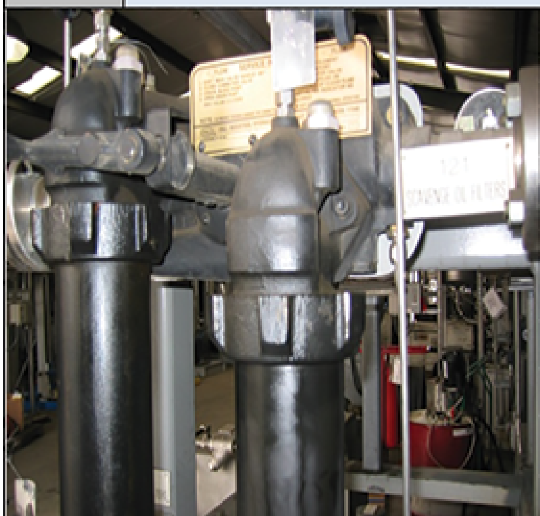
B-121 PM Outage | K-121 PM Outage | B-122 PM Outage | K-122 PM Outage | B-123 PM Outage | K-123 PM Outage | B-124 PM Outage | K-124 PM Outage | LINDEN 5 PM OUTAGE | Do Not Delete

MAINTENANCE PMs	BURL TASK SHEET		
PRE FILTER CHANGE TURB / GEN	TS-6	☐☑☐☐	Need to inspect prior to outage to determine what needs to be changed Turb, Gen, or all Inspected the inlet pre filters and found all of them in need of replacement. Removed all filters and put in the appropriate dumpster and pre staged all new pre filters and disposed of all card board boxes. Installed all new pre filters
ENGINE COMPARTMENT CLEAN/WIPEDOWN	TS-7	☐☑☐☐	Simple Green or wash soap. Power washed the entire engine compartment as well as all the aux skids.
EXHAUST SYSTEM INSPECTION (HIGGOT KANE)	TS-8	☐☑☐☐	Complete on day 1 so repairs can be scheduled M&RS welders completed weld repairs to the Higgot Kane. Inspected and completed the FME closeout. U59011499-U5800037...
ENGINE BOROSCOPE / FUEL NOZZ INSP	TS-9	☐☑☐☐	6 nozzles need to be removed for TCT, Gas hoses then replaced when installed.9-26-19 completed the HPT,HPC, Combustor and the CRF clamps. TCT completed the boroscope with no major findings. Did not need to replace any hoses all hoses on 122 have the blue strip they have all been changed out.
WATER WASH SKID	TS-10	☐☑☐☐	Completed the inspection of the W.W. skid.
TURBINE LUBE OIL SKID	TS-11	☐☑☐☐	Put other duplex filter in service, only change old in service filter, verify and write date on filter. Changed the in service filters and retagged with the new date.
HYD START SKID	TS-12	☐☑☐☐	Removed and replaced all (4) four hydraulic starter skid filters.
SPRINT SKID	TS-13	☐☑☐☐	TS-13 items 1,4,5,6,7,8 only do not replace filters, do not swap filters

2. Descriptions of some maintenance PMs are provided along with comments entered by the maintenance team (red)

PSEG PEAKING TS-11	LM6000 PM OUTAGE TASK WORK SCOPE			
	Turbine LO Skid PM		K12 B12	
Station/Unit	0		W/O #	0





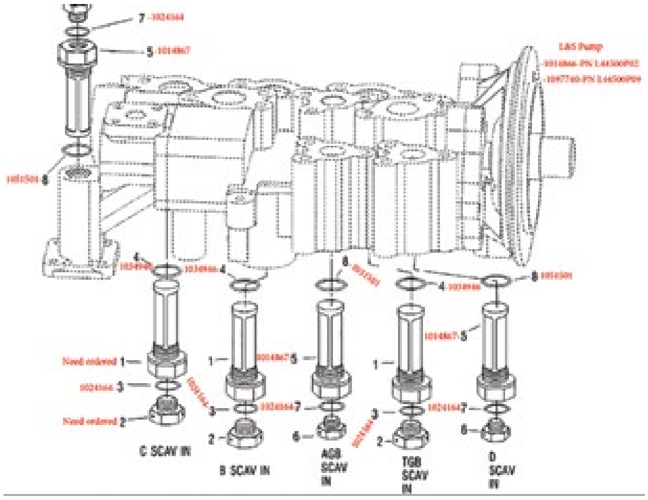
Special Equipment / Permits			
Basic Hand Tools	Filter Wrench		
Flashlight	Grease gun		
References			
Procedure Work Package-See Tab F			

Parts required / on reservation			
FOLIO #	Description	QTY	Part Status
1012809	Scavenge Filter (Pall Filter Only) Turbine Lube Oil	2	
1067106	Oil-Jet Turbo Synthetic, Mobil Jet II	3 -55 Gal drums	As Needed

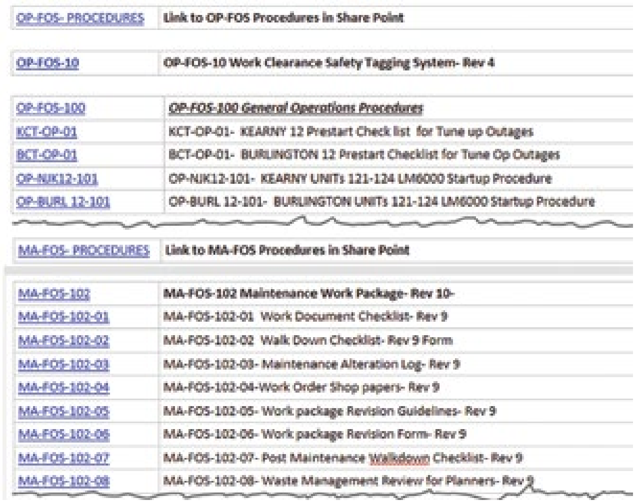
No.	PROCEDURE STEPS
1	Remove the (2) scavenge in-service filters and replace with new filters. MM# 1012809. Fill new 3/4 way with new Mobil Jet 2 oil. If in service ID tag is NOT present REPLACE all (4) scavenge filters.
2	Set valving selector to opposite filters that were not changed to put them in service. Tag these filters as IN SERVICE with date and Tag the new filters as NEW with the date. Identify which filter is IN SERVICE A or B in findings/CA
3	Top off resevoir. If the lab has dermined that the Turb lube oil is marginal, drain lube oil into properly labeled drum for removal. Refill with MOBIL JET 2
4	Visually inspect all lines, valving, hoses and flanges for any leaks, abnormalities or integrity issues. Check security of all flange bolts.
5	WASH SKID - Clean skid, utilizing appropriate cleaning solution.
6	Housekeeping - Ensure area is picked up, tools accounted for and any garbage/refuse is removed. Return area to better than as found condition.

3. Example of where a "Task Sheet" hyperlink takes the user. This is what an O&M tech would use in the field. It can be printed out or used on a tablet. Some seasoned veterans still prefer paper, but younger personnel typically embrace technology, so flexibility in presentation is important.

The example presented shows the PM for the TS-11 Turbine LO skid. It lists all required parts and where they are located. Most task sheets also will have a hyperlink to the GEK or reference document for the basic procedure described. There is a task sheet for every job undertaken

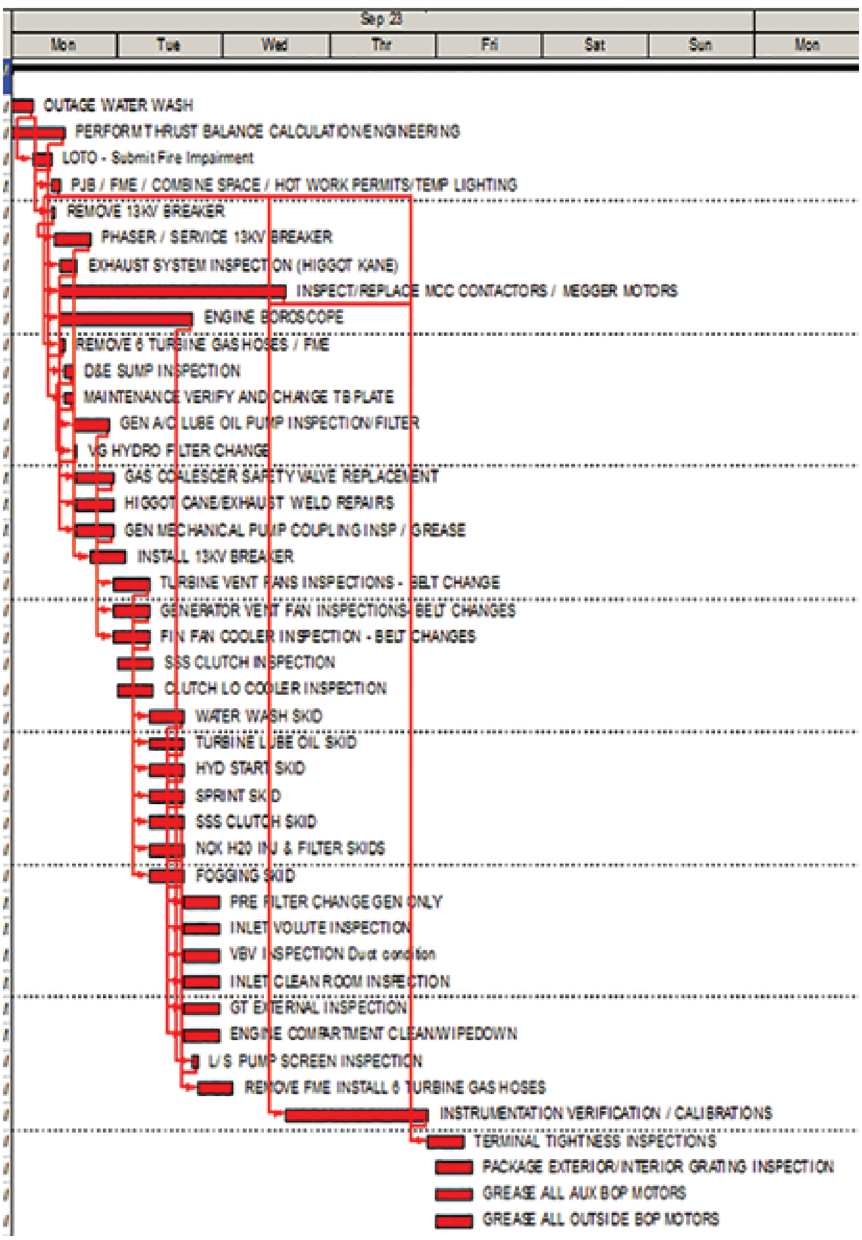


4. **Screen shot** is of a pump accessed via an IPB link. It shows key parts, part numbers, and location in supply



OP-FOS- PROCEDURES	Link to OP-FOS Procedures in Share Point
OP-FOS-10	OP-FOS-10 Work Clearance Safety Tagging System- Rev 4
OP-FOS-100	OP-FOS-100 General Operations Procedures
KCT-OP-01	KCT-OP-01- KEARNY 12 Prestart Check list for Tune up Outages
BCT-OP-01	BCT-OP-01- BURLINGTON 12 Prestart Checklist for Tune Op Outages
OP-NJK12-101	OP-NJK12-101- KEARNY UNITs 121-124 LM6000 Startup Procedure
OP-BURL 12-101	OP-BURL 12-101- BURLINGTON UNITs 121-124 LM6000 Startup Procedure
MA-FOS- PROCEDURES	Link to MA-FOS Procedures in Share Point
MA-FOS-102	MA-FOS-102 Maintenance Work Package- Rev 10-
MA-FOS-102-01	MA-FOS-102-01 Work Document Checklist- Rev 9
MA-FOS-102-02	MA-FOS-102-02 Walk Down Checklist- Rev 9 Form
MA-FOS-102-03	MA-FOS-102-03- Maintenance Alteration Log- Rev 9
MA-FOS-102-04	MA-FOS-102-04-Work Order Shop papers- Rev 9
MA-FOS-102-05	MA-FOS-102-05- Work package Revision Guidelines- Rev 9
MA-FOS-102-06	MA-FOS-102-06- Work package Revision Form- Rev 9
MA-FOS-102-07	MA-FOS-102-07- Post Maintenance Walkdown Checklist- Rev 9
MA-FOS-102-08	MA-FOS-102-08- Waste Management Review for Planners- Rev 9

5. **Abbreviated listing** of quick REF links to O&M procedures



6. **Schedule of key elements** typically involved in a unit PM outage

7F USERS GROUP

The 2020 Digital Conference hosted by the 7F Users Group was the first web-based annual meeting conducted by a user group serving owner/operators of gas-turbine-powered simple- and combined-cycle generating plants in the US. Most of nearly 700 registered users believed the 13-day event, conducted over five weeks from June 16 through July 16, exceeded expectations—except possibly for some hiccups identified with the virtual vendor fair on the first two days of the event.

The conference was viewed as highly successful by CCJ's editorial team. The content was compelling and easy to access; plus, no travel required, no negative budget impact. The Q&A following the presentations was more robust and efficient than at most face-to-face (F2F) meetings, which can have "dead" time as microphones are passed around the room and attendees gravitate to email

A major benefit of the virtual 7F meeting was that most of the proceedings were recorded and are available to users (details in the sidebar) who might have been called away from a session they had planned to attend, or want to listen to a given presentation again to confirm details.

The downside of virtual conferences, of course, is that there's no personal interaction with colleagues, which can be extremely valuable. Looking ahead, the editors think the format of future user-group meetings may have both online and F2F components.

A big "thank you" is due members of the 7F Steering Committee (photos) for developing the technical program and for dedicating the considerable amount of personal time required to transition from a F2F format to a virtual one. There was no roadmap for doing this. It took countless hours of experimenting and rehearsing to arrive at a format that would meet expectations. Note that screen shots of committee members substitute for the traditional group photo this year.

Presentations by owner/operators

Safety

The Safety Session on the first day of the meeting, chaired by Dominion's Chuck Spanos, followed introductory remarks by the 2020 Steering Committee Chair Matt Dineen of Duke Energy. Presentations addressed two of the industry's hottest safety topics: Hex chrome and Covid-19 mitigation.

Hex chrome: You may be aware of it but how much do you really know? The well-organized hex-chrome presentation is ideal for a lunch-and-learn session in the plant break room to be sure all personnel are on the same page with regard to this issue. It begins with a review of the health effects associated with exposure and provides guidance on exposure limits. Control measures to protect workers—respirators, protective clothing, increased ventilation, adjustments in the way a task is performed, etc—follow.

Cleaning methods are an important part of the presentation. Surfaces contaminated with hex chrome typically must be cleaned by HEPA-filter-equipped vacuums or by wet methods, such as wet sweeping or wet scrubbing. GE does not recommend use of dry methods for contaminant removal—especially wire brushing and compressed air—because they may cause the residue to become airborne. Also, waste material or debris contaminated with hex chrome must be collected and disposed of in sealed, impermeable bags or other closed, impermeable containers.

The OEM's Product Service Safety Bulletin (PSSB) 20180709A-R4 and OSHA 3373 were recommended information resources. The first alerts against the use of anti-seize compounds that contain calcium and have the potential to result in the formation of hex chrome when applied to chromium-containing materials and exposed to elevated temperatures. The anti-seize compounds recommended for Frame 6, 7, and 9 gas turbines are Kluber paste HEL 46-4500 and Bonderite L-GP GP460.

The speaker said he was not aware of any reported hospitalizations tied to hex-chrome exposure, which is not characterized by an "acute" attack. However, health-related effects could show up years later. A person wouldn't necessarily know if he or she was contaminated by hex chrome or inadvertently ingested it. Those users with a nuclear background might see similarities with inadvertent exposure to radioactive material.

Covid-19: Is there anything else we should know, except accurate facts? The speaker developed slides on what had been reported at the time of the meeting: symptoms, groups at high risk for severe illness, precautions, contact guidance, and employee protection. Nothing new here, and to the speaker's credit, he didn't spend valuable time rehashing this material. Instead he focused on a so-called outage planning heat map and changes his colleagues might consider to their outage execution plans for mitigating exposure.

The heat map described in the presentation and available to you on the Power Users website identifies "at-risk" outages and mitigations and the value of holding regular meetings to update outage plans.

Lessons learned during recent outages suggested the following changes

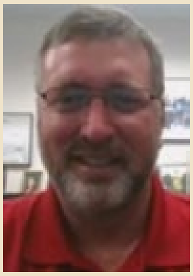
To dig deeper

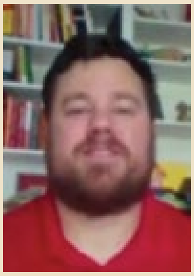
A broad range of subjects was addressed at the 7F User Group's 2020 Digital Conference. Dig deeper into any of the topics covered in this report by visiting the Power Users Presentation Library, where slides and/or videos are posted for your professional development (use QR1 to connect). However, you must be registered on the website for access. Simple process if you don't already have a "library card:" Simply scan QR2 into your Smartphone or tablet for the registration form.

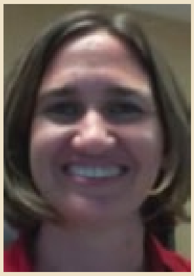
QR1

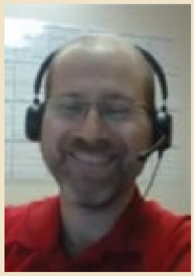
QR2

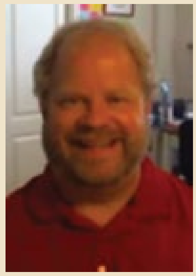
7F Steering Committee, 2020

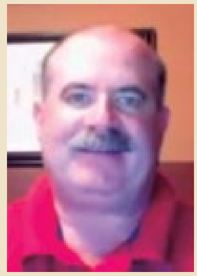

Bryan Graham
Entergy

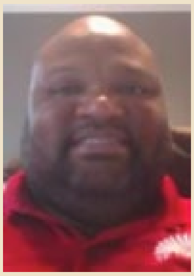

Chuck Spanos
Dominion Energy

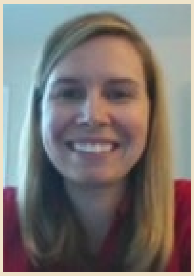

Christa Warren
Tenaska

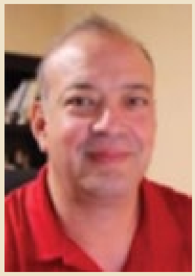

Ed Maggio
Tampa Electric

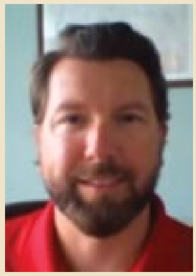

Jeff Gillis
ExxonMobil

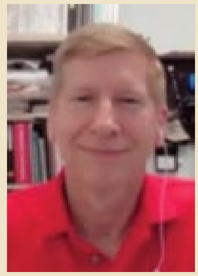

John Rogers
SRP


Justin McDonald
Southern Company


Katie Honey
Xcel Energy


Luis Barrera
Calpine


Matt Dineen
Duke Energy


Tim Null
Eastman Chemical

to consider regarding outage execution to avoid exposure:

- Segregate shift teams. Use phone or other digital means to communicate during shift turnovers. Provide a separate trailer for each shift.
- Maintain social distancing during morning toolbox talks and move them outside (weather permitting). Strive to conduct meetings in 15 minutes or less.
- Eliminate weekly group safety meetings; move them online if need be.
- Schedule breaks in a manner to minimize personnel contact.
- Organize work on the deck plates so only necessary personnel are present and try to maintain the suggested 6-ft distancing to the degree possible. If a "safe" distance cannot be maintained, issue additional PPE to compensate.
- Limit one person per row of seats in company vehicles.
- Stress increased personal hygiene. Add hand-wash stations and increase cleaning frequencies in common areas as necessary to achieve goals.
- Monitor the temperatures of workers as they enter the site.
- Be aware of the increased potential for heat-related stress created by wearing extra PPE.

Perhaps the most important lesson learned: Day-to-day productivity has not been impacted significantly by implementation of the above rules. The biggest concern for anyone with outage responsibility: The chance of an entire job being shut down if someone in the workforce were to test positive for Covid-19. Be vigilant, maintain strict adherence to the health aspects of your outage plan.

Combustion

The first presentation in the Combustion Session, chaired by John Rogers of SRP, reviewed one user's experience with FlameTop 3.0™, which combines the performance improvements offered by PSM's Flamesheet and G-Top 3.0 products.

Project update on FlameTop 3.0. The shortlist of Flamesheet performance goals/results:

- Confirmed: Turndown to 50% output while maintaining permitted NO_x and CO emissions of less than 9 ppm each; achieved turndown to 40% output.
- Confirmed: Less than 5 ppm NO_x at 40% output, less than 7 ppm at full load.
- Confirmed: Less than 9 ppm CO at 40% output, about 1 ppm at full load.
- Confirmed: Efficiency equal to or better than gas-turbine efficiency prior to upgrade.
- Confirmed: Efficiency at 50% load less than 130% of the full-load efficiency; less than 127% achieved.
- Confirmed: Elimination of visible emissions on startup.

The shortlist of G-Top 3.0 performance goals/results:

- Confirmed: Maintained all Flamesheet achievements.
- Confirmed: Increased gas-turbine output by 5.79%.
- Confirmed: Decreased unit heat rate by 1.71%.
- Confirmed: Eliminated seasonal tuning.
- Evaluating: Longer maintenance intervals made possible by different modes of operation.

After FlameTop 3.0 installation, the 2 × 1 cogen plant, powered by unflared 7241 engines, experienced several engine trips triggered by the flashback protection system. Suspected issue: Increased sensitivity to fuel-gas-skid condensate formation leading to autoignition. Combustor mods implemented in November 2019 to eliminate the problem were successful. FlameTop 3.0 was said to have allowed the cogen facility to better align with the host site's steam and electrical demands. Satisfied customer: The second unit will be converted to FlameTop 3.0 during an upcoming hot-gas-path inspection.

Lessons learned during commissioning. Three valuable experiences were shared by a user who was involved in the commissioning of two 7FA.04-powered 1 × 1 combined cycles early this year. Both units are equipped for dual-fuel firing with DLN 2.6+ combustors, and have bypass dampers. Fired hours on the units just ahead of the meeting were 3300 (68 starts) and 3100 (95 starts). Run profile: Baseload with automatic generation control (load following).

The speaker urged attendees plan-

ning a commissioning to understand how their unit's warranty handles newly issued TILs (Technical Information Letters) to save aggravation and money down the road. His units were able to incorporate most TILs during the construction and commissioning process. However, some TILs were assigned after the units were received and would have required significant disassembly for compliance. Suggested work was postponed for a future outage.

The need to verify that no foreign materials remain in the machine when it is buttoned-up for operation was stressed. The speaker said, "The seemingly most-simple task can have severe consequences if not performed with rigor."

During inlet-guide-vane calibrations in preparation for performance testing of one unit, damage was found on several R0 blades. Inspection revealed that a ball of duct tape had been left in the inlet and was ingested. A dozen blades were damaged and blended; there were no vibration issues afterwards. However, tape residue had reached the seventh stage and was not completely removed by water washing.

Commissioning of one unit on oil proved difficult. It could not be tuned when in the liquid-fuel mode because of high exhaust spreads. Note that these units are equipped with pressure-atomized liquid-fuel systems (acronym is XAA), which eliminate the need for atomizing air. No coking has been experienced, but operating time on oil was less than about 50 hours for each gas turbine. The user said more run time was required to fully evaluate the reliability of the liquid fuel system

XAA is an emulsification system that mixes liquid fuel and water ahead of the end cover. The speaker reported that water injection starts at about 40 MW following a pushbutton start on oil only. Water is used to flush the fuel system after burning oil.

Learn how GE engineers found and eliminated the gremlins responsible for the operational problem by accessing the presentation on the Power Users website. To learn more about this system, request GEK 121513 from the OEM.

Combustion polling results guide discussion session. The 7F was the first user organization to use electronic polling as a method for guiding and contributing to topical discussions, according to the editors. Tenaska's Christa Warren, the 7F Users Group's vice chair for 2020 makes liberal use of polling in her interactions with the group. She led a brief discussion session on a couple of combustion issues that appeared on agendas of previous meetings to see if there was anything new to talk about.

One subject was fuel-nozzle damage, which had been experienced by 56% of the attendees. As for cause, 28% of the respondents named fuel contamination; "other" and "unknown" received 64% of the votes. Warren put up photos of fuel-nozzle damage on the screen to get some feedback. One user said that at least some of the damage shown likely came from burning because the flame was not detached from the nozzle like it should be. Another offered that proper use of atomizing air is critical to nozzle damage control. Yet another said most damage he has seen was on PM2 and PM3 nozzles. High NO_x and ammonia were said to be key indicators of fuel-nozzle damage.

Another topic was the adverse impact of cold weather on operability. Here are the questions Warren asked the group:

- Do you have autotune installed? More than three-quarters (78%) of the responding attendees said "yes," with 63% of the users equipped with a GE system.
- Do you have issues during cold weather with high-dynamics alarms that require an operator response? Answers: No, 45%; rarely, 41%; frequently, 14%.

One comment was that model-based control works well, except possibly in cold weather. Suggestion for those with issues: Operator intervention to possibly change NO_x, for example.

Compressor

The Compressor Session with Warren at the helm, opened Day Two of the user presentations. Topics were Row 1 damage from inlet FOD and the value of pressure-washing inlet guide vanes (IGVs).

Inlet-duct liner-attachment failure releases heavy vinyl material that damages R1 blades. This presentation should be reviewed by personnel at any plant with an inlet duct, or inlet silencers, manufactured by J&G Steel. The speaker reported on his plant's issues linked to manufacturing errors made by the vendor since a 2016 borescope inspection found insulation in the cooling passage of a first-stage nozzle. TIL-1995 (April 2016), "Silencer/Inlet Bleed Heat Duct Inspection," was the first response by the OEM; TIL 2173 (December 2019), "Inlet Silencer Panel Inspection," was the second.

The CliffsNotes version of this presentation is that pieces of the vinyl moisture/noise barrier, located between the inner liner and the mineral-wool insulation/outer wall of the inlet duct, were released when stitch welds failed. The welds, which anchored the inner liner to support plates for the insulation system, were ground flat in error, weakening those joints. Vibration likely caused the weakened welds to fail

The speaker said the damage to the Row 1 compressor blades resembled ice damage. All first-stage blades were removed, without pulling the rotor. Two of the blades with bent corners were blended; three blades with more substantial damage were replaced.

Pressure-wash IGVs to restore efficiency. This presenter's plant pressure-washes the bellmouths and inlet guide vanes of its gas-turbine compressors every quarter—sometimes more frequently if a drop in performance so dictates. The pressure-wash idea was pursued after a roll of paper towels used for cleaning the IGVs was left inside the machine prior to restart and caused considerable damage.

The gas turbines operate in a challenging process environment and foul quickly. The pressure washer is operated by plant personnel at 3200 psig; the nozzle is held 2 to 3 in. from the vane surface. A typical cleaning procedure is as follows:

- With IGVs in the closed position, saturate the vanes and bellmouth with water.
- Coat the vanes and bellmouth with ZOK at full concentration. A manual pump-up sprayer is ideal for this purpose.
- Allow the ZOK to soak in and loosen the debris for about 10 minutes. Important not to let the ZOK fully dry because that would make it much harder to remove.
- Pressure-wash the vanes and bellmouth with water.
- Open the IGVs and repeat the process. An added benefit of opening the IGVs is that you clean the first two or three stages as well.
- Offline water-wash the entire compressor before returning the unit to service.

At this plant, pressure-washing the IGVs alone boosts output of the 7FA.03 gas turbine by 4 to 6 MW. These numbers increase, of course, if a full compressor water wash follows the pressure-wash step. Plant personnel can complete a pressure wash in less than two hours. A full water wash and pressure wash takes about eight hours.

Readers considering a pressure wash will benefit from reviewing the presentation, which offers valuable details and safety hints.

Auxiliaries

Battery storage/GT peaker integration. If you want to stay on the cutting edge of gas-turbine facility design, access this presentation on grid-scale battery energy storage systems (BESS), made during the first segment of the Auxiliaries Session (Day Two), chaired by Entergy's Bryan Graham. Owner/operators are getting acquainted with a variety of grid-scale BESSs. But one thing's for sure: Many of them will be destined for existing gas-turbine and combined-cycle facilities.

This presentation reviews a 7.4-MWh lithium-ion BESS designed to black start a 2001-vintage 150-MW 7F.03 simple-cycle gas turbine/generator. The batteries are specified for a 10-yr life based on one charge/discharge cycle per month. Note that black-start equipment often is started for test purposes more than for an actual black start.

Replete with extensive electrical one-line and circuit diagrams, the slides should be especially attractive to electrical engineers. Other users will take note of the detailed sequence-of-events descriptions for how the BESS and gas turbine (with an upgraded load commutated inverter, LCI) work together during synchronization and startup.

Grid-scale battery geeks will benefit by learning about the extensive BESS fire suppression system, which is comprised of three major subsystems:

- An extensive lithium-ion gas detection monitoring array in each of the battery enclosures. Each enclosure contains 21 individual sensors connected up into two controllers.
- A spray suppression system inside the enclosures which deploys a fluid mixture of 30% inert gas and 70% potassium particulate.
- A water spray nozzle system in between the enclosure rows to prevent heat transfer from one enclosure to others across the walkway.

Battery enclosure temperature control is critical for BESS systems; each enclosure is equipped with two 100% redundant 6-ton HVAC units comprised of a 13,000- to 67,000-Btu/hr chiller, 15-kW heater, and variable-speed blower operating between 850 and 1700 cfm.

Startup posed several challenges and lessons for others. For example, the harmonic filters were designed based on the original LCI design data. However, the live data captured during unit start revealed the noise was much worse. So, the harmonic filter was redesigned for the actual data, which doubled its size.

The black-start procedure required many revisions after several failed start attempts caused by logic oversights, wiring and hardware issues, etc. However, after the first successful startup, everyone on the project was surprised that the battery had still retained 94% state of charge, a key measure of the depth of the cycle, battery life, and performance.

Lube-oil conditioner upgrade. There have been significant improvements in lube-oil polishing technology since this baseload 1 × 1 STAG 107FA plant began commercial operation at the end of 1997. Its lube-oil system has a single 10,000-gal tank serving both the gas and steam turbines.

A portable oil conditioning unit purchased in 2000 had reached end-of-life and plant personnel jumped at the opportunity to purchase a modern system equipped with the latest filtration capabilities and instrumentation to dramatically reduce both particulate count and moisture content.

A review of this presentation is a good first step for those dissatisfied with the performance of their lube-oil conditioning system.

Non-chemical approach to cooling-tower algae control. River Road Generating Plant, a 7F-powered 1 × 1 combined cycle, originally used chlorine for algae control in its cooling tower. At the first NPDES permit renewal, the state of Washington's Dept of Ecology compelled the facility to eliminate the use of chlorine and shift to bromine.

After several years of bromine use, the plant began to experience intense blooms of a resilient and chemically resistant form of filamentous blue-green algae, which was out of control in spring and summer. Algae could grow more than 2 ft/day on sunny days, requiring cleaning of the forebay trash screens every two or three days. A crane was required to dispose of the nominal 2-ton harvest.

With chemical solutions limited, plant management challenged staff to explore the following non-chemical options: electrocoagulation, ozone generation, ultraviolet light, ultrasonic devices, magnetic devices, modulated molecular oscillation pipe wraps, lattice oscillation devices, radio-frequency generators, and tower shading.

One of the first steps was the trial of an ultrasonic device designed to kill the type of algae affecting the plant in its single-cell form—before it could morph into colonies. The floating transducers emit ultrasonic sound waves that oscillate in frequency, and change periodically, to kill multiple types of biological growth and to prevent mutant strains from developing.

Ultrasonic waves create a so-called "sound barrier" at the water/air interface that prevents some types of algae from floating to the surface for photosynthesis; without surface light, algae die.

Bacteria are killed as well. This means colonies of bacteria are not available to adhere to cooling-tower surfaces. The strand-type algae found at the plant will not attach to surfaces that do not have a layer of biofilm, and the offending cells pass through the system. But while providing a substantial reduction in algae growth, ultrasound did not eliminate the algae infestation during the summer.

Sun shades were considered because algae require sunlight for photosynthesis. This low-tech solution helped to reduce algae growth and the cost of chemical treatment.

Ultrasound and sun shades together reduced the amount of algae dramatically, but not completely. Radio-frequency devices, which successfully helped control the effects of biological growth and silica in small cooling towers for HVAC systems, were tested next. The underlying theory is that radio frequency disrupts the lifecycle of the algae in its single-cell form.

Plant and vendor personnel worked together to develop and implement an industrial-scale test plan. The speaker displayed results slides at intervals of about 10 days over a six-week period and the results were compelling. The last slide showed no algae were present. The test was repeated and results were the same. Another benefit: Silica drops to the bottom of the tower basin and is removed during blowdown.

While the benefits of RF devices are impressive—including improved personnel safety, reduced chemical consumption, longer intervals between cleanings of condenser tubes—the speaker pointed out that you never completely eliminate algae because the cooling tower is open to atmosphere. Thus, bromine still is injected, but only every fifth day.

Benefits still to be quantified include the reduction in calcium silicate scale in the condenser and plate heat exchangers, and the reduction in cooling-tower chemicals possible—such as silica dispersant. Stay tuned to CCJ for updates.

Plant replaces exciter during peak demand with minimal financial impact. One of Green Country Energy's 9A4 generators experienced a ground-fault trip on its Kato brushless exciter because of a winding insulation failure—after nearly 18 years (about 80,000 hours) of service. The nominal 800-MW plant is equipped with three 7F-powered 1 × 1 combined cycles; the steam turbines are married to 9A4 air-cooled generators.

Routine inspections and tests were

conducted over the years and the exciter historically had been reliable. The stator had been removed numerous times, the rotor never.

The plant's highly capable staff was challenged to remove and replace the exciter during a period of peak demand while limiting financial impact. This included the following actions:

- Reduce peak-demand forced-outage penalties to the extent possible.
- Locate a replacement exciter.
- Evaluate making repairs onsite.

Several hurdles were encountered:

- Kato no longer manufactured replacement brushless exciters for the 9A4. An interesting finding given the 9A4 had been introduced only 20 years earlier.
- No direct-replacement brushless exciter was available from an alternative manufacturer.
- Removal and installation of the exciter rotor requires specialty tooling that the plant didn't have.
- The repair cycle for rewinding the exciter would require a lengthy forced outage.

The goal was to develop a plan to minimize the forced-outage impact by locating and installing a replacement exciter while the failed exciter was repaired and put in the GCE warehouse. Luckily, a new old-stock spare exciter was located at a partner facility that the plant had shared parts with previously.

Finding the Kato instructions for exciter rotor removal and replacement vague and inaccurate, staff reached out to other plants to discuss their lessons learned and best practices. Some owner/operators reported success, others said there were complications that led to complete removal of the generator field for offsite repairs—attributed to binding of the exciter rotor on the generator shaft.

Thus, the solution was to purchase the spare exciter identified and manufacture in-house the specialty tooling required for removal and replacement. That tooling has since been loaned to at least one other plant.

The bottom line: Plant staff took what easily could have been a three-week outage and completed it in six days, the speaker acknowledging that this was possible because of industry cooperation in obtaining the new exciter and the sharing of experiences by others to develop a good work plan.

Energy-efficient turbine oil. Mobil SGC™ 918 EE is a new turbine oil designed to provide energy-efficient benefits in GE 7FA and 6FA gas turbine/generators. Developed jointly by ExxonMobil and GE, it is the first product to meet GEK 121603, the OEM's energy-efficient turbine-oil specification. The new formulation is based on Mobil DTE 932 GT, which the presenter said has been used successfully throughout his company's frame fleet for the last decade.

According to the user presenting, the new oil provides an overall turbine efficiency improvement when compared to conventional ISO 32 viscosity grade lubricants. Performance was measured in a GE-designed bearing rig, the 7HA test stand, and during 7FA and 6FA field demonstrations.

The speaker reviewed the technical evaluation process used by personnel at the 7F-powered cogen plant charged with the investigation. But before digging into the details, he polled the audience with these two questions:

1. Have you changed the type of lube oil in your gas turbine? Attendee feedback: Yes, 29%; considering it, 20%; no, 51%.
2. For those who did not respond with a "no," 60% said they performed a full technical evaluation, 18% had the lube-oil suppler to do the evaluation; the remainder simply relied on the experience of others.

The evaluation process described by the speaker began with two two-hour brainstorming sessions in which key participants participated. After back-and-forth calls over about a week's time to iron out details, work began with a gathering of P&IDs for the turbine involved in the demonstration. These were used to identify all components and instruments that comprise the following systems: lube oil, hydraulic oil, trip oil, lift oil, and generator seal oil.

Next step was a review of system components by machinery engineers from the plant owner/operator, lubrication experts, and OEM personnel to identify potential concerns with the lower viscosity of SGC 918 EE compared to that of the DTE 932 GT currently used. Note: Because the new formulation is based on the current oil, the evaluation team excluded from review the compatibility of coatings and elastomers with the SHC 918 EE.

The speaker then described the type of matrix used to guide the technical evaluation process. This slide might be of benefit to others considering an oil change—that is, any oil change, not necessarily a switch to SHC 918 EE. One illustration offered concerned lift oil: Would a system adjustment be necessary because of the different viscosity? In this case the answer was "no."

Another one of the concerns evaluated involved hydrogen seals on the generator: Would there be a need to increase generator seal-oil flow and hydrogen consumption to maintain generator H_2 purity? The lower viscosity dictated a change to a bolted seal to maintain hydrogen purity.

The sump for the gas turbine selected to demonstrate the value of SGC 918 EE in an industrial setting has been filled with the new oil; a July restart is planned. Connect to the 7F Forum for progress reports as they become available.

Case history of a heat-exchanger leak: Little things can mean a lot. The presentation at the 7F Users Group's 2020 Digital Conference that had generated the most questions and discussion among attendees through Week Three concerned a leak in a plate-and-frame lube-oil cooler.

Go figure! How could a mundane leak generate much interest at a high-tech meeting? Read on: There are some lessons learned you may benefit from.

The background: One 7FA at a 2 × 1 combined-cycle cogeneration facility was out of service for an outage. Lube oil to the unit was shut off, but cooling water was still running through the plate-and-frame heat exchanger. This had been standard practice for the last 18 years. During that time plant personnel had performed the periodic heat-exchanger cleaning required without incident.

The problem: Water pushed through the exchanger's gaskets after the lube-oil system was secured. Water then ran through the exchanger discharge and all associated systems, and contaminated the 6400-gal oil reservoir. By the time the leak was found and the water shut off the reservoir level had risen by more than 3 in., causing oil to flow from the explosion doors. A quick calculation revealed that about 400 gal of water had been added to the oil reservoir, creating a milky mixture in the tank.

Staff considered that after its last cleaning the heat exchanger might not have been tightened to the applicable "crush" specifications for that model and the number of plates it has. The exchanger was disassembled and the gaskets inspected. No damage to gaskets or plates was in evidence, so the lube-oil cooler was cleaned and reassembled.

Alfa Laval, the manufacturer, was asked to provide a formula to guide reassembly and assure the proper crush. The total inside spread between the end caps of this unit with 106 plates was calculated at 18.56 in.

Given that proper crush is so important to leak prevention, consider verifying the specs for your exchangers. And when using outside labor for cleaning, share this information with that team; it's not just a matter of "tightening" a few bolts/nuts after cleaning a plate-and-frame exchanger, as some might think.

Another thought was that the leak began when the lube-oil system was shut down because the oil cooled. The logic: When the oil was hot, expansion prevented leakage of water into the oil side of the unit.

In either case, the takeaway is obvious: Avoid leakage by shutting down the water system before taking the lube-oil system out of service. This lesson learned has been incorporated into plant procedures.

However, a couple of attendees listening to the presentation reported having the reverse occur, with lube oil leaking out when water was "isolated in the compartment." The fix here was gasket replacement and right-torqueing. This exchange among users, and others like it during the 7F event, was proof that a virtual conference done correctly can be as effective as a conventional meeting for sharing experiences—possibly even better.

Another attendee suggested all gaskets be replaced every couple of years or so because they lose their resiliency. Yet another mentioned baking the gaskets to cure them after cleaning. There was no follow-on discussion related to this suggestion, however.

The presenter said a vacuum truck was brought onsite to remove the oil/water solution in the lube-oil sump. The dregs then were mopped up by hand, the lube-oil filters replaced, and the tank refilled. Entire process took three days. The plant didn't pursue centrifuging/vacuum dehydration to save the oil because the cogen facility was necessary to support process operations.

A similar situation was reported by another attendee who said the issue at his facility was brittle gaskets in the heat exchanger that failed once the oil pressure was off the unit and cooling water was still in service. It was a mess, he said, with oil spilling out the explosion doors as the speaker had reported earlier.

This tank also was drained and mopped clean before new oil was added. Oil could not be salvaged, the user said. Two days were spent trying to save it before deciding on disposal. Next step was to replace gaskets on all of the plant's plate-and-frame heat exchangers serving the 7Fs and D11 steamer. All those assets were commissioned around 2000.

The takeaway from this session suggests that if you have Alfa Laval lube-oil coolers installed during the bubble years and have not replaced their gaskets it might be time to consider doing so. A user suggested buying a spare set of plates with gaskets (glued on or clipped on) then swapping them out with the plates in service. Job should take about four hours based on his experience.

Someone else added that when you send plates to Alfa Laval for refurbishment a Zyglo inspection also is performed. It detected a pin hole in one of this user's plates that allowed oil to enter the cooling-water system.

How to quickly, safely remove hydrogen from your generator in an emergency. If your staff is not experienced in initiating an emergency purge of hydrogen from the generator, personnel at Hermiston Generating Plant, a 474-MW, 7FA-powered 2 × 1 combined-cycle cogeneration facility have a solution to consider.

Hermiston developed an emergency hydrogen purge procedure during plant commissioning nearly 25 years ago. It required entering the collector compartment and opening the lower compartment where the purge valves are located. But this could be problematic in the event of fire and/or release of CO_2 into the compartment.

The goal was to make an emergency purge safer for the individual performing this task. Several options were considered. Here's what was done: Use the logic already in the Mark V Control Sequence Program and add logic to allow the control room to remotely initiate and purge hydrogen with no one near the generator. The relatively simple upgrade was facilitated by replacing the original hydrogen control cabinet with one from EOne.

Drawings of the successful mod are provided in the presentation. After the logic updates were completed, an emergency hydrogen purge was performed on each unit from the control room. Success! Today, the system is tested annually or when hydrogen is removed from the machine during extended maintenance shutdowns.

Rotor

Discussion format of rotor session creates a vibrant exchange of experiences. The 7F Steering Committee invigorated the Day Seven program by leading off with a discussion session on rotors rather than a user presentation on the subject, as had been the norm for the other days of the event. The format was simple: Two committee members greased the skids, so to speak, on the subject of rotor maintenance, and attendees provided a seemingly endless string of questions and experiences. In fact, the discussion leaders had to hit the session trip button so the next speaker could make his presentation.

The two discussion leaders combined have fleet-level maintenance responsibility for more than five dozen 7FAs. They began with a brief introduction of the OEM guidance documents of greatest importance to anyone involved in the rotor-maintenance process—read end-of-life (EOL) inspections and life-extension work. They are GER-3620, "Heavy-Duty Gas Turbine Operating and Maintenance Considerations" and Technical Information Letter 1576-R1, "Gas Turbine Rotor Inspections."

TIL 1576-R1 refers you to GER-3620 for overall guidance on all centerline maintenance. The latter is now at Rev N (November 2017) which is important for you to have. Don't have a copy? A simple Google search can provide access.

Rotor life limits for the 7FA are 144,000 factored hours or 5000 factored starts, depending on whether your machine is starts- or hours-based. The pages in Rev N of interest to this discussion are 30 to 35, with Fig 45 being particularly important. Reason is that the impact of forced-cooling on rotor inspection calculations is now a consideration, replacing the "trip from load factor" in earlier versions of the GR-3620 document.

Attendees were polled on how they operate their units. More than half (52%) said their machines were hours-based, 16% starts-based. For users with multiple units, 27% said they had a mix of hours- and starts-based machines. Interestingly, only 5% of the attendees said their units had switched from starts-based to hours-based, or vice versa.

Calculation of factored starts can be challenging. There was considerable discussion of what to include in your determination. One of the session leaders illustrated how he calculated the rotor maintenance factor for one unit, which was 1.4 multiplied by actual starts.

The other discussion leader said this was fine, provided the entire rotor has been together for its entire life. If not, track the operating histories of individual components—such as the compressor and turbine if they have been decoupled. This approach likely benefits the owner. GE, it was said, considers the rotor one component.

Other points also were made to illustrate the complexity of factored-hours/starts calculations (particularly the latter). Attendees were urged to do make their calculations as accurate as possible to avoid leaving "life" in the rotor before removing it for an EOL inspection. How would you factor the following into your calculations?

- Control system changes.

- Staff changes.
- Ownership changes.
- Upgrades—such as going from 24k hours to 32k on a Dot 04 upgrade

An idea for extending rotor lifetime surfaced: Shift your high-hours machine to a starts-based unit. No guidance was offered, however.

It might appear that calculation of the maintenance factor might be a task assigned to the DCS. But that's not true.

A poll showed only 14% of the attendees used the DCS to calculate maintenance factor; 37% said "No" outright. Another 16% said they weren't sure; double that number track maintenance factor outside of the DCS.

Safety drives rotor EOL inspections. The experts say gas-turbine casings are not designed to withstand a rotor wheel burst, so if that were to happen personnel could be hurt, possibly killed. Rotor disassembly and inspection can mitigate this risk by identifying wheels that should be replaced. The failure of other components, it is said, would cost money and time but likely would not be life-threatening. Cyclic operation is of particular concern because it induces thermal transients and mechanical stresses on the rotor.

Attendees were asked if they were planning on 7F rotor maintenance in the next five years. "Yes," based on GER-3620 guidance, was checked by 57% of the users participating; "No," 29%. The remaining 14% said they had to learn more before deciding.

A few takeaways from the conversation included the following:

- Experience from units hitting the 5000-starts limit: Turbine sections typically are in "pretty rough condition."
- The aft end of the compressor gets most wear and tear on cycling units. Think about replacing the 17th and 16th stage wheels at EOL, perhaps even one or more earlier rows.
- Expect to replace the first-stage turbine wheel on most starts-based units.
- Poll: Have you performed a rotor lifetime assessment? "Yes," 22%; "No," 78%.
- One of the nation's largest utilities reportedly has not yet hit EOL on an hours-based unit.
- Poll: What are you planning for? Exchange rotor, 29%; lifetime extension, 32%; new rotor, 12%; undecided/do not know, 27%.

Exhaust

Strut cracks dictate exhaust-frame replacement. A major inspection in March 2020 on one of the gas turbines for a 2 × 1 7FA.03-powered combined-cycle power block at Gila River Power Station revealed severe rubs in the compressor and turbine sections upon unit disassembly. The machine, which did not run at all for 18 months beginning in 2017, operated base-load after returning to service. It had accumulated 53,000 operating hours (1760 starts) since commissioning in the early 2000s. Since the unit's prior outage, a 2014 HGP, the gas turbine had run a nominal 20,000 hours (300+ starts).

Severe rubs were in evidence on one side of the turbine's first-stage shroud blocks and on the compressor stator airfoils in Rows 13, 14, and 15 on that same side. Plant personnel found rotor clearances tight on the right in almost all rows of the turbine and compressor.

Schaffer Precision Alignment was contracted to check unit alignment (laser) and found the exhaust frame had shifted 0.071 in. to the right. Advanced Turbine Support, onsite to perform a borescope inspection, was asked to inspect the exhaust struts for any obvious signs of damage. Visual indications were found on two struts with confirmation by eddy current on one. A through-wall crack also was confirmed.

The search for a replacement exhaust frame ensued. The owner opted to purchase one in an as-is/where-is condition to minimize schedule impact. The replacement frame was removed from an unfired unit and shipped to the site. Upon arrival, it was inspected with the following observations:

- Large gouge in the stainless-steel liner.
- Support legs had a water jacket around them.
- Bearing housing was a three-piece design.

Plant personnel believed that the gouge probably occurred when the weld was ground out during removal of the exhaust frame. The gouge was filled in with weld material and the frame installed at Gila River. Other actions taken were these:

- Weld repairs were made on the exhaust manifold.
- New oil seals were installed on the old bearing housing.
- The existing support legs were reused to avoid having to deal with the water jacket on the new legs. All units in the fleet were believed by staff to be working well without the water jacket.
- Stainless-steel exhaust seals were replaced with Inconel 718.

Schaffer Precision returned to check alignment with the replacement exhaust frame. It was located slightly to the left and high. The condition of bearing No. 2 and its position were checked and the experts agreed that it could be reinstalled and satisfactory alignment could be achieved by adjusting the bearing's position. That's what was done.

End notes:

- The unit was restored to service after a 45-day outage, nine days less than originally scheduled.
- The old exhaust frame is awaiting root-cause-analysis investigation to determine why the struts cracked.
- Balance was not an issue after the work was finished.
- Damaged airfoils in the compressor were simply swapped out because replacements were available and the job could be completed quickly with new stator blades.

User feedback

A valuable feature of Power Users conferences is audience polling, which was pioneered by the 7F Users Group a few years ago. The steering committee and presenters use polling to ask owner/operators for their opinions on industry trends, the information needs of attendees, etc. Because the feedback is virtually instantaneous, it can identify where clarification or more detail is required on a particular subject during the presentation of interest.

Below are some of the polling questions asked during the 7F 2020 Digital Conference. The responses both characterize the audience and provide a snapshot of what your industry colleagues are thinking on topics of importance to owner/operators.

Audience

How many times have you attended a 7F Users Group conference (including this year)?

- My first meeting, 46%
- Two years, 20%
- Three to five years, 21%
- Six or more years, 13%

How would you rate your level of 7F knowledge?

- Newbie, 14%
- Rookie, 10%
- Intermediate, 37%
- Seasoned, 25%
- Expert, 4%

What is your primary role?

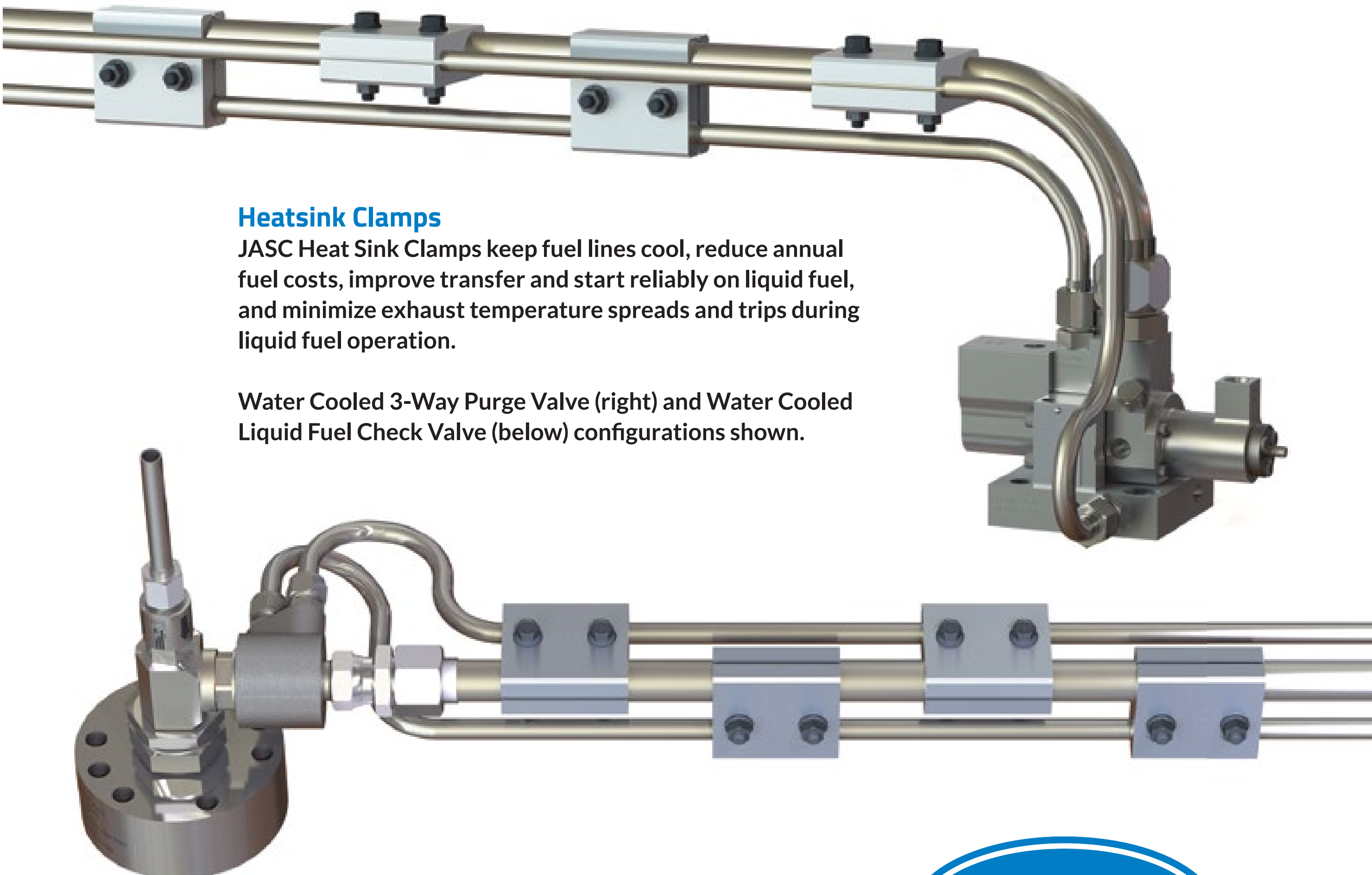
- Maintenance manager, 12%
- Plant manager, 10%
- Maintenance engineer, 16%
- Turbine engineer, 28%

JASC Designs Have Provided Over A Decade Of Liquid Fuel System Reliability

JASC Water Cooling Technology Provides Increased Operating Intervals Between Liquid Fuel Runs

Water Cooled 3-Way Purge and Water Cooled Liquid Fuel Valves

Water cooled fuel controls utilized to negate the impact of coke formation and maintain ANSI class 6 sealing in the checked direction.



Heatsink Clamps

JASC Heat Sink Clamps keep fuel lines cool, reduce annual fuel costs, improve transfer and start reliably on liquid fuel, and minimize exhaust temperature spreads and trips during liquid fuel operation.

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

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sales@jasc-controls.com

JASC®

- Asset manager, 11%
- Other, 22%

How often do you interact with power traders or dispatchers?
- Multiple times a day, 7%
- Daily, 22%
- Weekly, 12%
- Rarely, 29%
- Never, 29%

General

What is the average age of your 7F and steam-turbine units based on COD?
- Less than 10 years, 15%
- 10-15 years, 24%
- 16-20 years, 48%
- More than 20 years, 13%

Operations

What system/component gives you the biggest headache, or impacts reliability the most, on your unit(s)? Check all that apply.
- Valves (for example, gas, compressor bleed valves, etc), 45%
- Instrumentation (for example, transmitters, T/Cs, etc), 38%
- Protection systems (for example, haz-gas detection, etc), 14%
- Inlet filtration system, 4%
- Covid-19, 12%
- Starting system (for example, static starter, etc), 7%

Three years into the future, how do you see your CCGT operating profile changing?
- More starts, fewer hours, 50%
- More starts, more hours, 13%
- Fewer starts, fewer hours, 5%
- Fewer starts, more hours, 16%
- No change, 15%

Three years into the future, how do you see your CCGT operating and ramp profiles changing?
- More part-load operation, more ramping, 65%
- More full-load operation, less ramping, 6%
- More full-load operation, more ramping, 9%
- More part-load operation, less ramping, 3%
- No change, 16%

Which type of flexibility would you choose if you could upgrade your plant today?
- Higher maximum output, 17%
- Lower minimum output, 31%
- Faster ramping, 5%
- Faster startup, 12%
- All of the above, 35%

Plant managers, maintenance managers/engineers: If you had the ability to cost-effectively cycle overnight versus turndown, would you want to cycle?
- Yes, 29%
- Absolutely not, 49%
- Maybe, 22%

Traders, asset managers: If you had the ability to cost-effectively cycle overnight versus turndown, would you want to cycle?
- Yes, 41%
- Absolutely not, 37%
- Maybe, 22%

Which type of generating unit do you think the more flexible CCGT displaced to produce additional megawatt-hours?
- Less-flexible CCGTs, 21%
- Simple-cycle GTs, 36%
- Steam turbines, 17%
- All of the above, 26%

How would you react if your trader/dispatcher asked you to cycle between 2 and 4 a.m.?
- No way, 26%
- Are you crazy? 21%
- OK, as long as power payments make up for the increased maintenance cost, 54%

What was the cause of your last failed start (pick one only)?
- Valves, 23%
- Static frequency converter, 3%
- Burners and nozzles, 7%
- Controls, 22%
- Instrumentation, 20%
- Hardware, 8%
- Excitation and generator, 14%
- Other, 4%

What concerns you the most at your site for forced-outage days (pick one only)?
- Transformer, 19%
- Instrumentation, 29%
- Rotor, 15%
- Bearings, 7%
- Steam-turbine unavailable, 19%
- Other, 11%

What is your most recent annual unit/block start/stop count on average?
- Fewer than 100 start/stops per year, 67%
- 100-200 start/stops per year, 33%

In the last 10 years, what start/stop count trend are you experiencing?
- Minimal or no change, 56%
- Up to 50% increase, 29%
- Roughly doubled, 11%
- More than doubled, 3%

Which 7F HGP TIL most keeps you up at night?
- 2045, 7F AGP Stage 3 bucket tip shroud creep, 40%
- 2181, Stage 1 nozzle creep degradation model, 23%
- 2006, 7F and 9F Stage 3 bucket airfoil distress, 17%
- Other/none, 20%

Maintenance

What rodent issue have you seen the most?
- Cable damage in cable tray, 27%
- Wire damage in electrical cabinets, 38%
- Insulation damage on piping, 15%
- Other, 20%

Do you currently use adjustable rigging in your lift planning for turbine rotor or case removal?
- Yes, 66%
- No, 34%

Combustion

How familiar are you with gas-turbine combustion?
- I'm a flame-stability expert, 5%
- I'm pretty good with what runs in my units, 42%
- I know the difference between a DLN 2.6+ and DLN 2.6, 27%
- Harry Potter's wand must be involved, 20%
- Gas turbines have combustors? 7%

What is your biggest concern when it comes to combustion operability?
- Tuning, 24%
- Hardware, 22%
- CDM and T/C health, 17%
- AutoTune, 15%
- Cold weather, 17%
- Nothing, my unit runs well, 6%

Have you experienced fuel-nozzle damage?
- Yes, 56%
- No, 44%

What was the cause of the fuel-nozzle damage?
- Quat operation, 8%
- Fuel contamination, 28%
- Other, 45%
- Unknown, 19%

If it was quat operation or unknown, are you changing your quat limits seasonally?
- Yes, 13%
- No, 86%

Do you have issues during cold weather with high-dynamics alarms that require operator response?
- No, 45%
- Rarely, 41%
- Frequently, 14%

Generators

What is your most common unplanned stator repair/upgrade finding during an outage?
- Endwinding dusting/greasing or resonance repair, 69%
- Belly-band tightening (or new belly-band install), 8%
- Stator rewedge, either full or partial, 23%
- Stator core looseness, 0%

What is your most common unplanned field /rotor repair/upgrade finding during an outage?
- Slot content (amortisseur spring) migration, 35%
- Main lead cracking or separation, 8%
- Field turn shorts, 49%
- Field ground, 8%

Does your site or HQ/fleet have a spare/exchange 7FH2 field?
- Yes, 21%
- No, 79%

How much time is on the outage schedule for generator rotor removal and replacement?
- Less than one day, 7%
- Two days, 28%
- Almost one week, 48%
- Too long, 17%

Auxiliaries

Have you converted to electric actuators on your gas control valves?
- Yes, 13%
- No, 87%

Are you planning to convert the hydraulic actuators on your gas control valves to electric?
- Yes, 11%
- No, 57%
- Don't know, 32%

Rotors

How well do you know RLE (rotor lifetime extension)?
- Extremely well. We currently are in discussions and formulating a plan, 35%
- Have discussed it with our engine representative, 24%
- Know what the acronym stands for, 35%
- Don't know about RLE, 7%

What's your rotor maintenance plan?
- Exchange rotor, 29%
- Lifetime extension, 32%
- New rotor, 12%
- Not decided/do not know, 27%

Is your rotor affected by TILs 1971 and/or 1972?
- Yes, 46%
- No, 20%
- Not sure, 31%
- It was, 3%

Is your turbine rotor maintenance hours- or starts-based?
- Hours, 52%
- Starts, 16%
- Multiple units, some with both 27%
- Was hours, now starts, 4%
- Was starts, now hours, 1%

Do you have maintenance factoring calculated in your DCS logic?
- Yes, 14%
- No, 37%
- Not sure, 16%
- Tracking outside the DCS, 33%

Are you planning on conducting 7F rotor maintenance in the next five years?
- Yes, based on GER-3620 guidance, 57%
- No, 29%

- Learning more before deciding, 14%

Exhaust system

How often do you inspect your exhaust-frame flex seals?
- HGP interval only, 47%
- Annually, 50%
- More frequently than annually, 3%

Lubrication

How long does your oil last?
- Five years or less, 10%
- Six to nine years, 31%
- More than nine years, 60%

How many hours do you lose annually because of an oil-related failure?
- Less than 12, 81%
- 12 to 24, 5%
- 24 to 48, 9%
- More than 48, 5%

What are your MPC values?
- Less than 15, 77%
- 15 to 35, 20%
- More than 35, 3%

Does your lab report the MPC hold time as required?
- Yes, 13%
- No, 28%
- Not sure, 59%

What type of lube oil do you use?
- Mineral groups 1 and/or 2, 58%
- Synthetic hydrocarbon groups 3 and/or 4, 26%
- PAG, 16%

Have you used an aftermarket turbine-oil additive?
- Yes, 31%
- No, 69%

Do you use a varnish-removal system?
- No, 30%
- Yes, rotating on several units, 33%
- Yes, full time, 37%

When did you install your varnish-removal system?
- Following a failed lab result, 60%
- Following an onsite failure, 28%
- With a new charge of oil, 12%

Have you changed the type of lube oil in your gas turbine?
- Yes, 29%
- Considering it, 20%
- No, 51%

What type of evaluation was done prior to changing the type of oil?
- Full technical evaluation, 60%
- Lube-oil supplier performed the evaluation, 18%
- Rely on experience of others, 22%

Presentations by suppliers

One of the unique aspects of the 7F Users Group's 2020 Digital Conference was the opportunity to interact online with nearly 50 third-party solutions providers. Ten of these companies were selected by the steering committee to conduct live Special Technical Presentations of one to two hours during Weeks Two, Three, and Four of the five-week program ending July 16. The remaining solutions providers participated in the conference with virtual booths in the Vendor Fair, conducted Tuesday and Wednesday of Week One. They connected directly with users via video (or audio) links.

In case you missed the opportunity to visit with one or more of these companies, the editors provide below summaries of the products/services they promoted at the meeting.

More importantly, all supplier presentations are available to owner/operators in the Power Users Presentations Library. However, you must be registered on the website to gain access. This is a simple process, as described on the first page of this report in the section, "To dig deeper." The QR link here takes registered users directly to the library.

Special technical presentations

As generators age and unit cycling increases bad things can happen

AGT SERVICES INC.

AGT Services' Jamie Clark has been on a mission for the last couple of years presenting at the annual meetings of all major users groups to alert owner/operators about the significant increase in generator failures his company and other service firms are seeing. These failures are related in large part to unit cycling and age, with lapses in attention to detail during inspection and maintenance contributing. Recall that most generators at 7F combined-cycle plants were designed for baseload, not cycling, service.

Clark's presentation at the 7F Users Group's 2020 Digital Conference, "Five Minor Generator Inspections Turn Into Three Majors for Repairs," illustrated the dramatic increase in the amount of emergent work some users are experiencing and its costly impact on both maintenance budgets and schedule.

His 7F presentation was similar to one he gave in June 2019 to the Frame 6 Users Group, attesting to the existence of an industry-wide problem, not one affecting a given frame.

Clark began his 7F presentation with a chart illustrating the dramatic increase in the number of starts experienced by a combined-cycle plant in Maine in the last decade compared to the start stats for the facility's first eight years of service. He then polled attendees, asking how the number of starts in the last 10 years compared to years earlier at their plants. Nearly one-third of the users reported up to a 50% increase in the number of starts; 11% said their starts had doubled; 3% said starts had more than doubled.

Next, he asked the users to share their most common "unplanned" stator repair/upgrade finding during an outage. If you think it is endwinding dusting/greasing or resonance repair, you're correct. Well over half the respondents said "yes" to that. Other choices were belly-band tightening or new install, stator re-wedging (full or partial), and stator core looseness.

Clark then highlighted the primary areas of the stator affected by cycling, including the following:

- Endwinding vibration/loosening, noting the higher risk for strand-to-strand series connections.
- Core looseness impacts, such as keybar rattle/belly bands and loss of core compression.
- Slot support system—including wedge system and side packing/ripple springs.

The speaker stressed that all stator parts are designed to work together as a system. Example: Bellybands restrain keybars and when loose allow keybars to "rattle" producing iron oxide particles. Add in some oil and you have greasing that lubricates the connections, further compromising tightness.

Later Clark would address the many areas of concern cycling poses for fields—including slot component migration, turn insulation migration, copper distortion, braze failures, issues with collector systems, and brushless exciters.

There's much you can learn from industry generator O&M experience to improve the reliability and availability of your plant.

If you were unable to participate in the AGT Services session, access the recording on the Power Users website. How much you learn in only one hour might be surprising.

Come up to speed on today's turbine tooling

Plant personnel are always challenged to perform outages faster, safer, better than previously; improved

tooling might be one way to help you achieve those goals. But it's difficult to keep up with new developments in a demanding plant environment. A virtual conference benefits in this regard, facilitating learning via field videos of actual work and simulations.

Enerpac had three experts—Mike Beres, Chris Stocker, and Phil Giagnacova—presenting on tooling solutions during its 1-hr session at the 7F 2020 Digital Conference last week. "Optimize maintenance: From turbine decoupling to rotor removal and alignment" was illuminating. It covered turbine-case removal, a safe and efficient coupling-bolt solution, turbine rotor removal, generator rotor removal, journal turning (field machining), etc.

The format was to review the "current state" of each of these applications and then demonstrate the "future state." To illustrate: The current state of turbine-case removal relies on fixed slings and mechanical turnbuckles. The risks posed by these methods include working from height, ergonomic issues, large heavy components, insufficient adjustability. The future state using the equipment demonstrated focused on hydraulic turnbuckles and adjustable rigging beams. They permit precision adjustment and from a hanging load, allow control away from the lift, and have ergonomic benefit.

The company's space-efficient ETCT (Enhanced Turbine Coupling Tool) solution was said to save more than six hours in tensioning a 7F coupling than the same job would take with a tool commonly used today. The time to tension joints on four 7FAs at one plant with current-state tooling was estimated at 32 hours. Enerpac tensioned the four units in just over nine hours. This is particularly impressive performance given 60% of users said coupling was on the critical path for their outage.

MD&A focuses on Mark VI/VIe controls, HGP parts, fuel nozzles, generators

MD&A divided its two-hour session into four parts so crammed with information of value to O&M personnel that having recordings of each segment available on the Power Users website benefits both those who missed the presentations and those who didn't but want to clarify some points. The video format used is convenient, enabling you to identify the information you want quickly.

What follows is a TV Guide-type summary of the material presented:

- A Mark VI/VIe presentation by Senior Controls Engineer Joe Clappis focuses on the Toolbos/ToolboxST trend recorder a/k/a trender. It is used for capturing and analyzing data and for troubleshooting—more specifically, for analyzing trip history data (hourly data between trips/stops, trip display data, and information captured by the dynamic data recorder. If you're unfamiliar with this tool, listen to the half-hour video. Clappis is a knowledgeable controls engineer, excellent presenter, experienced teacher, and patient. You might just be introduced to an element of the Mark VI/VIe that can save you considerable analytical time.
- Lifetime extension of 7FA HGP components was covered by Engineering Manager Jose Quinones, PE. Life-limiting factors of HGP parts, lifetime extension steps, implementation of repairs, and upgrades/modifications/improvements are included in the presentation. Quinones moves quickly through this material and you may have to listen to him a second time to confirm specific points. Perhaps the most valuable portion of the presentation is case histories that begin with evaluation of field condition, repair options, possible improvements for life extension, and results.
- Fuel-nozzle end-cover-insert life extension was discussed by GM Joe Palmer of MD&A's Fuel Nozzle Services Div. He covered system and product lifecycle analysis, technical advancements and life extension, and testing and validation. The graphics used to explain the cracking issue, design enhancements, and repairs are of great value to the unfamiliar user.
- 7FH2 field-winding shorted turns and groundwall failure by James Joyce, a generator specialist at MD&A essentially is a short course the explains what shorted turns are, what causes them, and how to test for shorted turns online and offline. The hot spots and thermal vibration that result from shorted turns are explained. Explanation of rewind and patch-repair options for dealing with shorted turns follows.

  Groundwall insulation failure is explained in the second part of the presentation. Damage and causes are described along with the recommended repair.

There were two special live technical presentations during Week Three of the 7F Users Group's 2020 Digital Conference—one by PSM, the other by Shell/Advanced Chemical Technologies—and one *extended* live technical presentation from Doosan Turbomachinery Services. The video recordings on the Power Users website (owner/operators only) bring you up to date on the products and services offered by these companies to help keep your plant safe, efficient, and reliable.

PSM presentation

"What Else Do you Need from your 7F Power Plants," was divided among Marc Paskin, senior technical lead, combustion and digital; Dr Alex Torkaman, manager, airfoils, upgrades, and rotors; Josh McNally, technical lead, combustion and digital; Tim Hui, manager, combustion and digital; Brian Loucks, technical lead, airfoils, upgrades, and rotors; Dr Greg Vogel, manager, technology programs; Dr Scott Keller, manager, airfoils, upgrades, and rotors; and Ian Summerside, global product manager for F-class and digital.

Technical topics covered during the one-hour seminar were:

- FlexSuite and FlexRamp upgrades.
- Gas Turbine Optimization Packages (GTOP™).
- FlameSheet™ install successes.
- Total flexibility with FlameTOP™.
- Proven rotor management solutions.

Shell/ACT presentation

"Varnish Mitigation—Not a One Size Fits All," is a collaboration between Chelsea Bukowski (Kovanda), well known to F-class users, and Dr Robert Profilet. Recall that American Chemical Technologies Inc was purchased by Shell in December 2019. ACT and its team continues to operate the ACT business on behalf of Shell for a transitional period.

The video recording covers the following:

- Introduction to Shell/ACT.
- Lubricant selection/base stock evolution.

- Varnish.
- Mitigation methods for varnish.
- Top-off fluids.
- Fluid solutions.
- Maintenance of turbine oils.

DOOSAN

Doosan Turbomachinery Services

The company overview/capabilities presentation by Glenn Turner, VP engineering, will be of particular value to users who have not yet visited the company's new Houston-area facilities and are not familiar with the company's products and services for the 7F, including its DART (Doosan Advanced Re-engineered Turbine) program. Also see the AOG (Alstom Owners Group) section in this issue.

Turner opens with an overview of Doosan's extensive facilities and engineering and manufacturing capabilities worldwide. He moves quickly through Houston's shop capabilities—including a 7FA major rotor overhaul. The DART program's technology upgrades for the 7FA.03 (compressor, combustor, turbine) will be of special interest to owner/operators. Combustion hardware improvements include fuel nozzles and the combustion assembly; plus, the company's autotuning solution. Upgraded designs of buckets, nozzles, and shroud blocks are part of the DART promise to deliver power and efficiency equal to or better than 7FA.04 AGP turbine components.

APG

APG empowering solutions for years to come

The nondescript title of this presentation does no justice to its compelling content. A simple "Aaron Frost" would have told you much more. Yes, Frost was back in front of the 7F group sharing his encyclopedic knowledge of metallurgy, repair experiences on selected hot-section components, and views on the promise of additive manufacturing for new parts and for the rehabilitation of old.

Frost was the second of APG's (Allied Power Group) three participants in the company's hour-long session, speaking for three-quarters of that time. If you missed the presentation and have responsibility for the repair of hot parts for 7F engines, or simply want to add to your knowledge, access the video on the Power Users website; you'll be glad you did.

Jeremy Clifton, VP sales and marketing, introduces APG and its recent acquisitions to attendees. Marty Magby, VP business development, follows Frost with an outline of how the company implements engine and plant overhauls to meet customer expectations.

Frost begins with a review of APG's experience in repairing more than 100 sets of first-stage shroud blocks for the 7FA.03, illustrating some of the enhancements the company has made to extend parts lifetime and improve performance. One example he gave is to add full NiCrAlY side-face coatings on shroud blocks to prevent the oxidation uncoated tiles often experienced after only one service interval. Such oxidation was known to create gaps between adjacent tiles and provide a pathway for seals to go downstream and do damage.

Another enhancement is forward outer block shroud hook recovery which involves machining off the crack-prone original Type 310 stainless steel material and restoring the hook with Hastelloy S weld material followed by finish machining.

Final steps in the restoration of shroud blocks included dimensional checks, finish grinding, and application of a bond coat and a high-density thermal barrier coating on the tile face.

In concluding this portion of his presentation, Frost provides details on the repair of first-stage shroud blocks for the 7FA.04, illustrating how the company's experience described above for the 7FA.03 qualified it to make Dot 04 repairs as well.

Frost links the shroud-block repair and additive manufacturing (AM) segments of his presentation, announcing that APG had successfully developed and printed a 3D 7FA.03 first-stage shroud tile. He is bullish on the future of AM for making critical gas-turbine parts but believes it will be years before it can be applied to mainstream production. An example he gave was that a single 3D tile for a 7FA.03 today takes about a day to make. Also, that commercial AM production equipment is incapable of making large parts—transition pieces, for example.

The big near-term advantage of 3D printing, Frost continues, is that single parts—such as shroud-block tiles—can be made and replaced, avoiding the need to purchase an entire row. Another advantage is that it's possible to "print" the damaged section of a given part—second-stage nozzle, for example—and weld it into the original. Plus, the portion being replaced can be made with an improved combination of material, design, and coating changes such that the repair is better than a traditional weld or braze repair.

The final segment of Frost's presentation discusses what he believes are design improvements to the OEM's third-stage bucket which can extend the lifetime of these parts. He says that AGP has repaired 30 sets of third-stage buckets without a post-repair issue. Attendees were referred to GE Technical Information Letters 2006-R1 (for the 7FA.03) and 2045 (for the 7FA.04) issued relative to third-stage bucket failure potential.

One of AGP's improvements is replacing the double-rail on original third-stage buckets with a single rail to reduce weight. Experience has shown this change can extend bucket lifetime from one HGP cycle to two. Also important to extending bucket life is AGP's tight temperature control during heat treatment and a special fixture that allows vertical orientation of the buckets in the oven to maintain bucket integrity.

HYTORC

Learn about bolting and specialty tooling for large fasteners

Mike Dolan, Hytorc's chief engineer for fasteners, had only a dozen slides and told the 7F audience at the outset that he probably would finish up in 45 minutes. Not! He barely got done in the hour maximum for his session. And it was all "good stuff," including lessons learned and best practices of particular value to O&M technicians—an ideal presentation for a lunch-and-learn at the plant.

Proper tooling for bolting, he stresses, can make maintenance safer, faster, and more efficient than it is with the tools you might now be using. While acknowledging that most bolting work can be done with simple hand wrenches, Dolan continues, large fasteners require power tools to load and unload them. Gas turbines can be a particular challenge: They have large bolts, and long-term operation at high temperatures and loads exacerbates bolting challenges. He calls gas turbines "galling incubators."

Dolan discusses torque control offered by powered wrenches and their safety attributes, and reviews hydraulic, bolt-heating, and mechanical tensioning. Galling gets deserved attention as does the company's tension nut system which eliminates that condition.

Access this recorded presentation today; you won't be disappointed.

A paradigm shift in gas-turbine lubricant maintenance

Presentations on turbine lubricants and/or their maintenance are oft-discussed subjects at user-group meetings. Plus, you can expect to see a half-dozen or more companies in the exhibit hall offering fluids and varnish-removal systems—all competing for your business. Having so much information from disparate sources can make it difficult for a user to decide on the optimal lubrication and treatment options for his or her plant.

How about starting anew? Listen to EPT's Matthew G Hobbs who recommends that you treat your turbine fluid as an asset, not a consumable. You'll probably make better decisions if you do, he says. Hobbs "knows his stuff" and has the sheepskin and experience to support his research and findings. Plus, he speaks clearly and is an excellent "explainer" of things you probably should know. The presentation is only an hour.

Hobbs encourages you to understand and use the tools at your disposal to eliminate unpredictable oil-related failures, which can cause astronomical unbudgeted expenses. His best-practices recommendations include these:

- Select high-quality lubricants from reputable manufactures/suppliers.
- Exercise caution with aftermarket additives.
- Demand reliable oil-analysis data.
- Use a conditioning system to remove varnish-precursors as they form.
- Clean your oil so it can clean your system.

Hobbs shows by way of a case study how to keep your lubricant costs affordable and predictable. Recall that most owner/operators generally decide on fluid replacement when the acid number increases by two- or threefold and additives decrease by 75%. In round numbers, this means that a nominal 10% annual rate of additive consumption equates roughly to a 10-year lifetime for your oil—assuming conditions remain the same over time. A polling question during the presentation indicated about half of the respondents were getting 10 years or less from their lubricants.

The details of a 10-year case study conducted by EPT for a plant using its ICB™ ion-exchange technology since COD to maintain the fluid in top condition, revealed an additive level at the end of a decade of service of 91%; the acid number has never increased. The oil is expected to serve for another 10 years—at least.

The paradigm shift, Hobbs says, is that by annually adding 5% top up with the existing brand of new oil, in conjunction with ICB conditioning, provides a step change in how the oil ages.

7FA LCI digital-front-end case history

John Downing, Turbine Controls & Excitation Group (TC&E), celebrated his company's 10th anniversary at the 7F Users Group's 2020 Digital Conference. He reminded the 300 or so owner/operators attending his presentation 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).

Downing says that 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. Failures usually are experienced in the controls and/or the cooling system.

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.

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. In this case, the controls are replaced with a modern alternative that extends LCI life by 20 years.

TC&E partners with TMEIC, one of the world's largest manufacturers of LCIs and drives, to provide a turnkey DFE solution that Downing says is far less expensive than the other two options.

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.

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 about five days; a turbine shutdown is not necessarily required, although, of course, the LCI will be unavailable for that period.

Vendor Fair

Webinars explaining products/services of value to owner/operators, 7F users in particular, were recorded for each of the companies participating in the Vendor Fair. All are available in the Power Users Presentation Library; run times are 30 minutes or less. BONUS: The presentations by companies identified with an asterisk and name in color are available to all CCJ readers at www.ccj-online.com/onscreen; no registration required. The QR link provided here is to facilitate access.

*Allied Power Group

Introducing APG Nexgen™ combustion technologies

APG President Jim Masso reviews the company's recent acquisitions—Nexgen (advanced fuel systems), Texas Metal Printing (3D printing of turbomachinery components), and Eta Technologies (largest non-OEM

V-series engine component and repair supplier)—and then summarizes the company's capabilities in NDT, metallurgy, chemical stripping, grit blasting, rotor repair, and onsite field service. APG's coating technology and capabilities are discussed next along with comprehensive combustion repair. A shop tour is included.

Custom engineered solutions for F-class owner/operators follow—including problem diagnosis and RCA capabilities, calibration and flow testing, and parts reconditioning. A technology solution of interest to many users is the company's brazed insert replacement for the 7FA fuel nozzle. Engineered solutions include output and firing-temperature increases, 7FA.04 repairs, life extension, etc.

*GTC Control Solutions

Operational tips through case studies, TIL 1524 and 1275 implementations, LVDT calibration

Chief Engineer Abel Rochwarger, respected by many in the industry for his controls expertise, helps users understand the factors that determine "single points of failure" and how to identify them, plus the not-so-evident aspects of the relevant Technical Information Letters that can be learned only after implementation.

The takeaways: Users with Mark VI controls will learn about previously unknown/undisclosed failure modes, how to determine if their control systems are potentially susceptible to them, and what the options are for avoiding future occurrences. Personnel from plants with Mark V controls will come up to speed on two new cards from GTC that can help extend the lives of their panels.

Bonus discussion: Average versus core-by-core LVDT calibration.

*Nel Hydrogen

Hydrogen generation ensures reliable hydrogen supply for CCGT powerplants

Dave Wolff discusses the use of onsite hydrogen gas generation as a safer, more economical alternative than delivered hydrogen for generator cooling. Users will gain an understanding of how ultra-pure, pressurized, dry hydrogen gas is produced onsite from electricity and water using the company's compact Proton Exchange Membrane electrolyser. Applicable system drawings are included.

*Nitto Inc

Introducing hydrogen detection tape

The physical properties of hydrogen gas make leaks extremely difficult to detect. Finding leaks quickly is important to ensure personnel safety and to protect critical plant assets. Dr Nahid Mohajeri, GM of advanced polymer technology at Nitto, explains the company's industrial-grade adhesive tape, which is applied to hydrogen-system components most likely to leak—such as flanges. The tape changes color from amber to black when exposed to even the smallest amounts of hydrogen—concentrations of 1%, for example. Powerplant experience is shared along with lessons learned.

*Parker Hannifin Corp

Reduce maintenance concerns and costs associated with gas-turbine fuel control valves

Jim Hoke, Parker's capital projects manager for power generation, provides users technical information on the company's line of electrohydraulic servo valves required for decision-making. The valves are approved by GE for use on its gas and steam turbines for the following applications: control of gas and liquid fuels, steam-valve actuators, inlet guide vanes, and stop/ratio actuators.

Key takeaways from the presentation include these:

- Parker's "soft-fail" electrohydraulic servo valves if plugged will not cause the downstream actuator to fully extend or retract—it will remain in place. However, the valve can be spring-biased to move the actuator to a preferred safe position.
- The product is a drop-in replacement for many servo valves in use—including hydraulic mounting and electrical connections.
- Large orifice diameters allow contaminants to pass through instead of obstructing flow.
- Hydraulic spool, designed with a significant chip shear force, enables continued operation in hydraulic systems experiencing varnish buildup.
- The robust design allows extended intervals between PMs, calibrations, and tests.

*Dekomte de Temple

Fabric expansion joint solutions for 7F CCGT plants

Jake Waterhouse, group technical director at Dekomte, is a frequent speaker at user-group meetings. Here he discusses the benefits of retrofitting the 7F flex seal, used where the diffuser transitions to the cold casing, with a high-quality fabric solution for longer life and greater durability in cycling plants. Other applications for fabric expansion joints include the HRSG inlet and outlet.

Inspection (visual and thermographic) is the first step in understanding the existing condition and technical requirements to develop a tailored long-term reliable solution, says Waterhouse. Another input to the decision-making process is a review of operational criteria to identify to the degree possible expected operating parameters going forward.

Waterhouse shows with drawings and photos the details of the company's expansion-joint offerings and presents case studies to illustrate the challenges posed by different gas-turbine models and the successful solutions implemented.

*Conax Technologies

Capabilities overview

If you're unfamiliar with Conax Technologies, which manufactures temperature sensors, compression seal fittings, and cable harness assemblies, watch the 2-min video for an overview of the company's capabilities and products for generating plants. In addition to standard off-the-shelf products, custom-engineered solutions are available to address the industry's most demanding challenges.

Here's a shortlist of products and services available from Conax:

- Exhaust-gas thermocouples.
- Sensor cable assemblies.
- Bearing temperature sensors and seal feedthroughs.
- Temperature-sensor harness assemblies.
- Vibration analysis, accelerated lifecycle qualification testing.

*Donaldson Company, Gas Turbine Systems

Technology solutions providing more power to you

Donaldson's Casandra Light and Mike Carlson walk you through the company's Three Pillars of Filtration methodology focusing on efficiency, water tightness, and pulse recovery rate to provide your plant the optimal filtration solution. Case histories illustrate the value in adopting Three Pillars.

*ESC/Spectrum

Optimizing your data acquisition system with StackVision: Best practices, sound advice

Andy Taer brings you up to date on the Austin (Tex) company and its data acquisition system software—including StackVision™ and SpectraView® Prism—for continuous emissions monitoring systems.

Products and services, in addition to the DAS software, include the following:

- Software IT services—including hosting, upgrades, and system migration server management.
- Software customer support, docu-

mentation, and training services.

- 8864 Data Controller hardware.
- CEMS maintenance and training.
- Stack testing for RATA, permit compliance, and engineering studies.
- Repair and calibration of CEMS equipment.
- Mobile testing systems and parts for CEMS.
- Compliance reporting services.

*Hilco

Coalescer separator, oil mist eliminator help bring fluid contamination problems under control

Two short videos illustrate how the company's equipment works and the results it offers in terms of water and contaminant removal. Hilco goes beyond filters to provide a full-service fluids-management process—from obtaining samples to analysis to consulting to field service.

The total oil maintenance service offered by the company contributes to a reduction in new oil purchases, lower disposal costs, less wear of lubricated parts, and less downtime.

Team Hilco posits that the reliability and efficiency of any filtration system depends chiefly on cartridge quality. The company offers a full line of cartridges for virtually every application—depending on size, filtration efficiency, and dirt-holding capacity. Most fluids serving in powerplants generally can be restored to a like-new condition. Hilco's world-class laboratory offers a full suite of test capabilities to support industrial filtration and fluid analysis.

*Mercer Thompson LLC and IEM Energy Consultants

Ensuring your LTSA is fit for the future

Many owners are rethinking their LTSAs given the proliferation of renewable resources challenging the operation of traditional fired assets. Jason Yost of Mercer Thompson, a frequent speaker at user-group meetings, and IEM Energy Consultants' Bill Ray and Craig Nicholson, say contracts negotiated years ago may not be calibrated for future needs. The speakers discuss some of the key areas and potential opportunities to consider, plus steps that can be taken to ensure owners are best positioned to effectively negotiate or renegotiate their LTSAs. Takeaways include negotiating strategies, best practices, and how to avoid common and costly pitfalls in the negotiation process.

*AP+M

"Outage in a Box"consumable kit solution for GE Frame 6B/7E/7F engines

Craig Sonnenberg and Jerrod Walters combined for a deep dive into AP+M's "Outage in a Box®"—one or more containers containing all the consumables required onsite for maintenance outages. The custom, cost-effective packages are delivered directly to the outage site. Walters and Sonnenberg say the company can provide a wide variety of parts from its global network—including engine, package, and BOP parts and components, inlet evap cooling misting nozzles, inlet filters, etc. Services offered include replacements of control, engine-support, and BOP systems.

*Braden Filtration LLC

Advancements in nanofiber technology for pulse filters

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

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

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

***Bureau Veritas**

Adjusting turbine-oil monitoring to the current situation

Jorge Alacorn, senior consultant and thought leader on the subject of "Reliability through Oil Conditioning Monitoring and Predictive Analytics" as applied to maintenance, focuses Texas-based Bureau Veritas' presentation on how to maximize the life of turbine oil by combining appropriate condition tests based on the application, risk of failure, and plant reliability objectives.

He and colleagues Jeremy Erndt and Barry Cato, help owners/operators:

- Select the correct oil analysis for their plants.
- Understand the importance of a proper oil analysis.
- Use oil condition monitoring as a predictive tool to avoid a turbine shutdown.

Services offered by the company include oil condition monitoring, plant lubrication audits, boiler and pressure-vessel inspection, ISO 15001 auditing and training, and leak detection.

***Groome Industrial Service Group LLC**

AIG tuning and permanent sampling grid

Jeff Bause and Steve Houghton explain how Groome's turnkey services enable owner/operators to reduce harmful emissions, improve plant performance, and extend the lifetimes of critical equipment. They go on to say the company's philosophy is simple: Provide quality, innovative services at a reasonable price for its five maintenance service lines—HRSG and refinery maintenance, industrial cleaning and support, surface preparation and coatings, and door and mechanical services.

HRSG maintenance, the service line of greatest interest to 7F users, is supported by strategic alliances with industry experts and catalyst manufacturers to ensure Groome offers the most widely supported and comprehensive turnkey services available in the industry. Specific services include the following:

- SCR catalyst systems.
- CO catalyst systems.
- AIG systems and controls.
- Retrofit and installation.
- Boiler tube cleaning.
- Industrial coatings.

***Pioneer Motor Bearing Co**

The "care and feeding" of fluid-film bearings

Dr Lyle Branagan, Pioneer Motor Bearing's engineering manager, is well respected in the electric-power community for his deep knowledge of bearings. Branagan's 7F presentation focuses on damage mechanisms found in fluid-film bearings for motors, turbines, and generators. Topics including theory of operation, bearing design features and materials of construction, and lubrication basics are reviewed in brief at the beginning of the presentation. This information serves as a backgrounder for the ensuing discussion of some typical damage mechanisms observed in today's bearings—with an eye toward prevention of recurrence and recovery from the problem.

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

Pioneer Motor Bearing specializes in the repair and service of large oil-lubricated bearings, with a focus on engineering problem-solving.

The company, a licensee of Siemens Energy, GE, and the UK's Mitchell Bearings, may be best known to users for its Babbitt-bearing repairs, new manufacture, reverse engineering, upgrades and custom designs, and technical support.

*VAW Systems Ltd

Exhaust system retrofit approach

VAW Systems' core business is the design and manufacture of engineered noise control products for gas turbines, fans, steam vents, and other applications. Dominic Crnkovich and Dennis Seltz introduce owner/operators to the company's line of silencers, filtration systems, and related components that promise to meet the high performance and quality demands of modern powerplants. The speakers say users can expect high acoustic performance within a relatively small footprint, plus low pressure drop in applications requiring that.

Segments of the presentation likely to be of greatest interest to users is an overview of exhaust-system failures and new challenges, the company's approach to exhaust-system repair/replacement, and improvements for system longevity.

*National Electric Coil

An improved self-locking amortisseur finger and spring assembly for 7FH2 generator rotors

Bill Harris, NEC's field services manager for rotating electrical equipment, presents on the importance to generator reliability of the Inconel Spring incorporated into the amortisseur/damper segment of 7FH2 rotors.

The Inconel Spring, he says, is prone to traveling on an axial migration path towards the retaining ring. Migration can lead to blocked cooling passages and the further effects of uneven heating across the rotor. Additionally, if the Inconel Spring makes its way under the retaining ring, damage to retaining-ring insulation can result—possibly even a ground fault.

Harris reviews the mechanisms of spring migration on the rotor components during operation and explains the structure and important function of the rotor's amortisseur/damping system.

NEC is a company that needs no introduction to most powerplant owner/operators. It specializes in shop and onsite repair and upgrade services for generators and rotating exciters of all makes and models and sizes. NEC also is an experienced winding manufacturer.

*Nord-Lock Group

Coupling-bolt issues and solutions with EzFit

Steve Brown, Nord-Lock's resident expert on expansion bolts, shows how a technology that has proven effective in critical power-generation applications is eliminating the costly, time-consuming challenge presented by seizure-prone fitted coupling bolts during outages.

It highlights recent cases that demonstrate the technology's value in the field. Plus, it offers preemptive steps that plant personnel can take to minimize flange-bolt faults in future maintenance situations.

Brown presents on the downsides and risks of using conventional bolts for turbine/generator coupling and helps users better understand the principles of mechanical expansion bolts—what they are, how they work, and how they mitigate the problems associated with conventional bolts.

*Rochem Technical Services

Compressor cleaning best practices

Following an introduction by Managing Director Martin Howarth, Steve Engelhoff, a familiar face at user meetings in the US, discusses cleaning best practices based on the company's technical expertise and field experience. Recall that Rochem offers a range of gas-turbine cleaning systems, precision-designed nozzles, and specialist compressor cleaning chemicals to help keep GTs operating a peak efficiency. The company's Fyrewash products are designed to address all types of fouling and to meet OEM and environmental standards worldwide.

*Parker Hannifin Gas Turbine Filtration

Inlet air filtration solutions

Paul Barron, North American regional sales manager, and Sales Manager Abby Rowe met users in their virtual booth, updating them on the company's line of inlet air filters and systems capable of superior performance over a wide range of environmental conditions. They reminded the owner/operators of the company's two popular brands of filtration products: Altair® and clearcurrent™. Parker's GT filtration options include the following: cartridge, vCell, pocket or panel filter. Complete gas-turbine inlet filtration systems, including evap coolers, also are offered.

Parker Hannifin was represented in two stands at the 7F Users Group's virtual Vendor Fair. The company's line of electrohydraulic servo valves, approved by GE for use on its gas and steam turbines, were promoted in the other booth and profiled earlier in this listing.

*Moog Inc

Conceptual hybrid IGV positioning systems for large GE frame engines

Moog manufactures precision motion-control and positioning systems for gas and steam turbines, but may be known best to powerplant O&M personnel for its servo valves used to control hydraulic cylinders in many power-generation applications. Steve Beddick and Ken Kauppila teamed up to review hybrid electro-hydrostatic positioning systems and how they can be configured to replace the hydraulic IGV actuation systems sometimes associated with operational issues on GE Frame 6 and Frame 7 gas turbines.

*Turbine Logic

Eliminating GT unplanned outages caused by combustion hardware and instrumentation failures

This presentation by Ben Emerson, manager, combustor and hot section, at Turbine Logic, and senior research engineer in Georgia Tech's School of Aerospace Engineering, introduces a novel combustion-dynamics monitoring algorithm and a case study to demonstrate its successful detection of a gas-turbine combustor fault. Recall that combustor faults can cause expensive damage to both combustor and hot-section components.

These failures often develop from small, insipient faults which product subtle signatures in the combustion-dynamics data. Fault signatures can be detected by advanced monitoring algorithms before parts fail and force the unit out of service.

The algorithm described in the presentation, developed in conjunction with EPRI, blends data analytics with combustion domain expertise. It is fielded on a fleet of frame units and has caught several faults at sufficiently early stages to plan repairs without a forced outage. Emerson presents an overview of the algorithm's core logic, enumerates the types of faults that the algorithm commonly catches, and closes with a detailed case history.

*AP+M

T2020 bi-phase compressor cleaner

AP+M had two booths at the 7F Users Group's virtual Vendor Fair. The company's "Outage in a Box" consumable kit solution for GE Frame 6B, 7E, and 7F engines was summarized earlier in this listing. The company's compressor cleaning solution is the subject here.

Craig Sonnenberg and Jerrod Walters connected for a deep dive into the features of the company's water-based T2020 bi-phase compressor cleaner, an advanced product with solvent cleaner characteristics but without the hazards associated with solvent cleaners.

*Liburdi Turbine Services

Case study of previously repaired 7FA first-stage turbine buckets

Justin Kuipers, a senior materials engineer with deep experience in gas-turbine component analysis and repair development, discusses the results of metallurgical analyses performed on four 7FA+e first-stage buckets. Each airfoil had been repaired by a different vendor using a different approach. The metallurgical condition and extent of the prior repairs are presented for each of the buckets following one additional service interval.

The 7FA+e presents demanding repair requirements. The first-stage bucket employs a hollow design with serpentine cooling passages, showerhead cooling along the leading edge, a tip cover plate, and welded and brazed details within the cooling passages. Such enhanced design features are conducive to challenging repairs with narrow tolerances—that is, less room for error. This calls for an increased reliance on metallurgical analysis for evaluating component condition, repair requirements, and qualification of repair results.

Key takeaways for users include the following:

- 7FA first-stage buckets have characteristic damage modes.
- Different shops have different repair strategies and processes, resulting in a range of possible outcomes from high-risk operation to good-as-new performance.
- Internal coatings must be replaced to achieve multiple repair cycles.
- Various heat treatments are used in repairs and they are important to understand.
- Know the critical quality-control steps in component repair and how to reliably extend the service lives of valuable components.

*Strategic Power Systems Inc

Powerplant analytics and optimization

Salvatore A DellaVilla Jr, founder and CEO of SPS is one of relatively few industry executives who needs no introduction. His deep knowledge of gas turbines goes back to the ordering boom that followed the Great Northeast Blackout of 1965. Most recently, DellaVilla was appointed managing director of the Gas Turbine Assn.

His presentation at the virtual Vendor Fair was about ORAP®, Strategic Power Systems' powerful database system that allows for the capture of data from powerplants operating worldwide and provides the value-added tools to support effective O&M decision-making.

Every powerplant requires data to make informed decisions and to satisfy its numerous reporting requirements, DellaVilla says. While a tremendous amount data are available, organizing it, and then transforming it into actionable information can be difficult and time-consuming. That's what ORAP does.

Case histories incorporated into the presentation highlight ways owner/operators have used ORAP to create an information architecture within their businesses—including RAM, KPIs, and benchmarking; critical- and capital-parts planning, and automation to optimize time and productivity.

Listen to DellaVilla and come away with the following:

- How to use data and analytics to drive down costs and improve productivity.
- Satisfy all management, ISO/NERC GADS, and other reporting requirements with one set of data.
- Benchmarking: Learn how you stack up against your peers.
- Optimize your availability: Use data to stop issues before they happen.
- Ensure knowledge transfer and consistency across multiple plants.
- Transparency and lessons learned: Don't repeat mistakes.
- Identify problems in the fleet that you might not have experienced yet.
- Have a complete perspective of your serialized parts—in operating units and inventory—including ageing over time.

*C C Jensen, Oil Maintenance

Remote oil condition monitoring as a CBM tool including varnish—an update

Has Axel Wegner ever missed an opportunity to speak before a group of powerplant owner/operators about his passion—lube-oil condition monitoring and filtration? Certainly not in the last 10 years. If you have not listened to the solutions-oriented chemical engineer and want to learn how to deal effectively with the following problems:

- Turbine oil varnish.
- Particles and water in lube oil.
- Bacteria, diesel bugs, fungi, particles, and water in backup diesel storage tanks for dual-fuel plants.

Listen to the presentation he

recorded for the 7F 2020 virtual Vendor Fair. You might even consider showing it to the plant O&M staff during a lunch-and-learn session.

Wegner points out that the "right" condition-monitoring and filtration system for any machine and oil type allows you to identify problems remotely and to take action before problems occur.

Badger Industries

Consolidate exhaust-system maintenance to reduce costs and maximize runtime

Operations Manager Matt Long and Field Service Manager Gary Neimann team up to highlight Badger's service options for streamlining the maintenance of exhaust-system components from the turbine to the HRSG. Highlights of the presentation include these:

- The value proposition for upgrading the flex seal rather than opting for the OEM's leaf seal replacement.
- Repairs available for the A042 diffuser duct for increased thermal efficiency and longer life.
- Single-source provider for expansion joints and service labor.

The company's products/services include the following: turbine exhaust expansion joint, 7F flex-seal upgrade, A042 diffuser duct, HRSG inlet expansion joint, pipe penetration seals, thermographic analysis, and failure analysis.

Emerson Automation Solutions

Advanced condition monitoring with Ovation

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

SVI Dynamics

Defining and implementing SCR improvements on gas-turbine exhaust

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

Industry veteran Bill Gretta, SVI Dynamics' SCR product-line director, understands. His company, he says,

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has incorporated years of knowledge and experience gained from work on SCRs manufactured by all of the major vendors into SVI's new SCR. If new is not optimal, SVI can provide in-depth analysis of your SCR to suggest enhancements that will improve reliability and efficiency.

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

JASC Controls

Pitfalls to avoid for enhanced liquid-fuel-system reliability

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

ARNOLD Group

Advanced steam-turbine-casing warming for startup

ARNOLD is perhaps best known globally for the insulation systems it provides for all types/designs of gas and steam turbines. Outside North America it is equally well known for its onsite turbine machining services.

Turbine warming systems have matured as product line in the last several years given the need for gas and steam turbines to start faster to satisfy grid requirements.

Pierre Ansmann, the company's global head of marketing, and Norman Gagnon, ARNOLD's North American project manager, provide users a primer on turbine warming systems. Their presentation covers the following:

- Maintenance and operational benefits for individual customers.
- Differences between various warming-system arrangements.
- Durability and reliability.
- The importance of proper insulation for a warming system.
- Warming-system controls.
- Cost and duration of initial installation and periodic maintenance.

Sulzer

A look inside Sulzer Turbo Services

Michael Andrepont, GM operations (gas turbines), and Jim Neurohr, area sales manager, take you on a 6-min tour of Sulzer Turbo Services' Houston shop and explain the company's capabilities regarding the 7FA—including HGP component, combustion hardware, and fuel-nozzle repairs, field services, rotor life evaluation, LTSAs, etc. Sulzer is one of the world's leading independent service providers in the repair and maintenance of all makes and models of industrial gas and steam turbines, compressors, and expanders. It offers a wide range of manufacturing, engineering, reconditioning, balancing, and coating services.

HRST Inc

GT upgrades: Low-load impact on HRSGs

Anand Gopa Kumar, who leads HRST's Analysis Dept, provides users critical insights on how increasing the turndown capability of their gas turbines to provide the operational flexibility required in many areas of the country today may impact the HRSG. He identifies areas within the boiler at risk of exceeding their design capabilities and possibly susceptible to long-term damage. Kumar also

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suggests modifications to the HRSG and associated equipment (including attemperators, internal liners, superheater tubes, steam separators, etc) to enable the desired turndown with minimal risk.

MD&A

7FA component lifetime extension

José Quiñones, PE, director of engineering for MD&A's San Antonio Service Center, the company's gas-turbine parts service facility, presents a tutorial on the life-limiting factors of hot-gas-path components. Included are typical steps to follow when conducting a lifetime-extension project. Plus, the upgrades, mods, and improvements—including advanced coatings—you should consider to extend the lifetimes of critical parts.

Gas Path Solutions LLC

Exhaust-diffuser relining and upgrades

Brian Nason, business manager, and Michael Busack, sales and field services manager, discuss the reconditioning services and upgrades offered for 7FA exhaust diffusers manufactured by C&W Fabricators, Quest, Braden, and others. Among the company's replacement solutions: inlet flex seal joint, outlet expansion joint, and internal free-floating liner system. Turnkey installation is provided.

Koenig Engineering Inc

Everything you should know about turning gears but don't

Tim Connor, aftermarket sales and field service manager, reviews findings from turning-gear teardown inspections, highlighting common failure modes and how to avoid them. An in-depth review of turning-gear operation and major components is especially beneficial for plant personnel with limited experience. Finally, Connor offers an action plan for ensuring long-term turbine starting and rolling reliability.

ExxonMobil

Pushing the needle: New strategies to improve gas-turbine energy efficiency through lubrication

Lubrication experts Mike Galloway, Jim Hannon, and Charlie Smith show how oils offering energy-efficiency benefits can improve your bottom line. They dig into the technical science and offer field and lab data to quantify the value of advanced lubrication strategies.

EagleBurgmann Industries LP

Expansion-joint maintenance from an owner/utility perspective

Mark Ahonen, aftermarket sales manager, provides an in-depth look at the 7FA exhaust joint—covering maintenance, repairs, upgrades, and a general owner's guide of critical areas to monitor.

GE Gas Power/ FieldCore

Technical content provided by the OEM, summarized here, was well-organized and thorough (given time constraints), with several dozen very capable managers and engineers from GE Gas Power and FieldCore making presentations, participating in discussions, and answering questions from wherever they were located—in offices, in homes, and at jobsites.

Tom Freeman, chief customer consultant for GE Gas Power-Americas, coordinated the OEM's program and was always on the ready to answer questions, fill an informational divot, provide background on speakers and discussion topics, etc.

Highlights of information incorporated into the OEM's presentations follows.

It is intended to provide a "flavor" of the broad range of topics addressed so you know what slides/videos posted on GE's myDashboard website you might want to access for a deeper dive (use the QR code for a direct connection). Think of the CCJ summaries as a "TV Guide" for the web—a shortcut to material of interest.

Opening remarks, Day Three, June 18

GE's first appearance at the event was on third and final day of the Week One program. The theme of the OEM's opening remarks was "Looking Forward to the Last 30 Years." Alvaro Anzola, VP of combined cycle services for the Americas, opened the program with a historical technical review of the 7FA. The first F-class gas turbine, rated 147 MW at a firing temperature of 2300F, began commercial operation at Vepco's (now Dominion) Chesterfield Power Station in June 1990.

A timeline highlighting significant events in the life of this frame—including DLN-2.0 in 1993, OpFlex solutions in 2004, Advanced Gas Path in 2009, etc—is a great slide for testing your memory. It and all of the other GE presentations are available on-demand on myDashboard. An interesting statistic from Anzola's presentation: GE deployed more than 5400 upgrades to the fleet from 2011 through 2019 to reduce emissions and/or to increase efficiency, reliability, output, and operational flexibility.

A special presentation, "Quantifying the Value of Flexibility," by Professor Mort Webster and others from Penn State's Dept of Energy and Mineral Engineering, followed. If you're an asset manager, or have responsibility for generator scheduling and dispatch, consider retrieving this presentation. It discusses the system dynamics that determine how a unit might be dispatched with features added to improve flexibility—such as higher maximum output, lower minimum output, faster ramping, faster startup—and the financial benefits of these improvements.

State-of-the-fleet presentations at user-group meetings typically keep attendee eyes glued to the screen. No different at this conference. Diane Beagle, GM of global product service, and engineering leaders Brian Moran, a GT expert and Josh Sater, a plant systems expert, compiled stats of interest to the group and reviewed hot topics in the fleet.

Example: F-class starting reliability data from Strategic Power Systems Inc's ORAP information system shows GE at 98.9% each year from 2016 through 2019 (except for 98.7% in 2018)—about half a percentage point ahead of the aggregate industry results that include the GE data. A poll of the attendees revealed that the leading causes of failed starts were valves (23%), controls (22%), and instrumentation (20%).

Also according to ORAP data, GE's F-class reliability (includes gas turbine, generator, and station equipment) outpaced the competition from 2016 through 2019, averaging more than 97.9% to the industry's 97.4% (including GE). When queried about the equipment responsible for most forced-outage days, users put instrumentation (29%) and transformers (19%) at the top of their lists.

Moran addressed these three "hot" topics in his presentation:

- DLN-2.6+ effusion plant cracking.
- Stator 5 root cause analysis.
- Flared enhanced compressor.

The first examined cracks between the center and outer fuel nozzles found in effusion plates with laser- and EDM-drilled holes after about 3000 hours of operation. Thermal strains from cycling were said to drive crack propagation along the high-heat-affected zones. Corrective action: Replace cracked caps with in-kind replacements until validation tests of a new TBC-coated effusion plate are complete—possibly by year-end.

The Row 5 RCA confirmed that the flared-7F events experienced in the fleet require "increased risk factors" for crack initiation—and that new and clean stator vanes have significant fatigue margin. Moran told attendees that the following issues could reduce fatigue margin: corrosion pitting, heavy tip rubs, FOD/DOD, and compressor surges. An elevated response would be caused by vane lock-up and loss of damping as well as heavy tip rubs.

Moran closed with a discussion on enhanced 7F flared compressor options, reviewing the features associated with Packages 2, 2+, 3, 4, and 5. He also discussed the enhancements for Rows S14-S16, reviewing both the "Big Foot" and "Little Foot" mods. You may recall that the advantage of the latter is that no casing machining is necessary and the work typically is completed in four days.

Sater spoke after Moran, focusing on the programs for the dedicated breakout sessions aggregated under a "Transforming a Mature Fleet" banner and scheduled four weeks hence in Week Five. Check out Sater's slides covering safety, maintenance, forced-outage mitigation, and outage considerations on myDashboard to gain access to materials of interest.

FieldCore, Day Eight, July 2

FieldCore Day was divided into the following four segments, each of which can be accessed by registered users on myDashboard:

- Opening remarks and state of FieldCore.
- 7F landscape/update and best practices.
- Houston Learning Center and training.
- Delivering capability.

The first recorded video features opening remarks by FieldCore President/CEO Amir Hafzalla (02:30), who introduced his company as Gas Power's field services arm, characterizing the business unit as "acting with humility, leading with transparency, and delivering with focus." It is GE, he said. Hafzalla stressed his goals of continuous improvement, safety, quality, and integrity. Note that the numbers in parentheses throughout the FieldCore segment are the times where the persons identified begin their presentations. This should help you access quickly the information of greatest interest.

Brad Hilt (13:00), managing director, GE Gas Power Services, began by reliving what he learned from customers at last year's 7F conference regarding field-service performance. Customers, in general, were not "happy campers."

Hilt explained how the company has addressed, and is continuing to address, the feedback received. Here are a few of the actions taken:

- Driving accountability, clear communication, and aligned roles/responsibilities for better customer outcomes.
- Shifting of the outage planning process from reactive to proactive.
- Building EHS and quality consistency into outage planning and execution.

Hilt then reviewed preliminary results from the performance-improvement effort. He listed several complimentary sound bites from surveys conducted recently by GE. Access the presentation and see if you agree. A survey of participants in the 7F meeting revealed that nearly half of the respondents believed the GE outage team performed noticeably or slightly better in the last year than previously. Roughly 30% checked "about the same."

The 7F landscape/update and best practices segment brought users up to date on FieldCore's achievements and introduced owner/operators to the service company's key personnel. Mort Smith (00:00), GM of the FieldCore service team in North America, spoke first, summarizing key takeaways and experience from work conducted in the first half of 2020—including improving job quality and a safety record second to none.

Ryan Hooley (07:00) of GE Gas Power was next, discussing the company's Covid-19 response and outage management. He said Gas Power executed 134 major events during the six-month period with no significant safety (Level A/B) or operational implications.

Underpinning this success was the creation of more than 15 procedures and protocols specific to Covid-19 safety, site execution, and preparedness. Plus, the prompt communication of changes to protocols, suspected and confirmed cases, best practices, and emerging risks.

Jeremy Williams (11:00), North American quality director for FieldCore, traced the continuing improvement in field-service work by the company. He pointed to the following 2017-2019 results: 35% reduction in "severe" events and a 40% reduction in customer lost-generation days. Credited were increased defect capture, aligned audit program, and increased leadership engagement around planning, resourcing, and execution.

Several Covid-19 solutions and best practices were integrated into this portion of the Day Eight program to illustrate employee commitment to better outcomes and customer support. The first "Covid Heroes" film clip showed Service Manager Matt Wallace's (13:10) success in producing large numbers of small plastic bottles of a foaming hand sanitizer for use by field personnel. Field Engineer Brian Manzo (14:50) then presented for a few minutes on a 7F outage excellence solution involving a well-stocked 8-ft conex container, complete with tools and spare parts for a given job.

Brian Yu, US West region outage manager, (22:40) illustrated the value of a partial LOTO, whereby getting fuel gas and CO_2 on LOTO as soon as possible allows field-service personnel to complete critical-path tasks in the compartment that normally would wait for a full LOTO. The obvious benefit is reduced outage time.

Yu next presented a best practice on a single-shift outage (23:50) piloted during a 7FA hot-gas-path inspection. It required about 14 shifts LOTO to LOTO instead of about 24 shifts (total of day and night shifts). Value to the customer included no plant support required at night, the inherent safety of not doing critical lifts at night, etc.

No safety recordables or first aids were reported and there were no quality misses. There were several considerations an adopter of this best practice should be aware of. Get those details by accessing the recorded presentation on myDashboard.

In the final portion of the segment, Jeremiah Smedra, US West & Canada region manager (25:50), discussed progress on a so-called "event equation and standard work" introduced at the 2019 meeting. The equation: Success = Planning + People (field engineer + craft) + Customer Interface + Execution + Closeout. The presentation was delivered in two parts, separated by a short Covid Hero clip featuring Bayo Akomolafe (30:10) making 3D-printed face shields. If you recall the event equation and would like an update, access the recorded presentation.

The Houston Learning Center (HLC) and training video is fast-moving, answering many questions plant and maintenance managers likely have about FieldCore's capabilities and offerings. Examples: How are FieldCore's personnel trained? What are HLC's capabilities? Can HLC train plant personnel in addition to GE/FieldCore personnel?

The first portion of the program, "The Training Center as a Competitive Advantage," (00:20) takes you through the facility, which is equipped with the latest tools and a 7FA engine and is staffed by instructors with field-engineering experience. Trainees are taught how to lift casings, remove/replace bolting, etc, using the actual tools they would have in the field.

Rob Randall, FieldCore's technical

training director, began his presentation (08:45) noting that GE invests $50 million annually in the training center and its programs. The mission: "First time right." The company's strategy is to build and maintain a multi-faceted, highly capable workforce (11:20), blending college graduates, experienced hires, and internal promotions into a cohesive field-service team.

Specialized training is developed and conducted for specific tasks to ensure field work meets expectations. One such program described by Jim Rosen (19:15), HLC training director, concerned how to change-out first-stage buckets in 7HA gas turbines to meet an urgent fleet need. Everyone who would be involved in this work gained the knowledge required hands-on at HLC.

There was a timeout for a short Covid Heroes clip on how Ben Gilder (23:50), attached to the West Region, worked with a local distillery to product hand sanitizer for field-service crews.

The next segment (25:12) discussed competencies and managing them. It focused on driving consistency in the workforce by defining expectations down to the task level. A robust system is in place to track progress and personnel capabilities. Expectation is this will contribute to optimal crew selection for specific assignments.

A live Q&A session (28:00) followed with Randall, Rosen, and FieldCore Technical Competency Director Stephen Simmons participating.

The final prepared remarks (30:55) concerned flexible, custom-tailored training solutions available to meet the total plant needs of owner/operators. Currently, the GE/FieldCore training "engine" delivers about 1800 courses annually to 7500 customers in more than 50 countries.

Delivering capability begins with an overview of FieldCore's "Covid-19 prevention field procedure" (00:50), a living document which continues to evolve based on experience. The final Covid Heroes segment of the day followed with Field Engineer Chad Locke (03:20) describing a sanitation upgrade—more specifically, a five-position bathroom trailer complete with hot running water.

FieldCore's John Millacci (05:50) then reviewed the value of the company's remote outage-support unit, a full-time global network of about three dozen experts at the ready to answer questions concerning O&M and other issues affecting customers. Field-service IT innovation was the next topic, valued for its fast ramp-up of knowledge and intellectual property required by field operations. Quality improvement was cited as one of the advantages of an interconnected workforce sharing information, contacts, best practices, etc.

"Maintaining competence," a goal of GE/FieldCore, is enabled by a program called HLC+ which provides connections with experts, next-level on-the-job training, and meaningful network connections.

The remainder of the Day Eight program focused on building expert crews by thoroughly evaluating the skills of candidate personnel, and the tools available to assure consistently high-quality outcomes. A crew assessment score was explained. It is a single risk score for each outage that combines individually weighted risk factors to ensure the best crew mix for the specific site and scope. A crew-score simulator is used to identify the best fit for the job based on technology, customer site, etc.

GE University I, Day 11, July 14

For many attendees, especially those with O&M responsibilities, the first day of the GE University program likely was the most valuable. It touched on a wide range of fleet concerns, offering guidance on how to deal with specific issues. Access the presentations on myDashboard for exposure to the following:

Compressor, Francesco Colombo, *compressor technical leader*

- 7F compressor risk management. Incorporates a must-have table that highlights some of the "risks"—such as S5 root cracking, S17 wear/migration—the units most susceptible (flared, unflared), whether hours- or starts-related, applicable TILs for details, and how to mitigate the risk.
- 7F flared enhanced compressor options. Presents the highlights of various 7F flared enhanced-compressor options for Packages 2, 2+, 3, 4, and 5, plus enhanced R0, enhanced S0-S5. The new Robust S5 replaces the Enhanced S5 as the go-forward standard configuration of ECP3 and higher. Guidance also is provided on how to mitigate corrosion pitting, reduce excess water ingestion, etc.
- Flared 7F stator Row 5 events. Explains increasing risk factors and recommended mitigations.
- 7F.05 VSV2 tip loss. Recommends inspection scope/interval (TIL-2167) and provides "what to do" ideas to mitigate tip rubs.
- 7F.05 T-fairing wear. High hours on turning gear identified as a key contributor. Recommends inspection scope/interval (TIL-2122). Low-speed turning-gear solution offered to alleviate the issue.
- Non-OEM pinned stator experience. Multiple field events said to confirm increased failure risk associated with pinned stator mods. GE recommends replacing non-OEM pinned stators with GE parts.

Turbine, Mike McDufford, *compressor and turbine fleet manager*

- 7F AGP/7F.05 fleet experience. No simple way to summarize the information presented. If you have a 7FA.05 the slides presented might prove valuable. Provides general overview of 7F AGP/7F.05 hot-gas-path hardware condition at the end of an interval and fleet experience to date thus far
- TIL-2045, 7F AGP S3B tip shroud creep. Same comment as above. Overview of TIL-2045 and recommendation to implement S3S cooling. The S3S cooling solution has completed validation testing with test results showing a temperature reduction of about 100 deg F possible with shroud cooling.
- TIL-2181, S1N creep degradation model. Update software to correct settings (T-fire) so parts do not run too hot for too long.
- 7F AGP S1N cover plate observations. Issue background, probable causes, containment and corrective actions given.
- TIL-2156, 7F 2SN repair experience. GE improving S2N durability with innovative technology.
- TIL-2006-R2, 7F.03 "post-repair" root cause analysis. Repair processing has improved; follow this TIL to mitigate running risk.

Combustion, Erin Brennan, *combustion fleet engineer*

- 7F DLN-2.6+ center fuel nozzle tip crack. RCA efforts are on-going; slide in presentation gives details.
- 7F DLN-2.6+ effusion plate crack. Upgraded effusion plate with TBC scheduled for field testing in Q4-2020.
- 7F XAA liquid fuel. System cleanliness critical to operational success; exercise XAA every six months at least.
- 7F DLN-2.6+ axial fuel staging.

Rotor, Matt Ferslew, *GT rotor principal engineer,* and Jorge Orlandini, *rotor technical leader*

- Rotor preservation PSIB (product service information bulletin). Valuable reference. One user learned that not properly laying up his rotor during an extended outage required a shop visit to correct issues that could have been avoided.
- F-class rotor inspections are critical for assuring long-term safe and reliable operation of your gas turbine. Early planning is important to success.
- Operational considerations and maintenance cost implications. Download a copy of GER-3620N for guidance. You can access with a simple Google search. Be sure the version you download is "N," published in October 2017. It has the latest equations for starts- and hours-based factoring. Be aware that operational factors can have significant impact on rotor-life inspection requirements and maintenance costs. A table presented is illuminating in this regard.
- Flat slot bottom and turbine-wheel inspection observations. Inspections completed to date have confirmed the OEM's recommendations in technical information letters. TIL-1971 units (F.01 and FA.01) are showing challenges to achieving 5000 factored fired starts, inspections required to determine true rotor capability. TIL-1972 capability depends on operational specifics and the actual initiation of any wheel cracks in FA.02/.03/upgraded FA.04 units.
- Rotor life-extension observations. Access the presentation and review the photos and drawings in the slides pertaining to this bullet point, and the one below. It's not possible to describe all the things you should be aware of in a few words.
- Recent/current rotor investigations.
- Rotor life management options. Critical to success is early planning—two years before a major that will be conducted between 96k and 144k factored fired hours or 2500 and 5000 factored fired starts.

GE University II, Day 12, July 15

Operability

- AutoTune evolution, Dave Boehmer. This presentation reviews terminology and associated documentation (GEK-121348, GEH-6740, etc). If you're not up to speed on MBC, ARES, and ETS, access these slides on myDashboard.
- AutoTune troubleshooting guidance, Dave Boehmer. Tips and awareness for avoiding runbacks, shutdowns, trips, and emissions excursions.
- Combustor operability, Stephanie Queen, *lead combustion fleet engineer*. Focus is on how to improve or navigate tight operating windows is provided by way of a couple of examples. Suggestions are offered on how to prepare for a successful remote tuning experience.
- Monitoring and diagnostics, Karen Miller. What GE's M&D Center in Atlanta does, how it operates, and what it tracks on your gas turbine are included in this presentation. It also provides examples of dynamics monitoring, exhaust thermocouple monitoring, performance-degradation analytic, impending-failure analytic, etc.

Accessories

- Gas fuel system reliability, Meg Lyman. Focus is on hydraulic oil varnish mitigation and the Parker servo-valve replacement option for Moog valves.
- Parts replacement lessons learned, Will McEntaggart, *consulting engineer*. Thinking of replacing that transmitter with a "smart" transmitter, or opting for third-party supplied thermocouples? Be sure you understand the risks regarding such things as temperature drift, response time, etc.
- Hazardous-gas system updates, Will McEntaggart, *consulting engineer*. Take the time to fully understand

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- Combined-Cycle Users
- Generators
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- Power Plant Controls
- Steam Turbines

"improvements" to the aspirated haz-gas system to avoid spurious trips.
- Compressor bleed valves, Will McEntaggart, *consulting engineer,* and Chelsea O'Connor. Focus is on software protection and several best practices to improve CBV reliability.
- Air inlet system, Chelsea O'Connor. Reviews reference documents for O&M of inlet-air filter compartments, evap coolers, inlet-air duct systems, etc. Plus, TIL-2173 recommendations for a successful silencer panel inspection.

Controls
- Static starter reliability, Randy Ortiz. Identifies startup issues traced to 89SS, 89ND, 89TS, and 89MD switches; reviews Rev 3 of TIL-1755; reviews TIL-2219 regarding the prevention of LS2100e trip and 52SS breaker opening with no trip fault; discusses documentation and recommended maintenance intervals for LS2100 and LS2100e.
- Excitation system, Randy Ortiz. Breaker inspection and maintenance update; collection of data for engineering or user analysis; troubleshooting EX/LCI with capture buffers.
- Controls protection rationalization, Chris Cooper. Rethinking protection to improve reliability.
- Obsolescence, Charlie Straka. Thoughts on being prepared to avoid unintended outage delays attributed to ageing control components.

GE University III, Day 13, July 16

GE/Baker Hughes overview for controls

A few important points gleaned from this short presentation by Rob Turner, *Mark VIe product manager:*
- GE and Baker Hughes have 20 years of history working together in oil-and-gas and power-generation applications.
- The Mark VIe is GE's controls platform for the future and Baker Hughes has access to that technology. GE remains the OEM for power generators and owns the Mark VIe technology, with Baker Hughes a strategic partner in this market sector.
- Baker Hughes continues to sell and service GE turbines in the oil-and-gas segment with Mark VIe control systems.
- GE account and service managers remain key paths for service and support for your units—including upgrades from legacy systems to Mark VIe technology, lifecycle planning for controls, post-installation services, etc.
- Notes of interest regarding control-system lifecycle status:
  - The Mark VIe is the only gas turbine/steam turbine/DCS controls platform in production. All previous platforms (Mark I, II, III, IV, V, and VI) have legacy status.
  - Regarding exciters for gas and steam turbines, the EX2100e is in production with the EX2100 having post-production status until 2021. Earlier excitation systems have legacy status.
  - As for starting systems, the LS2100e is in production with the LS2100 having post-production status until 2021. Earlier starting systems (Innovation LCI and DOM+) have legacy status.

Global repairs services
- Lean journey, Cameron Muhlenkamp, *lean leader.* A GE priority is to leverage lean to improve processes and eliminate waste. This presentation updates on actions taken and what's ahead.
- Repair technology update, Camilo Sampayo, *senior repair engineer.* As the 7FA fleet matures, new pressures and repair needs are being identified and addressed. Repair costs are increasing because parts are ageing and new damage modes are coming into view. Examples of the latter include bucket slashface wear, thin airfoils from multiple repairs, deterioration of base and weld alloys, etc. Solutions summarized are 7FA.04 S2N heavy repairs and 7FA.03 S1B slashface restoration.
- Quality update, Charles Wilpers, *senior quality manager.* A strategic focus for GE Gas Power is delivery world-class technology built on a foundation of quality, reliability, execution, and trust. A major focus this year is on improving GE's customer communications along with its issue-resolution process. This presentation updates on those focus areas and the company's quality roadmap.

Asset management
- Hot gas path, Louis Veltre, *7F product manager.* Several slides speak to optimal repair migration paths and strategies and likely are of considerable value to anyone responsible for gas-turbine O&M—particularly at the fleet level. One of the messages is to capture cost synergies with already planned repairs and to focus your spend on value adders—such as improved coatings, improved sealing, optimized cooling.
- Rotor life management, Louis Veltre, *7F product manager.* One of several presentations focusing on the rotor, this one discusses rotor maintenance strategies for increasing life potential and reviews end-of-life options—including repowering, upgrade, replacement, exchange, extend.
- Additional considerations, Louis Veltre, *7F product manager.* Improving operational safety with a safety shut-off valve, increasing reliability with an electric gas control valve, increasing turndown with an overboard bleed system, reducing ongoing O&M costs with a robust exhaust frame, increasing the reliability of the liquid-fuel system (if installed) with water flush and other enhancements, etc. CCJ

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EMISSIONS CONTROL

Ammonia oxidation in simple-cycle SCRs can cause understatement of catalyst activity

By **L Muzio** and **S Bogseth,** Fossil Energy Research Corp, and **Frederic Vitse**, GE Power Portfolio

Selective catalytic reduction (SCR) is widely used to reduce NO_x emissions from gas-turbine powerplants—both simple- and combined-cycle units. Once the catalyst is installed it is important to monitor its activity periodically. This involves removing a sample from the unit and testing for its activity in a laboratory. Test frequency can vary from yearly to every two to three years, depending on site-specific issues relating to potential catalyst poisons.

Protocols developed by Germany's VGB for testing SCR catalysts from coal-fired boilers are described in Refs 1 and 2. EPRI's Catalyst Testing Protocol, published in 2007, is explained in Ref 3. EPRI later (2015) released testing guidelines for SCR and CO catalysts used in gas-turbine powerplants (Ref 4).

This article discusses issues with testing SCR catalysts used in simple-cycle gas-turbine systems that are not addressed in the testing guidelines. The catalysts in simple-cycle units typically operate in a temperature range of 750F to 850F; more typically, 800F to 850F.

The guidelines in Ref 4 for testing gas-turbine SCR catalysts describe two ways to monitor catalyst life:

- Monitor the parameter "catalyst activity, K," over the life of the catalyst.
- Monitor the NO_x reduction achievable by the catalyst at the NH_3 slip limit—again over the life of the catalyst.

The authors focus here on measuring catalyst activity in the laboratory. Note that K varies with the chemical composition of the catalyst, its geometry (for example, mass transfer in the catalyst channels), and operating parameters (for example, temperature and area velocity). Area velocity (Av) is the ratio of flue-gas flow to the active catalyst surface area. Lower Av means more catalyst per unit of flue gas.

To determine catalyst activity, the NO_x reduction is measured across the catalyst and its activity is calculated from the equation:

[Eq 1] $K = -Av \ln(1 - \Delta NO_x)$,

where ΔNO_x is the measured NO_x reduction across the catalyst and Av is the area velocity, which depends on the area of the catalyst in the catalyst channels.

Laboratory test conditions typically are arranged to duplicate full-scale temperature and area velocity. The EPRI guidelines specify that the activity be determined at a NH_3/NO_x ratio of 1.2.

The challenge with simple-cycle SCR catalysts operating at relatively high temperatures (800F to 850F) is that reactions other than the basic SCR reaction can occur—as indicated by equations A to C below.

SCR reaction:

$NO + NH_3 + \frac{1}{4}O_2 \rightarrow N_2 + \frac{3}{2}H_2O$ [Eq A]

Parallel reactions:

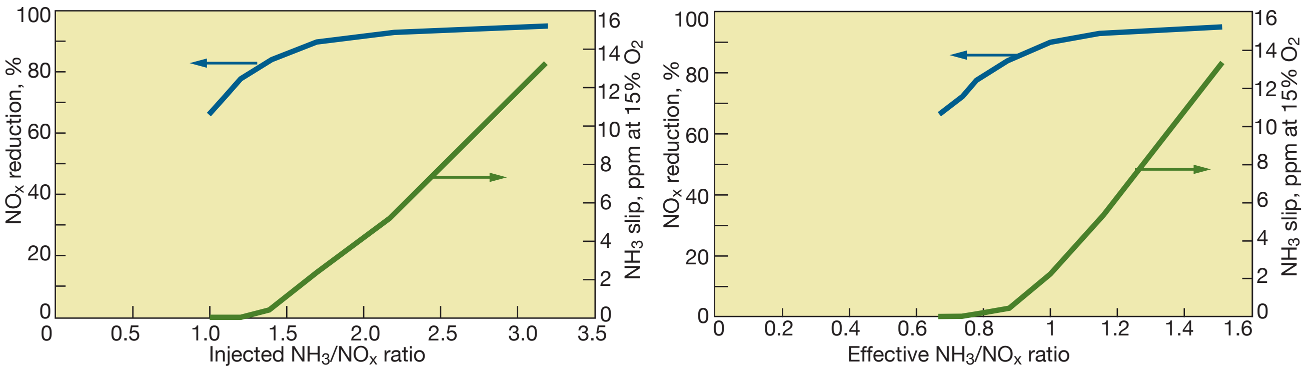
- Direct oxidation of NH_3 to N_2

  $NH_3 + \frac{3}{4}O_2 \rightarrow \frac{1}{2}N_2 + \frac{3}{2}H_2O$ [Eq B]
- Indirect oxidation

  $NH_3 + \frac{5}{4}O_2 \rightarrow NO + \frac{3}{2}H_2O$ [Eq C]

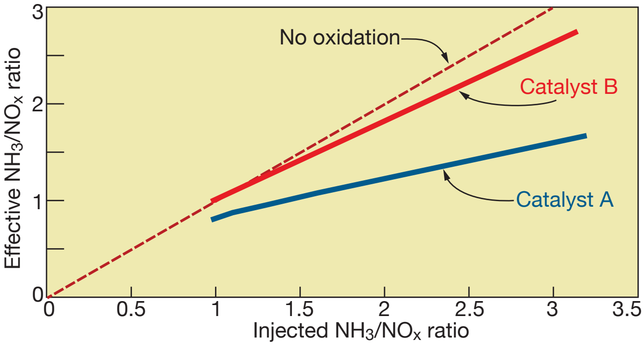
  $NO + NH_3 + \frac{1}{4}O_2 \rightarrow N_2 + \frac{3}{2}H_2O$ [Eq A]

These parallel oxidation reactions of ammonia essentially compete for the ammonia that is injected and used for SCR NO_x reduction. For instance, the EPRI GT SCR catalyst testing guidelines specify that an inlet NH_3/NO_x ratio of 1.2 be used to measure the activity. If ammonia oxidation reactions described by equations A to C are taking place in parallel, then the ammonia available for the SCR reaction (Eq A) is less than the NH_3/NO_x = 1.2 injected as specified in the guidelines. This will result in a lower NO_x reduction and an artificially low activity K. If not accounted for this can lead to a premature recommendation to change the catalyst.

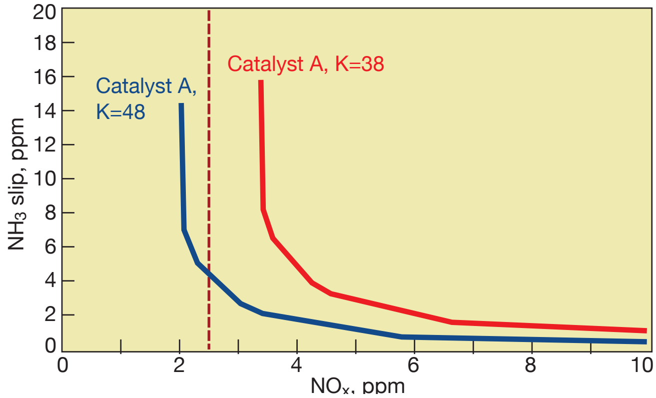


1, 2. NO_x reduction and ammonia slip are plotted against the injected NH3/NO_x ratio for Catalyst A at the left. The same catalyst data are replotted at the right against the effective NH_3/NO_x ratio





3. Ammonia oxidation is plotted against the amount of NH_3 injected



4. SCR performance shown here was calculated using catalyst activities presented in Table 1. Also, area velocity, 19 m/hr; velocity RMS, 15%; NH_3/NO_x RMS, 10%; NO_x inlet/outlet, 25/2.5 ppm

A second impact of these side reactions is that even if the required NO_x reduction can be achieved, the required reagent consumption can be higher than anticipated.

It is not the authors' purpose to discuss what catalyst formulations and properties promote these oxidation reactions. Rather, some typical examples presented below show the impacts of the oxidation reactions along with recommendations on how to deal with these issues during laboratory testing.

The following discussion focuses on laboratory tests of SCR Catalysts A and B. Fig 1 shows test results in terms of NO_x reduction and NH_3 slip as a function of the inlet NH_3/NO_x ratio for Catalyst A at 850F and an area velocity of 10.8 m/hr.

The following observations are noteworthy in this figure:

- NO_x reduction continues to increase markedly as the injected NH_3/NO_x ratio increases from 1.0 to 2. One normally expects this curve to flatten at NH_3/NO_x ratios just over 1.0 at laboratory conditions.
- At NH_3/NO_x ratios greater than 2, the NO_x reductions achievable are quite high.
- NH_3 slip does not start to increase until the NH_3/NO_x ratio approaches 1.5. Typically, one would expect the NH_3 slip to increase as the NH_3/NO_x ratio exceeds 1.0.

These characterizations point to the side reactions involving NH_3 oxidation competing with the basic SCR reaction. The magnitude of the oxidation reactions can be quantified by calculating the NH_3/NO_x ratio based on the measured NO_x reduction that is actually occurring, along with the measured NH_3 slip:

$$\text{[Eq 2]} \quad \left(NH_3/NO_x\right)_{effective} = \frac{\left(NO_{x_{in}} - NO_{x_{out}}\right) + NH_{3slip}}{NO_{x_{in}}}$$

The difference between the injected NH_3/NO_x ratio (NH_3/NO_x-in) and the "effective" NH_3/NO_x ratio (NH_3/NO_x-eff, Eq 2) is the amount of the injected NH_3 that was oxidized via the parallel reactions discussed above and not used for SCR NO_x reduction. To determine this effective NH_3/NO_x ratio, an accurate NH_3 slip measurement is required, along with the inlet and outlet NO_x concentrations during the laboratory tests.

To illustrate these oxidation reactions, the data in Fig 1 are replotted in Fig 2 using the (NH_3/NO_x)-eff ratio, as calculated from Eq 2, as the x-axis.

As can be seen in Fig 2, these trends appear more "as expected" for an SCR process:

- NO_x-reduction trend curve flattens as NH_3/NO_x-eff increases above 1.0.
- NH_3 slip begins to increase at $NH_3/NO_x > 1$.

For the performance data shown in Fig 1, if the SCR system must achieve 90% NO_x reduction, the actual injected NH_3/NO_x ratio required would be a nominal 1.7. By contrast, Fig 2 shows that the actual NH_3/NO_x ratio participating in the NO_x reduction need only be about 1.0 for 90% NO_x reduction—provided there was no NH_3 oxidation in parallel with the SCR reaction.

In terms of tracking catalyst activity and life using an inlet NH_3/NO_x ratio of 1.2 as specified in the testing guidelines, the catalyst activity would be calculated to be 16.3 m/hr. Using the effective $NH_3/NO_x = 1.2$ results in an activity of 29.7 m/hr—almost double. Clearly, unless oxidation is accounted for, management of Catalyst A is difficult using the current EPRI testing guidelines.

Not all catalysts exhibit the same degree of ammonia oxidation. An easy way to compare catalysts is to compare the relationship between the injected NH_3/NO_x ratio and the NH_3/NO_x-eff calculated from Eq 2. This comparison is shown in Fig 3 for Catalyst A and a second catalyst, Catalyst B, tested under similar conditions. Using a linear curve fit through the data shown in Fig 3 indicates that for Catalyst A, 48% of the injected ammonia at $NH_3/NO_x = 3$ is oxidized and does not participate in the SCR reactions.

For Catalyst B, the ammonia oxidation is less than 12% at $NH_3/NO_x = 3$. Also, the amount of oxidation increases as the amount of ammonia injected increases: At NH_3/NO_x-eff of 1.0, Catalyst A and B oxidize 20% and 0%, respectively.

Table 1 compares the activity K measured for Catalysts A and B if the measurements are done at either an inlet NH_3/NO_x ratio of 1.2 according to the testing guidelines, or at the effective NH_3/NO_x ratio defined in Eq 2. Note that Catalyst B exhibits little oxidation: There is little difference in the measured activity (76 versus 76.5 m/hr). However, for Catalyst A, which exhibits a higher level of ammonia oxidation, there is a large difference in the activities (38 versus 48 m/hr).

If the activity measurements shown in Table 1 are to be used to make performance predictions, there will be a large difference in these predictions for Catalyst A. Fig 4 shows the predicted performance for Catalyst A operating at an area velocity of 19 m/hr and inlet NO_x of 25 ppm with a velocity and NH_3/NO_x maldistribution of 15% RMS and 10% RMS, respectively.

If the SCR system must achieve 90% NO_x reduction, and the activity

Table 1: Activity (K) measurements for Catalysts A and B

	Catalyst B		Catalyst A	
Area velocity, m/hr	22	22	19	19
NO_x at catalyst inlet, ppm	25	25	25	25
Ammonia oxidation at NH_3/NO_x=1.2, %	2	2	18.5	18.5
Injected NH_3/NO_x ratio	1.2	1.22	1.2	1.76
Effective NH_3/NO_x ratio	1.18	1.2	0.98	1.2
NO_x reduction, %	96.8	96.9	86.5	92
Activity (K), m/hr	76	76.5	38	48

Table 2: Activity (K) measurements for Catalyst A at different sample lengths

Parameter	NH_3/NO_x=1.2 Bench scale*	NH_3/NO_x=1.2 Full length	NH_3/NO_x=1.4 Bench scale*	NH_3/NO_x=1.4 Full length
Temperature, F	850	850	850	850
Area velocity, m/hr	16.8	16.8	16.8	16.8
NO_x at catalyst inlet, ppmv at 15% O_2	25	25	25	25
NO_x at catalyst outlet, ppmv at 15% O_2	2.5	4.5	1.9	3.3
NH_3 oxidation, %	10.9	22.7	20.1	23.2
Injected NH_3/NO_x, mol/mol	1.16	1.2	1.41	1.39
Effective NH_3/NO_x, mol/mol	1.03	0.93	1.13	1.07
NO_x reduction, %	90.0	82.0	92.6	86.8
Catalyst activity (K), m/hr	38.7	28.8	43.7	34.0
Ammonia slip, ppmv at 15% O_2	3.35	2.7	5	5

*Approximately 30% of full-scale length

measurement was only made at NH_3/NO_x = 1.2 based on the inlet ratio, one might conclude that the catalyst is "beyond end-of-life." However, making the measurement at an "effective" NH_3/NO_x ratio of 1.2 (Eq 2), the catalyst can still achieve 90% NO_x reduction.

If activity measurements are to be made on these catalysts operating at high temperatures, you should consider how these activity measurements will be used.

Even if the catalyst activity measurements are being made to track relative activity (K/Ko) where the catalyst vendor has specified a K/Ko value at the "end-of-life," there can be issues. If the amount of ammonia oxidation changes as the catalyst ages, then the K/Ko parameter based on an activity measured using an inlet NH_3/NO_x ratio of 1.2 may also be in error.

Impact of catalyst size. When testing a catalyst for which the oxidation reactions of ammonia are not negligible, special care must be taken to understand the impact of catalyst length. Table 2 shows that, all other parameters remaining constant during lab tests, the catalyst length can substantially favor the overall kinetics of ammonia oxidation over the deNO_x reaction.

For NH_3/NO_x = 1.2, the longer catalyst sample resulted in an increase in the ammonia oxidation by more than a factor of 2. As a result, the NO_x reduction decreased from 90% to 82%. At the higher NH_3/NO_x ratio of 1.4, the ammonia oxidation increase was less, about 3%, but still reduced NO_x from 92.6% to 86.8%.

Therefore, if catalyst performance is to be validated by lab testing at reduced scale, particular attention should be given to the amount of ammonia oxidation observed at that scale. If the amount of ammonia oxidation is large, a performance test at full-scale catalyst length is recommended to capture a representative activity under field conditions.

Recommendations. For SCR catalysts operating at temperatures of 800F to 850F, oxidation of a portion of the injected ammonia must be addressed when characterizing catalyst performance in the laboratory. The current testing guidelines for gas turbine SCR catalysts are silent in terms of these parallel oxidation reactions at such high temperatures.

When laboratory catalyst tests are conducted, measure ammonia slip along with the inlet and outlet NO_x measurements. This will allow calculation of the effective NH_3/NO_x ratio (Eq 2), resulting in a more accurate determination of the actual catalyst activity as well as quantifying what fraction of the injected ammonia is oxidized and does not participate in the SCR NO_x reduction process.

As mentioned earlier, the gas-turbine SCR testing guidelines also describe a test where catalyst performance is tracked over time by measuring the NO_x reduction that can be achieved at the NH_3 slip limit with laboratory operating parameters matching full-scale operating parameters. While this procedure is not directly influenced by ammonia oxidation, it would be good if along with the NO_x reduction achievable at the NH_3 slip limit, the test results also include the inlet NH_3/NO_x ratio needed to yield the NH_3 slip limit. This would allow changes in ammonia oxidation to be monitored as the catalyst ages. CCJ

References

1. *"Guidelines for the Testing of deNO_x Catalysts,"* VGB-R 302 He, VGB Technical Association of Large Power Plant Operators, 1998.
2. *"Common Best Practices for Bench Scale Reactor Testing and Chemical Analysis of SCR deNO_x Catalyst,"* Supplement to VGB-R 302 He, 2nd Ed, STEAG GmbH, May 2006.
3. *"Protocol for Laboratory Testing of SCR Catalyst Samples,"* 1014256, 2nd Ed, EPRI, 2007.
4. *"Laboratory Testing Guidelines for Gas Turbine Selective Catalytic Reduction (SCR) and CO Catalysts,"* 3002006042, EPRI, 2015.

SAFETY

Working safely in a power plant with a medical implant

By James E Timperley, J E Timperley Consulting LLC

By some counts, over 300,000 electronic medical devices—such a pacemakers, defibrillators, cochlear, and neurostimulators—are implanted in Americans annually. Millions of these appliances are in service, covering all age groups in today's population. This means that perhaps 1% of all people entering a powerplant may have some kind of electronic medical device. Providing a safe working environment for these individuals is more important than ever.

Electrical interference can pose a serious problem: It can disable any of these electronic devices. This danger can be from high-voltage electric fields, as in a switchyard, or high magnetic fields near large generators, bus systems, and/or transformers. Plant personnel normally are protected against dangerously high voltages by secure fences or metal structures.

However, high magnetic fields are another matter. Signage warning to maintain a safe distance when a microwave oven is operating has been standard for decades. Similar signage is needed for protection of people working in generating stations—including staff, contractors, and visitors. But this is an often-overlooked precaution where high 60-Hz magnetic fields are present. Such signage could be similar to the high sound-level warnings in locations where double hearing protection is required.

There are several suppliers of medical appliances. The inherent sensitivity of these devices to high electric or magnetic fields varies widely, and how a doctor programs a specific device also influences it sensitivity to outside influences. Only a physician and the device manufacturer can provide specific guidance for maximum field safety limits for each appliance.

An internet search for work-related safety protocols provides little useful information about the industrial work environment. Online information discusses warnings about exposure for a variety of commercial products—such as metal detectors, cell phones, 2-way radios, portable generators, arc welding equipment, gasoline ignition systems, electric fences, and medical procedures. There is almost no information available on the strong power-frequency electric or magnetic fields present in powerplants.

Most modern generating stations have meal-clad electrical equipment. This greatly reduces external electric (E) fields. The magnetic (B or H) field also is reduced by the metal, but penetration of these enclosures by high magnetic fields still can be a problem. Electric current of 5000 amps or higher usually poses a risk, and most powerplants will have current of this magnitude on the main bus, the auxiliary bus, near the transformers, and/or near the switchgear. All these locations easily can have extremely high gauss readings.

Measurement of magnetic fields must be conducted in the specific plant and plant environment where a worker or visitor may be exposed (photos). Contractors are available to conduct such surveys, but they must be accompanied by plant staff with an understanding of the equipment. The load when readings are collected must be recorded. Preferably, the survey will be taken at or near maximum load. In general, a high reading is considered to be 1 gauss or more.

In sum, a magnetic-field survey of a plant is not difficult to perform. With accurate measurements, and proper interpretation, areas of high magnetic fields can be determined. These areas then can be properly posted with appropriate signage.

In order for everyone onsite to be properly informed, it is strongly recommended that the high electric and magnetic fields, and the posted signage, be a topic included in the safety meetings conducted for all plant visitors. These precautions may prevent a serious medical emergency to personnel served by any of these medical devices. CCJ

Isolated phase bus—21 kV, 8k amps

2870-hp motor, 13.8 kV, 100 amps

480-V switchgear—150 amps one side; 200 amps other side

Inspection, maintenance priorities for ageing HRSGs

By David Benjamin, Contributing Editor

Editor's note: The traditional annual conferences of all user groups serving the gas-turbine sector of the US electric-power industry scheduled between Mar 1, 2020 and Dec 31 have been canceled because of the Covid-19 pandemic. The 30th anniversary meeting of the Western Turbine Users (slated for March 29 to April 1 at the Long Beach Convention Center) was one of the organizations so affected.

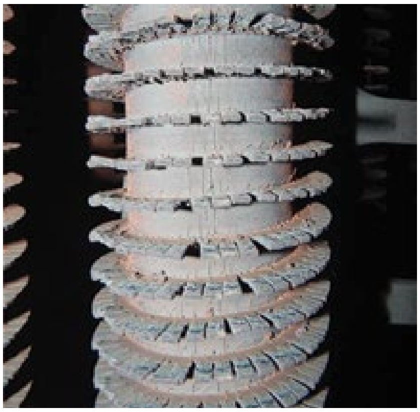
Ned Congdon, PE, of HRST Inc, who was scheduled to speak in the Special Technical Presentations session on March 31, shared his talking points on problems to anticipate with ageing HRSGs with David Benjamin, an aero user, who developed the article that follows from those notes.

Many heat-recovery steam generators (HRSGs) were installed during the combined-cycle boom of 2000 to 2005, putting them roughly halfway through their 30-yr design lifetimes. While the majority of boilers experience some form of tube distress by this point, there is much that can be done to bolster their health. With good operations and maintenance informed by experienced judgment, typical design lives can be extended appreciably. It is crucial to know what to look for, and when to take corrective action. Informed forethought can help avoid costly repairs requiring extended forced outages.

Congdon highlighted the following points in his presentation, among others:

- Duct-burner flame management.
- Internal oxide deposits on superheater and reheater tubes.
- Duct-burner liner replacements.
- Creep-damage assessment of piping for superheated steam.
- Return-bend economizer failures.

The HRSG expert discussed the ways in which careful duct-burner flame management is essential for maintaining the health of an ageing boiler. Many simple operational parameters are commonly overlooked, and can contribute significantly to the likelihood of tube failures. It is crucial to maintain proper flame shape, to ensure a uniform vertical distribution of flue-gas, and to prevent flames from overextending and impinging on downstream tube panels.



1. Upper-level tube damage attributed to an elongated duct-burner flame

For HRSGs with supplementary firing, the highest tube-metal temperatures and heat fluxes typically occur on the tube banks immediately downstream of the duct burners. Tube-overheating failures typically occur in this area. Sometimes, finless screen tubes with reduced heat-transfer characteristics are placed in front of the primary superheater/reheater surface to take brunt of the heat flux. In that case, the risk of a tube overheating is highest for the superheat/reheater surface immediately downstream of the screen tubes.

Duct-burner flames should be checked by operators during rounds. When looking through a viewport, a good rule-of-thumb is that the flame should extend no more than half to two-thirds of the length of the firing duct. Flames should be independent of each other, and should be completely horizontal. It is important all flames be of uniform length; higher elevation flames may be longer, which signifies non-uniform gas flow. The visible portion of the flame should end no closer than 6 ft from the first tube panel. Be sure flames never contact the tubes! Tube damage resulting from an elongated upper-level duct burner flame can be seen in Fig 1.

A good 21st century alternative to viewports is a set of duct-burner cameras. They may be mounted on the floor, roof, or walls of the firing duct and send a wireless signal to a DAQ device connected to the plant's main control system. Cameras require purge air for cooling. Because the cameras are monitored from the control room, they can help identify early signs of burner trouble while avoiding the hazards and inconsistencies of frequent (or infrequent) viewport use. Fig 2 shows a recently installed duct-burner camera.

2. Camera was retrofitted to help identify early signs of duct-burner trouble

Flow control. Congdon noted that users often will be forced to repair perforated flow-distribution plates in the hot gas path, and may chose not to replace them because of the high frequency of their decay. While it may be possible to remove perforated plates without going out of emissions compliance, insidious maintenance issues can develop.

The most frequently observed problem resulting from removing perforated plates from the gas path is bad flame shape—local back-eddies are a particular issue that damages liner and burner components. Another issue associated with perforated-plate removal is excessive flame length in the upper portion of the duct. This can lead to non-uniform tube metal temperatures, overheating of the tubes at high elevations, and, ultimately, tube failures.

Flow-distribution plates slow down the gas velocity in the lower portion of the firing duct where turbine outlet pressure is highest. Without the perforated plates in place, the exhaust flow profile would naturally favor the lower portion of the firing duct, and higher elevations would have significantly less exhaust gas flow.

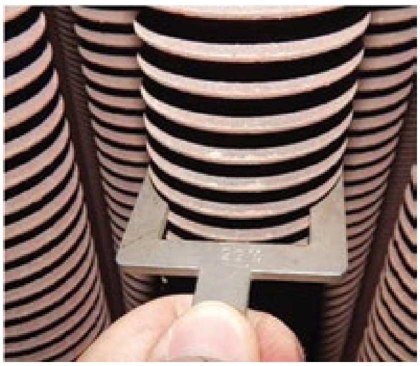
With reduced gas flow, mixing is diminished. The stoichiometry becomes offset, since burner elements put out uniform quantities of fuel, but the quantity of air is suppressed at higher elevations. Even though the flow velocity is lower, the flame takes much longer to consume the fuel, resulting in an extended flame length. This is often referred to as a "long lazy flame."

Thus, it generally is not a good idea to remove perforated plates from the gas flow path. The result is often slowly forming damage to the higher portions of the tube panels, where inspections tend to be less common. Such tube damage often goes unnoticed until a full-on leak demands a forced outage. A drone inspection can aid O&M teams to pinpoint upper-level tube damage in boilers where an uneven gas flow profile is suspected.

Internal deposits. Congdon discussed several problems associated with the growth of oxides along the inside walls of superheater and reheater tubes made of steels containing chromium. In small quantities, oxides protect the tubes from corrosion. However, too much internal oxide growth, or an uneven distribution profile, can insulate sections of tubes, creating temperature imbalances that can cause creep damage and ultimately lead to failure.

Many chromium steel alloys have been used in the manufacture of superheater and reheater tubes. High-chrome alloys, such as T91, generally produce less oxide growth, but also tend to be more expensive. Many ageing boilers were fabricated with lower chromium-containing alloys, such as T11 and T22, and are highly prone to oxide growth over time. Superheater and reheater panels with high heat flux are especially vulnerable to damage from internal oxide growth, because tubes in these sections generally were not designed with a high margin for wall thickness or deviation in temperature gradients.

3. Superheater tube is prepped for ultrasonic NDE



4. OD of superheater tube is measured for swell

Internal oxide growth along a superheater or reheater tube can result in tube swelling over an extended period of time, and may eventually lead to a complete rupture. The oxide layer insulates the internal surface of the tube, adding an additional thermal resistance to the heat-transfer path between the flue gas and the steam. This causes the tube metal to reach thermal equilibrium at a higher temperature, overheating the metal.

With added thermal resistance from an excessive internal oxide layer, the operating temperature of the tube metal goes up. The tube wall then becomes slightly more plastic, and the tube slowly begins to yield to the hoop stress generated by the steam. Over time, the tube will swell as the tube metal starts to yield as creep.

Aside from reducing burner heat release, there is little that can be done to reduce internal oxide growth in low-chromium-content steel alloy tubes. Superheater and reheater tube panels with high heat flux should be inspected regularly during the latter half of the boiler's design life. Internal oxide growth can be qualitatively assessed by borescope inspection, and can be quantitatively measured using NDE techniques. Fig 3 shows a superheater tube being prepped for an ultrasonic NDE.

If excessive oxide growth is suspected, it's a good idea to measure tube ODs at strategic locations to get an idea of how much swelling has taken place. Swollen tubes must be replaced; they generally cannot be saved. If the OD has swollen by 3% or more, HRST recommends derating the burner until the tubes can be replaced.

A quantitative engineering analysis is required to determine by what percentage the burners must be derated to preserve the lifespan of the tubes to the next available outage. It is generally good practice to be proactive in identifying and replacing swollen tubes before they rupture. Fig 4 shows a superheater tube's OD being measured for signs of swelling.

High levels of internal oxides also can result in the liberation of oxide flakes and particulates into the steam. This can be erosive to steam turbine blading. If excessive oxide growth is suspected, consider installing a duplex strainer before the steam-turbine inlet, if there is not already one in place. This can prevent erosion damage to the first few stages of blading from liberated oxides.

Firing ducts. Congdon discussed failures of stainless-steel liner panels typical of older boiler designs. Type-309 stainless steel often was used to line firing ducts in boilers installed 15 or more years ago. Type 309 has good oxidation resistance, but tends to warp in high-temperature environments.

5. Failed return-bend economizer tube is at left, an active leak at right

Many users find themselves having to repeatedly reline boiler walls around the duct burner during maintenance outages. Some users who had encountered this problem found success in retrofitting the lining with ceramic-fiber modules. While there is a high one-time cost incurred by this, it reduces the frequent need to reline the firing ducts. A cost-benefit analysis may favor this decision in the long-run, while it may also increase reliability and reduce downtime.

Steam-line creep. In ageing plants, it can be helpful to investigate the health of high-temperature steam lines with regard to creep damage. The potential for creep damage can be analyzed remotely using process modeling software to determine the most likely weak spots in the pipes. The analysis can then be assimilated into a site-specific test program to strategically focus the NDE on the most probable locations for damage.

Return-bend economizers. Congdon discussed the commonly encountered failure of return-bend economizers resulting from tube-to-tube temperature differentials with a top-supported structural design. Ageing return-bend economizers often are prone to failures at the bends. Temperature differentials may develop between economizer tubes during transient startup periods, causing uneven thermal expansion of the tubes. Return-bend economizers usually are top-supported at the inside of the tube bends by a support beam.

Tubes at high temperatures will elongate and no longer support the load of the economizer. Thus, the mechanical load concentrates on the cooler tubes, causing an off-design distribution of weight. The result is a higher concentration of stress at the bends of the cooler tubes, which can lead to cyclic stress, fatigue, corrosion fatigue, and stress corrosion cracking failures. Fig 5 shows a failed return-bend economizer tube at the left, an active leak at the right.

Temperature differentials occur naturally during startup in return-bend economizers where cold water flows into the top of the top-supported header. These conditions may be exacerbated by air pockets in the bends, which are not vented easily. Operationally, maintaining a small but steady water flow through the economizer during startup can help smooth out the temperature differences.

A good long-term maintenance solution is to retrofit a support system that isn't prone to transient differential stress loading. HRST developed a support system design for return-bend economizers that can redistribute the stresses to the bottom of the unit. Supports can be retrofitted to eliminate the support rods in favor of a bottom-supported design with spring isolators to help buffer transient deformations. This design prevents high stresses at upper tube bends, eliminating the risk of failure in those locations. CCJ

TURBINE TIPS, No. 7 in a series

Benefits accrue from observing startup, operational, shutdown sequences

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

Turbine Tip No. 7 from the PAL solutions library applies to General Electric Frame 5, Frame 6, and early Frame 7 gas turbines equipped with Mark V control systems.

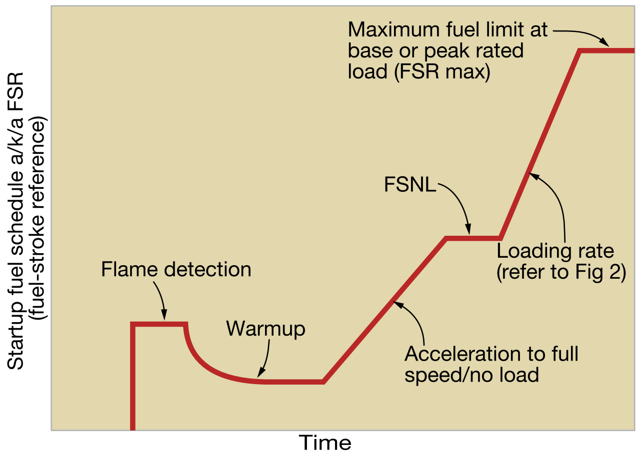
It is common for plant O&M personnel to focus their attention on the gas turbine during engine startup, operation, and loading. Fig 1 charts a variable called fuel stroke reference (**FSR**) from initiation of the start signal up to baseload for continuous gas-turbine operation.

It was developed from a family of algorithms embedded in the Speedtronic™ Mark V control system that program fuel flow during firing, acceleration to full speed/no load (FSNL), and ramp to baseload. GE control-system design addresses the OEM's concerns about over-firing during startup, as well as about the rate of temperature rise and shaft acceleration.

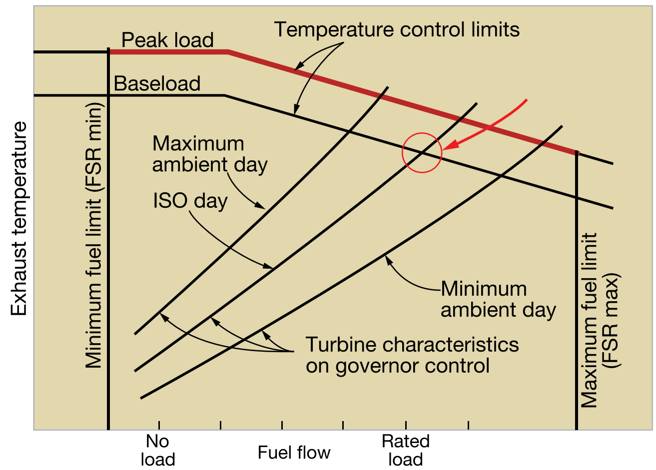
Note that it is possible to control fuel flow to less than the values illustrated should turbine exhaust temperature or shaft acceleration become excessive during startup.

The loading process from FSNL to baseload or peak power follows the demand for fuel flow according to the three curves shown in Fig 2. Since the unit is synched to the grid, speed (engine and fuel pump) has been eliminated from the algorithm used to draw this portion of the Fig 1 chart.

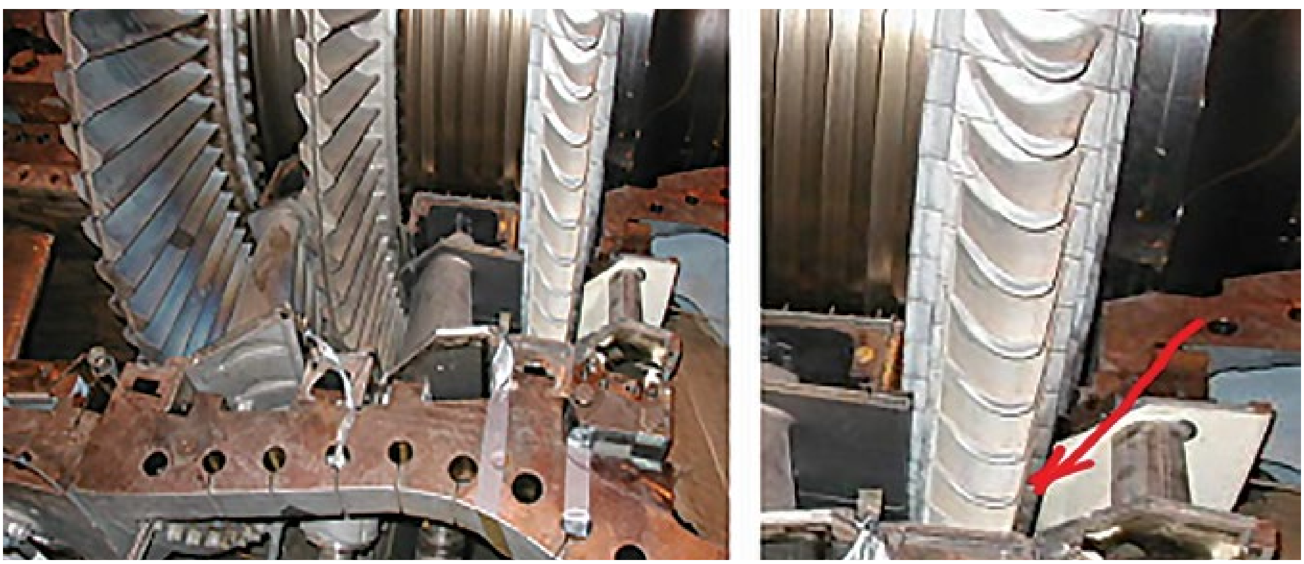
For simplicity, only three sloped lines are presented in Fig 2. The one



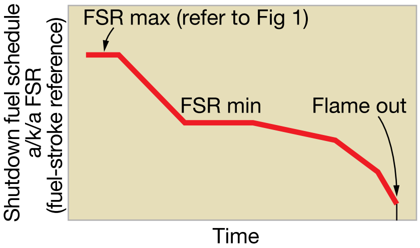
1. Starting profile for a typical legacy Frame 5 or 6 gas turbine equipped with a Mark V control system



2. Typical loading profiles for gas turbines on days of high, low, and ISO ambient temperatures



3. Turbine section of a Frame 6 illustrates three-stage arrangement (left). Arrow in photo of first stage at right points to where firing temperature is calculated (not measured)



4. Coastdown profile for a typical legacy Frame 5 or 6 gas turbine equipped with a Mark V control system

to follow depends on compressor inlet temperature (**T-amb**) and the subsequent level of compressor discharge pressure—called **CPD** in today's Speedtronic nomenclature.

Keeping the turbine under proper control by the Speedtronic system always has been of paramount importance to GE. Setting of fuel limits for fired operation is part of this and dates back to the 1950s when the Young & Franklin fuel regulator was the control device of choice.

Notice that the ambient-temperature curves in Fig 2 extend to different exhaust temperatures. However, all of these end points represent the same turbine firing temperature limit—say 2000F. In some documents, this is called turbine inlet temperature (**TIT**), calculated at the trailing edge of the first-stage turbine nozzle. The starting points (100% speed) take different amounts of fuel because changes in the density of ambient air affect the **CPD** value.

The gas-turbine controls are designed to determine, and to limit, turbine firing temperature **Tf** in the space just upstream of the first-stage buckets (at right in Fig 3); the three-stage turbine section is at the left. Note that **Tf** is not measured but rather a calculated value using thermodynamic equations incorporating **CPD, Txa,** and constants like the specific-heat values.

Seldom do operators pay attention to the gas turbine during shutdown processes, which can be revealing as to the general health and condition of the machine. The condition of bearings and seals, alignment, and compressor-blade clearances often is unknown. Many plant operators seem only to wait for the turbine to go on ratchet (or turning gear) for cooldown, before departing the site. Scant attention is payed to such things as these:

- Shutdown time. GE does not want to extinguish fuel flow immediately after the main generator breaker (**52G**) opens during shutdown, but rather reduce fuel flow gradually to avoid quenching the combustion and hot-gas-path components. Operators should pay close attention to the presence of flame as the unit goes from 100% to 80% speed. This takes about two minutes from circuit-breaker opening.
- During spin down, the time to reach rotor rest after flame is extinguished, operators should remain observant. For example, attention should be directed to the time it takes for the rotor to spin freely to rest. If the shaft comes to rest too quickly, it may be indicative of tight or worn bearings, seal rubs, or misalignment of internal components. Also possible on a Frame 5 or 6B: Improper alignment of the load device with respect to the gas turbine.
- Emergency lube-oil pump (**88QE**) start. Does the pump turn on to assure oil flow all the way down to rotor rest? This is necessary because the main oil pump, gear-driven off the engine rotor, does not deliver sufficient oil at the proper pressure to help cool down the bearings and protect the Babbitt metal against wiping.

  The emergency lube-oil pump generally has AC and DC motor drivers on the same shaft. When shaft speed drops below about 1000 rpm, the motor-driven pump takes over to provide ample cooling lubricating oil. If AC power is lost, the battery-powered DC motor is activated.
- On Frame 5 and 6B gas turbines, operators should visually confirm that the ratchet cycle has started and that the rotor is actually turning with partial strokes. For Frame 7s, operators should confirm turning-gear start and a slow rolling of the shaft. **CCJ**

Hydrogen: A quick reality check

Editor's note: What follows is a short report from the United States Energy Assn's (USEA) webinar, "The Role of Hydrogen and Renewable Gas in Decarbonization," June 12, 2020, moderated by Llewellyn King, executive producer and host, White House Chronicle. Panelists from Guidehouse, which acquired Navigant Consulting Inc in October 2019, were Mark Eisenhower, partner, Energy, Energy Sustainability & Infrastructure, and Daan Peters, director, Utilities & Energy Companies.

If you are struggling to make sense of all the information coming at you about hydrogen (H_2) as the fuel of the future, be content in knowing that color coding has come to the rescue. Grey H_2 is what is typically available today, a byproduct of petrochemical and other industrial processes. Blue H_2 is grey H_2 with the CO_2 captured, stored, and or reused. Green H_2 is that produced in splitting water by electrolysis using non-carbon generated electricity, primarily solar and wind but also nuclear.

According to the Guidehouse consultants, H_2-enriched natural gas can be transported and distributed in the existing and extensive natural gas pipeline systems around the world. However, some modifications will be required, especially to valving and compressor stations. H_2 requires three to five times the compression energy as natural gas. H_2 is also far lighter than natural gas, making it more susceptible to leakage from all flanges, joints, and connector components. Existing pipelines would have to be "cleaned" if they were to transport 100% H_2.

Other work around the world has shown that existing gas turbines can burn mixtures of H_2 and natural gas, again with some modifications.

But H_2 is not going to make a dent in the electricity industry's energy source mix unless (1) natural-gas prices rise substantially, (2) the value of carbon rises substantially, (3) governments enact mandates for the use of H_2 or otherwise act to elevate the value of carbon, (4) electric and gas industries make substantial investments in H_2 infrastructure, and/or (5) green H_2 production costs decline substantially (for example, if renewable electricity costs continue to decline).

Guidehouse noted that Europe is making a bigger and faster push to H_2 than the US. Developers and governments are "looking to build 180 GW of offshore wind and using at least part of this electricity for the electrolysis operations, Germany wants to ramp up H_2 production "very quickly," and Japan (heavily dependent on imported liquefied natural gas) seeks to bring large quantities of H_2 from Australia.

The Guidehouse participants also noted that most carbon capture and storage (CCS) projects have failed, although most were at coal plants. When asked how H_2 compared with use of grid-scale storage options—such as large batteries, compressed air energy storage, or pumped-storage hydroelectric—the panelists responded that H_2 may be better for "long-term, seasonal" storage. **CCJ**

Highview rolls out liquid-air-based system for long-duration storage

For gas-turbine-plant owner/operators, Highview Power Storage Inc's grid-scale storage system at least looks and acts like the kind of power system you're already familiar with. It's called CRYOBattery™, and is based on the compression and expansion of the most common fluid around—air.

Unlike lithium-ion and other solid-state batteries, some flow batteries, and flywheels, CRYOBattery is specifically designed for long-term storage, and is expected to compete with pumped-hydroelectric and proposed compressed-air energy-storage technologies. From that perspective, one of CRYOBattery's notable attributes is it does not introduce any technical risks that are *unfamiliar* to power and process systems engineers.

Dry air with no combustion drives the turbine/generator (figure). To reduce the size of vessels and pipes, the air is cryogenically cooled, compressed, and stored as a liquid in well-insulated tanks at temperatures approaching –320F, similar to what is done in large-scale air separation plants to produce oxygen and nitrogen gases at high volume.

According to Highview Power's CEO Javier Cavada, the system is designed for storage discharge durations from five to 20 hours and the typical initial plant sizes will be 50 MW, or assuming an eight-hour discharge, 400 MWh. Larger facilities will be built by duplicating this basic unit size.

The first of two most attractive "use cases" at this time is firming-up of wind and solar power. For example, Cavada believes his technology can compete with gas-fired combined cycles "chasing the wind." The other use case is providing grid ancillary services—such as spinning reserve, reactive power, voltage support, and others.

The technology was pilot-tested in the UK at a 5-MW/15-MWh facility integrated with an engine-based landfill-gas generating plant. Encore Renewable Energy, Burlington, Vt, and Highview announced in December that they are developing a minimum 50-MW/400-MWh facility to "resolve the longstanding electricity transmission challenges surrounding the state's Sheffield-Highgate Export Interface." A 50-MW/250-MWh facility is being built in the UK.

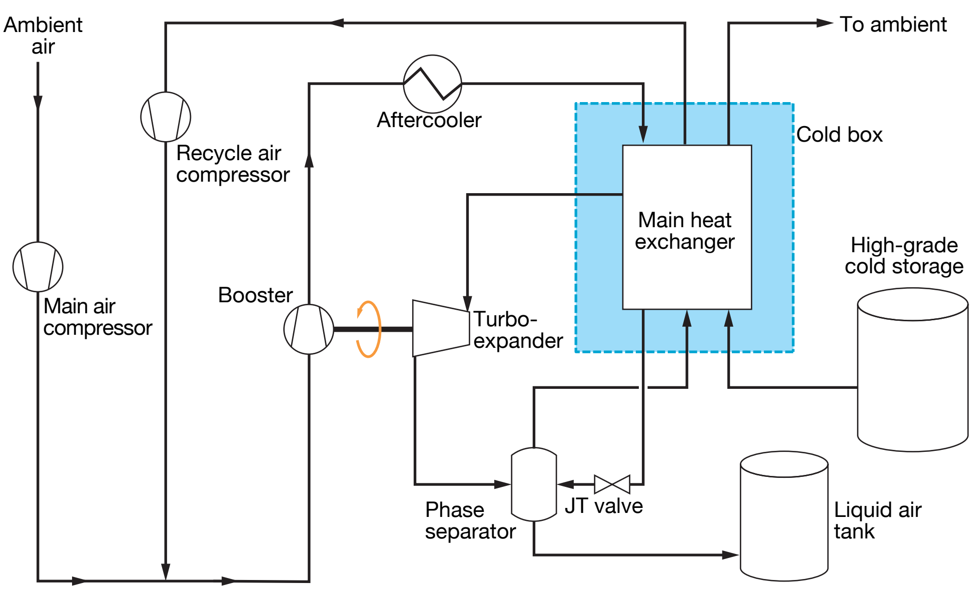
The proprietary elements of the technology, or "secret sauce," involves what Highview calls the "high-grade cold storage," which raises the round-trip, or overall charge/discharge, efficiency of the process. According to Cavada, Highview Power's IP "consists of a combination of process and cycle innovations as well as technical and operational knowhow, captured in our proprietary BLU controller."

CRYOBattery employs gravel-filled vessels (packed-bed columns in chemical engineering parlance) as the cold storage medium because it allows very high energy density, which is derived from the material's specific heat capacity and physical density. Gravel can also withstand thermal and hydrostatic stresses and is low-cost, as detailed in an article entitled "A New Contender for Energy Storage" published in The Royal Academy of Engineering's INGENIA quarterly.

Cavada puts the round-trip efficiency at 60% minimum but says the system can be designed for higher efficiency but that leads to a higher capital cost. Because CRYOBattery can make use of waste heat, it can also be considered, as other grid-scale technologies are, in hybrid plant designs. Covada said, "400F waste heat is good, 800F is great, although volumetric flow is as, if not more, important."

CRYOBattery plants require no water and "discharges air cleaner than it takes in for the process." One of the guiding principles of system designers has been to use only industrial grade, proven components.

Thus, if a CRYOBattery facility is being discussed for your area, fear not: They'll need people like you to run it. CCJ



Cold box and high-grade cold storage (gravel in packed-bed columns) represent the "secret sauce" in the CRYOBattery process, intended for long-duration, grid-scale storage. Source: The Royal Academy of Engineering's INGENIA quarterly, March 2019

New tools for locating pitting, wall loss, corrosion, cracking in headers, tubes, welds

By Steven C Stultz Consulting Editor

TesTex Inc specializes in electromagnetic non-destructive testing and has developed innovative methods and equipment for combined-cycle HRSG healthcare. Founded in 1987, the company, both multi-industry and global, maintains a focus on heat-recovery steam generators in the challenging combined-cycle world. Its primary mission is fast, accurate, and cost-effective NDT services using pioneering state-of-the-art equipment and expertise.

CCJ connected with TesTex at the *HRSG Forum with Bob Anderson*. Showcased at the 2018 meeting were proprietary Remote Field Electromagnetic Technique (RFET) equipment for detecting internal tube pitting and wall loss, and a proprietary Low Frequency Electromagnetic Technique (LFET) system to examine finned tubes from the gas side.

The goal of both is to locate and identify pitting, wall loss, caustic and phosphate gouging, corrosion attack including FAC, cracking, erosion, and manufacturing defects. Also on display was the Balanced Field Electromagnetic Technique (BFET), and a curious new contraption called "The Claw."

TesTex personnel collaborate with both EPRI and ASME to keep a sharp and expanding focus on HRSG challenges and common areas of concern. They take pride in the company's unique equipment and innovative application skills.

Variety and invention

This editor began professional life in the offshore oil and gas industry, intrigued by what that industry was doing deep in the Gulf of Mexico, and elsewhere. It seems TesTex has some similar roots, using robotic multichannel sensor arrays (LFET) and automated ultrasonic technology from its Houston office on the massive rigs and platforms with extensive arrays of heat exchangers and piping. Industries do learn from each other.

So when an Alaska pipeline had a containment incident resulting from internal pitting corrosion (a potential shock to the environmentally sensitive North Slope) the US Dept of Transportation put out an urgent call for creative fast-screening NDT. They needed a quick alternative to their primarily manual UT techniques.

TesTex LFET, along with company technicians and NDT engineers, became a critical part of this large-scale, critical and urgent remote-area inspection.

Closer to home, and to the power industry, TesTex developed and applied an ultra-high-speed eddy-current inspection system to a large condenser system, to keep it operating until the next scheduled outage. The condenser contained 18,000 tubes, 40 ft long, and the inspection was wrapped up within five days. Damaged tubes could then be plugged, enabling the owner/operator to get back online.

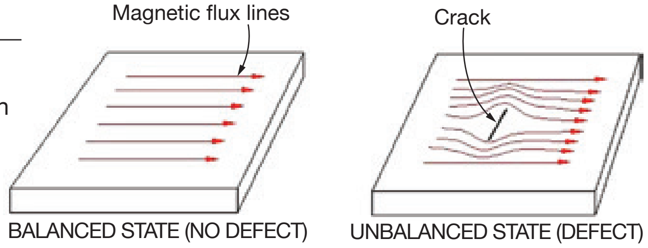
Balanced field for HRSGs

The TesTex BFET also has an interesting history, plus a recent development labeled "Mini-Claw."

"The technology was developed to enhance the signal responses produced from small defects, such as cracks, and specifically for tube-to-header weld issues in HRSGs," says Shawn Gowatski, manager of the company's Solution Providers Group.

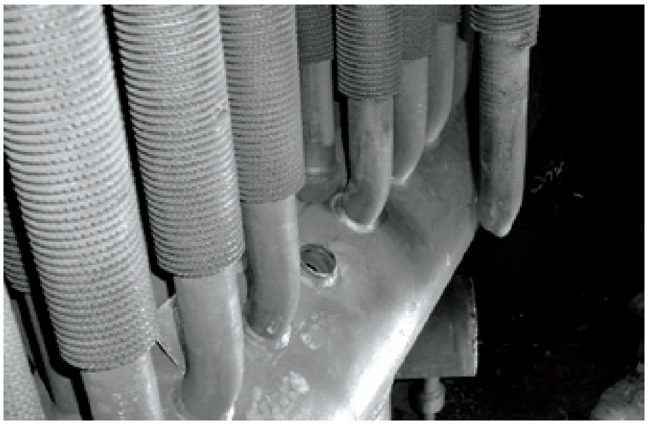
He tells us how it works: Briefly, electromagnetic coils are wound and placed in a balanced state, with the coils in both the x and y geometries at zero potential to each other. "With the excitation coil in the x geometry and the sensor coil in the y, a different signal is produced over defected areas," says Gowatski.

"The alternating current produced by the excitation coil is uniform and undisturbed if no defects are present. If there are defects, the current is interrupted and the current is forced to travel around them in distorted

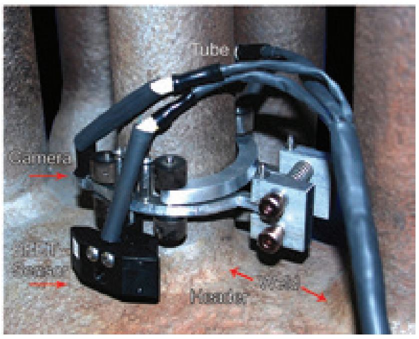


1. How flux lines react to a clean area (left) and when a crack is encountered (right)

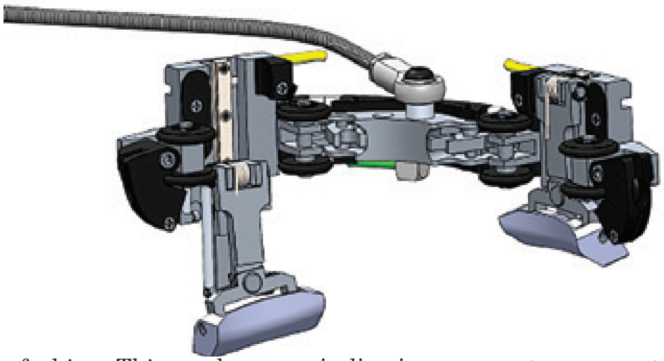
2. Hawkeye probes come in a variety of designs



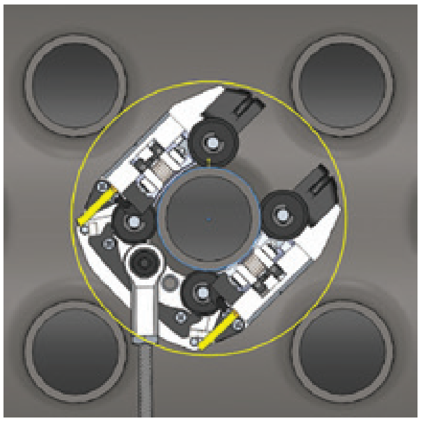
3. Tube-to-header weld failure in a heat-recovery steam generator (left)



4. Claw scanner positioned on a tube-to-header weld (right)



5. Mini-Claw with left sensor arm extended (left)



6. Mini-Claw attached to a 1.5-in.-diam tube with 1.25 in. of clearance between it and adjacent tubes (right)

fashion. This produces an *indication* that signals a defect, and this can be both detected and then quantified by applying proper calibration standards" (Fig 1).

BFET can test different types of metal by adjusting the test frequencies, which range from 100 to 30,000 Hz, and can test at speeds up to 1 ft/sec.

TesTex's initial use of BFET centered on two types of probes, Hawkeye and Hawkeye DP (deep penetrating). The Hawkeye probe can penetrate up to 0.250 in. into the surface, the Hawkeye DP up to 0.375 in. The probes, traditionally hand-held (Fig 2), are in wide and varied use today. Probe surfaces can be machined to match required geometries (for example, a specific radius for tube and pipe welds), and multiple probes can be rigged for large areas.

TesTex has used this technology to inspect deaerators, piping, tube stubs, drums, distillation columns, dryers, heat exchanger shells, and other pressure vessels. All data are viewed in real time and recorded.

360-deg BFET

A major issue for both ageing and newer HRSGs is tube-to-header cracking and potential failure (Fig 3), experienced largely through leaks at the tube-side toe of the weld. But this occurs in a very congested, tightly spaced environment. Traditional inspection methods, such as magnetic particle (MT) and others, can only reach the exposed 180 deg—at best.

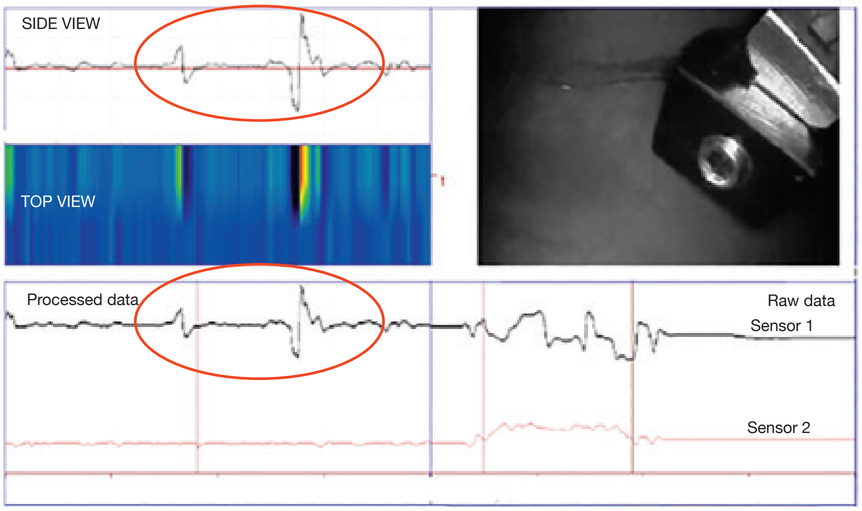
"It can be used anywhere an owner/operator suspects cracking within 0.25 in. of a surface," notes Gowatski. "High-pressure superheaters and reheaters are particularly vulnerable due to ongoing unit cycling."

TesTex developed the BFET, and in collaboration with EPRI, various tools for its application on HRSGs. One of these is the Claw (Fig 4).

With the Claw, BFET probes and cameras are placed on the welds using a C-clamp housing that attaches to the tube. Once attached, the assembly moves circumferentially around the weld examining for cracking, lack of fusion, porosity, and other defects. This technology detects surface cracks, as well as subsurface cracking within 0.250 in. of the surface.

A feature of the technology is that no surface preparation is required, and the inspection covers the entire 360 degrees of the weld. For most competing technologies, surface preparation can be difficult and time-consuming. Plus, radiography requires personnel evacuation from the area.

Says Gowatski, "Quality readings can be acquired through coatings such as paint, epoxy, and rubber. Uniform scale and rust do not present problems either. However, coal ash deposits, rough, uneven, or repaired welds, and pitted surfaces can present challenges. But they do not preclude successful use of BFET," he explains.



7. Waveform of a reheater tube reveals a strong indication as described in the text. Crack was located on the back side of the tube which prevented access for mag-particle inspection to confirm the finding

The BFET probes ride along the contour of the tube-to-header weld and cameras monitor and record the entire process. But the significant achievement is investigation of the entire circumference. Even when a second technology is used for verification, this is normally limited to the 180-deg exposed area, limited by accessibility.

Another feature is the ability to eliminate liftoff (and/or probe wobble) and noise from the signal. As Gowatski explains, "There are two components of the BFET signal that we view, Asin and Acos. To have a clean signal without noise, the angle that we view is rotated and changed to put most of the noise on the Acos signal. By doing this, any cracks or small inclusions are shown prominently in the Asin signal."

Claw technology is being used to detect fatigue cracking and other issues in headers with diameters from 4 to 14 in., and in tubes of 1.5, 1.75, 2.0, and 2.25 in. diameter.

Both the Claw and the new Mini-Claw (Fig 5) can check header welds on tubes with bends above or below the header. The latter is designed specifically for 1.5-in.-diam tubes and with extremely tight clearances between adjacent tubes—down to 1.25 in. (Fig 6). It has now been used successfully on multiple HRSGs.

Detect and record

With both the Claw and Mini-Claw, the balanced-field electromagnetic technique waveform is displayed in five different windows (Fig 7). The bottom right window shows the raw data, the bottom left the data processed. The two lines in the bottom two windows show the results from each sensor. The top line is from Sensor 1, the bottom line from Sensor 2.

The middle left window is a simulated C-scan, the top left window a zoomed-in view of the data from the second sensor. The top right window shows a capture using the on-board camera.

Turnaround

TesTex has become known for its innovation and quick turnaround without interfering with operations, based on an informal survey of users. The company's 200-plus person global network, headquartered in Pittsburgh, works primarily from US offices in Philadelphia, Houston, New Orleans, Atlanta, Bakersfield, and South Bend, as well as from locations in Canada, Trinidad, the United Kingdom, France, and India.

For more information, visit www.testex-ndt.com. CCJ

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

Aeroderivative Gas Turbine Support

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

AGTServices

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

American Chemical Technologies

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

AP+M

One of the largest worldwide independent stocking distributors of both heavy-duty and aeroderivative gas turbine parts. A reliable partner with an extensive inventory of more than 10,000 parts quickly delivers genuine OEM parts for operators, end-users, depots, and repair facilities.

ARNOLD Group

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

Bearings Plus Inc

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

Black Start LLC

Provides multi-discipline technicians for industrial start-up, commissioning, and outage field services. We are a veteran owned business, based in the Pacific Northwest, and proud supporters and alumni of Perry Technical Institute.

Braden

Global leader in the power generation industry for design, manufacture, installation and retrofit of auxiliary equipment for GTs and has established itself as the most experienced and trusted name in the design of auxiliary systems for GT power plants.

Bremco

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

C C Jensen Oil Maintenance

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

Caldwell Energy

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

Camfil

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

Catalytic Combustion Corp

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

Chanute Manufacturing

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

Crown Electric Engineering & Manufacturing

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

Cust-O-Fab Specialty Services

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

Cutsforth

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

DEKOMTE de Temple

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

Donaldson Company

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

ECT-Engine Cleaning Technologies

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

Environex Inc

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

Emerson Automation Solutions

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

EthosEnergy

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

Groome Industrial Service Group

Offers a variety of SCR and CO catalyst cleaning and maintenance services nationwide and has formed strategic alliances with industry experts and catalyst manufacturers to ensure that Groome offers the most widely supported, comprehensive, turnkey service available.

Hilliard

The HILCO® Division cost-effectively brings fluid-contamination problems under control and engineers a full-range of filters, cartridges, vessels, vent mist eliminators, transfer valves, reclaimers, coolant recyclers and systems, and membrane filtration systems.

Hydro

Engineered solutions enable combined-cycle plants to achieve pump reliability and reduced O&M costs. As the largest independent pump rebuilder, Hydro works hand-in-hand with pump users to optimize the performance and reliability of their pumping systems.

Hy-Pro Filtration

Provides innovative products, support, and solutions to solve hydraulic, lubrication, and diesel contamination problems. Company's global distribution and technical-support networks enable customers to get the most out of their diesel, hydraulic, and lube-oil assets. ISO 9001 certified.

IC Spares

Specializes in the supply of new, remanufactured, and repair services of GE Speedtronic turbine controls for GTs, STs, and drive controls with an extensive stock of new and remanufactured parts available for next day delivery and backed by 2-year warranty.

IOT Integration Services

Many years of experience in power generation building and deploying industrial networks and configuring control systems and plant data historians while ensuring network and security structures support the transfer of your information.

JASC

Engineers and manufactures actuators and fluid-control components for power generation, aerospace, defense, and research applications to improve operational capability and performance.

KnechtionRepair Tools

Manufactures tools designed to make thread repairs to both the female and male ends of cross-threaded compression fittings. In most cases, the repair will be accomplished without removing the tube from the system.

Kobelco Compressors America

Provides robust, high-efficiency fuel-gas compressors for use with all major types of gas turbines—including GE, Mitsubishi, Alstom, Siemens, Rolls-Royce, and Solar. Over 300 of the company's screw-type compressors have been supplied for gas turbines.

Lambda Technologies

Providing complete surface enhancement solutions and specializing in understanding, measurement and control of local residual stresses, Lambda is an established leader in materials testing and life extension technology. An integrated total solutions approach improves component life and performance.

Liburdi Turbine Services

Advanced repairs employ the latest technologies and are proven to extend the life of components for all engine types. Company specializes in high-reliability component repairs and upgrades for blades, vanes, nozzles, shrouds, combustors, and transitions.

Mechanical Dynamics & Analysis

One of the largest turbine/generator engineering and outage-services companies in the US. MD&A provides complete project management, overhaul, and reconditioning of heavy rotating equipment worldwide.

Mitten Manufacturing

Leading fluid system packager for numerous OEMs, EPC firms, utilities, and plant operators all over the world offering a number of value-added designs, spare parts management, and field services.

National Breaker Services

Industry leader in switchgear life optimization, life extension, and system upgrades. Manufactures new, highly customized low- and medium-voltage switchgear and provides on-site troubleshooting, maintenance, and testing of existing systems.

National Electric Coil

Leading independent manufacturer of high-voltage generator stator windings with expertise in design and manufacturing of stator windings for any size, make, or type of generator. This includes diamond coils, Roebel bars—including direct cooled, inner-gas, and inner-liquid cooled bars—and wave windings.

Nord-Lock Group

World leader in secure bolting solutions, strengthening industrial and public infrastructures with high-quality, safe, and innovative solutions. Products include wedge-locking washers, mechanical tensioners, hydraulic tensioners, and expander systems.

Parker Hannifin Gas Turbine Filtration

With over 50 years of experience delivering innovative solutions for GT inlet filtration and monitoring fleet-wide performance data, our industry and applications experts will select the appropriate filter for your site designed to meet specific operating goals.

Power and Industrial Services

P&I was founded in 1978 with the goal of providing improved replacement parts for the electric utility market. P&I offers a complete range of duct burner solutions from simple replacements to complete turnkey projects as well as a complete line of HRSG access door solutions.

Praxair Surface Technologies

Leading global supplier of surface-enhancing processes and materials, as well as an innovator in thermal spray, composite electroplating, diffusion, and high-performance slurry coatings processes. Company produces and applies metallic and ceramic coatings that protect critical metal components such as in gas turbines.

Proco Products

Global leader in the design and supply of expansion joints for piping/ducting systems. For over 30 years, Proco has manufactured the highest quality rubber and molded PTFE expansion joints, braided flexible hose assemblies, low torque sealing gaskets, and rubber check valves.

PSM

Full-service provider to gas-turbine equipped generating plants, offering technologically advanced aftermarket turbine components and performance upgrades, parts reconditioning, field services, and flexible Long Term Agreements (LTAs) to the worldwide power generation industry.

Rentech Boiler Systems

International provider of high-quality, engineered industrial boiler systems. Rentech is a market leader in providing HRSGs for cogeneration and CHP plants. It is in its second decade of designing and manufacturing high-quality custom boilers—including HRSGs, waste-heat boilers, fired packaged boilers, specialty boilers, and emissions control systems.

Sargent & Lundy

Provides complete engineering and design, project services, and energy business consulting for power projects and system-wide planning. The firm has been dedicated exclusively to serving electric power and energy-intensive clients for more than 120 years.

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.

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.

Umicore Catalyst

Our air pollution technology includes a series of unique catalysts for Selective Catalytic Reduction (SCR) systems for the control of nitrogen oxides (NO_x), and the reduction of carbon monoxide (CO) and volatile organic compounds (VOCs), from stationary and mobile sources.

ValvTechnologies

Global leader in the design and manufacturing of zero-leakage metal-seated ball valve solutions for severe service applications. Committed, dependable partner providing the best isolation solutions to ensure customer satisfaction, safety and reliability, and improved process and performance.

Vogt Power International

Supplies custom-designed HRSGs for GTs from 25 to 375 MW and has extensive experience in supplementary-fired units. Scope of supply includes SCR and CO systems, stack dampers, silencers, shrouds, and exhaust bypass systems.

Young & Franklin

Premier fuel control supplier for combustion turbines for both long-term hydraulic solutions and, more recently, innovative all-electric controls solutions. Product scope supports natural gas, liquid, syngas, and alternative fuels as well as providing air controls to provide proper fuel to air mixtures.

Zokman Products

Distributor of ZOK27 and ZOKmx gas-turbine compressor cleaning detergents. ZOK27 is a single cleaner and inhibitor in one that cleans and protects the engine—and also inhibits corrosion. ZOKmx is a power cleaner formulated to replace solvents providing exceptional cleaning without the health and environmental risks associated with solvents.


SIEMENS
Ingenuity for life
Benefits:
Increased Capacity
Fast Start / Fast Ramp
Extended Turndown
Grid Balancing Services
Spinning Reserve
Black Start Capability
Energy Arbitrage
100%
0%
0
100 sec
200 sec
Energy storage solutions to meet dynamic changing needs
Siemens Synergen battery solutions come with a large array of benefits. Depending on your specific needs, Synergen can help diversity revenue, increase plant flexibility, reduce costs, add plant capabilities and increased revenue generation possibilities. With the goal of decarbonizing the future, Synergen optimizes the use of renewable energy sources.
Which solution is right for you? Contact your Siemens Energy sales representative to find out more about the many available solutions to help you meet your decarbonization goals.
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