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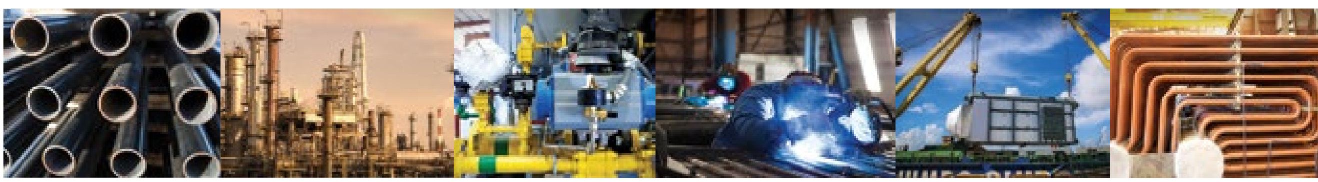

User-group meetings

2016

October 3-6, ACC Users Group, Eighth Annual Conference, Dallas, Tex, Westin Dallas Park Central. Details at www.acc-usersgroup.org as they become available. Registration/sponsorships contact: Sheila Vashi, sheila.vashi@sv-events.net. Speaker/program contact: Dr Andrew Howell, chairman, andy.howell@xcelenergy.com.

November 1-3, 7EA Users Group, Annual Conference and Exhibition, Hershey, Pa, The Lodge. Chairman: Jason Hampton, jason.hampton@ethosenergygroup.com. Details/registration at http://ge7ea.users-groups.com.

November 15-17, Australasian HRSG Users Group, 2016 Annual Conference, Sydney, Australia, Rydges Sydney Central. Visit conference website for details: www.etouches.com/ehome/ahug2016. Chairman: Dr R Barry Dooley, bdooley@structint.com. Conference secretary: Rachel Washington, rachel@meccaconcepts.com.au.

2017

February 19-23, 501F Users Group, Annual Meeting, Reno, Nev, Peppermill Resort Spa. Chairman: Russ Snyder, russ.snyder@cleco.com. Details/registration at http://501f.users-groups.com when available. Contact: Tammy Faust, meeting coordinator, tammy@somp.co.

February 28-March 2, HRSG Forum with Bob Anderson, First Annual Meeting, Charlotte, NC, EPRI Campus. Details/registration at www.HRSGforum.com when available. Contact: Alan Morris, amorris@morrismarketinginc.com, 516-869-0220.

March 19-22, Western Turbine Users Inc, Las Vegas, Nev, South Point Hotel & Casino. Chairman: Chuck Casey, ccasey@riversideca.gov. Details/registration at www.wtui.com when available. Contact: Charlene Raaker, raaker.charlene@prodigy.net.

April 23-27, CTOTF™ Spring Conference & Trade Show, Orlando, Fla, DoubleTree by Hilton Hotel at the Entrance to Universal Orlando. Chairman: Jack Borsch, jborsch@lakeworth.org. Details/registration at www.ctotf.org when available. Contact: Ivy Suter, ivysuter@gmail.com.

May 15-19, 7F Users Group, 2017 Conference & Vendor Fair, San Antonio, Tex, La Cantera Hill Country Resort and Spa. Chairman: Clift Pompee, clift.pompee@duke-energy.com. Details/registration at www.powerusers.org when available. Contact: Sheila Vashi at sheila.vashi@sv-events.net.

An industry in transition

Jason Makansi, president of consultancy Pearl Street, Tucson, Ariz, often is retained by CCJ to advise on industry trends and technology developments/deployments—including their business, financial, regulatory, and environmental impacts. He rarely is off-base. Most recently we asked Makansi to paint a picture of the industry today, to help guide editorial planning for the Outage Handbook you just received. Here's what he told our editorial team:

The power industry is undergoing gut-wrenching transformation. Economic growth has been tepid at best; therefore, electricity demand has been weak or negative. Coal is receding. Nuclear is threatened. Baseload generation is undervalued. Gas is as inexpensive as it's been in recent memory. And the forward price curve probably hasn't been this favorable over your entire career. Environmental restrictions are like throwing more proverbial straw on the camel's back. After being a topic of discussion for a decade, the "brain drain" has become hard reality. Variable renewable generation wins in political mindshare.

Grid participation is dynamic—rattled minute-to-minute by intermittent wind and solar; ancillary services, balancing, and day-ahead markets; baseload unit retirements, and many other factors. Some gas-fired combined cycles have had more than five owner names on the shingle over the last 10 to 15 years. Peaking gas turbines are running in intermediate load. Intermediate load units are running baseload. Some supercritical coal units cycle from min to max load every hour to fill in around renewables.

And in the shadow of all of these clearly visible trends is the most potent market driver of all— value and opportunity are moving downstream, away from large power generation facilities and long transmission lines and towards the distribution end of the grid. Distributed energy, microgrids, off-grid/on-site systems, net metering, behind the meter, local electricity storage, rooftop PV, and even fuel cell appliances all are vying for a share of what some call the "transactional" grid.

Want to dig deeper? Watch this column for an announcement about CCJ's upcoming power-industry marketing seminar, featuring Makansi as the discussion leader. Better yet, write Bob Schwieger, editor, today at bob@ccj-online.com to be sure you're first in line to receive the news. Seating will be limited.

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Mining data to identify problems, improve performance takes perseverance, know-how

The editors corralled Bob Anderson, principal, Competitive Power Resources, Palmetto, Fla, shortly after he concluded a planning meeting for the first "HRSG Forum with Bob Anderson," Feb 28-Mar 1 and 2, 2017, to ask how he approaches problem diagnosis using data from the plant historian.

Anderson, a former plant manager and HRSG troubleshooter for a large utility's F-class fleet, said the value of captured data for performance and problem assessments can't be overstated. He shows by example, below, that one data plot can tell several stories and suggest multiple corrective actions.

Anderson stressed that while the conclusions derived from the exercise described may look simple to identify, the process of getting there requires the ability to combine a high level of plant/process operating experience with a high level of knowledge on the reaction of plant components, materials, and systems to various stimuli.

Furthermore, he continued, correct conclusions require the willingness and ability to always question your findings objectively. This requires the time to think about what data might "shoot down" your preliminary conclusion, then collect, re-plot, and review those data as many times as it takes to accept your findings without question.

Anderson added, "The experience, discipline, and time required to conduct such self-questioning is critical to a quality result. Mike Pearson, an Ontario-based consultant and master of this analytical approach, was my demanding mentor."

HRSG FORUM WITH BOB ANDERSON
Feb 28 - Mar 2, 2017
EPRI Campus, Charlotte, NC

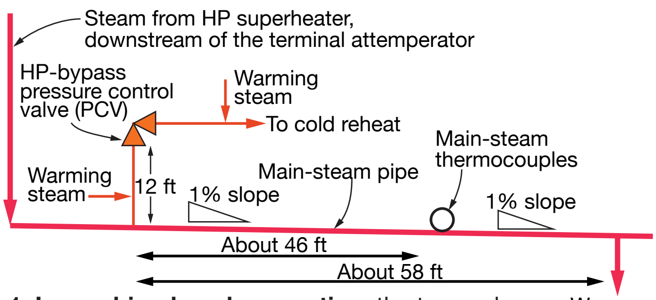
Case history

The gas turbine (GT) at a 1 × 1 single-shaft combined-cycle plant designed for flexible operation has a staged combustion system that permits emissions compliance and a relatively good heat rate down to low loads. The HRSG is a three-pressure, reheat, horizontal-gas-flow unit equipped with only HP (high pressure, main steam) and RH (reheat steam) terminal attemperators. There is no duct burner or SCR.

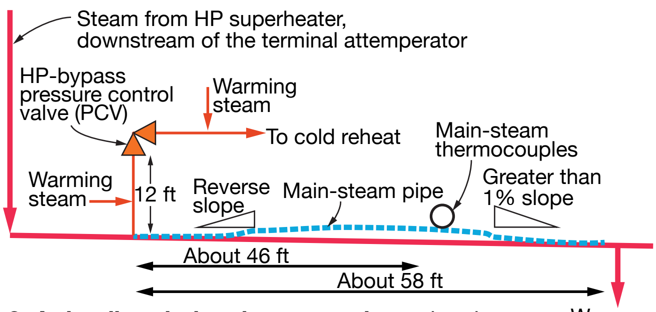
The facility is designed to operate in the following modes:

1. High GT and high steam-turbine (ST) load in combined cycle (Fig 1).
2. Low GT load and low ST load (sliding pressure) in combined cycle.
3. Low GT load and *zero* ST load in open cycle (Fig 2).

The problem: Repeated severe water erosion damage to the HP bypass pressure control valve (PCV). This caused the PVC to leak in combined-cycle service, requiring multiple repairs at significant unbudgeted costs and involving long forced outages.



1. In combined-cycle operation, the top and bottom of the main steam pipe are at the same temperature and the pipe remains straight



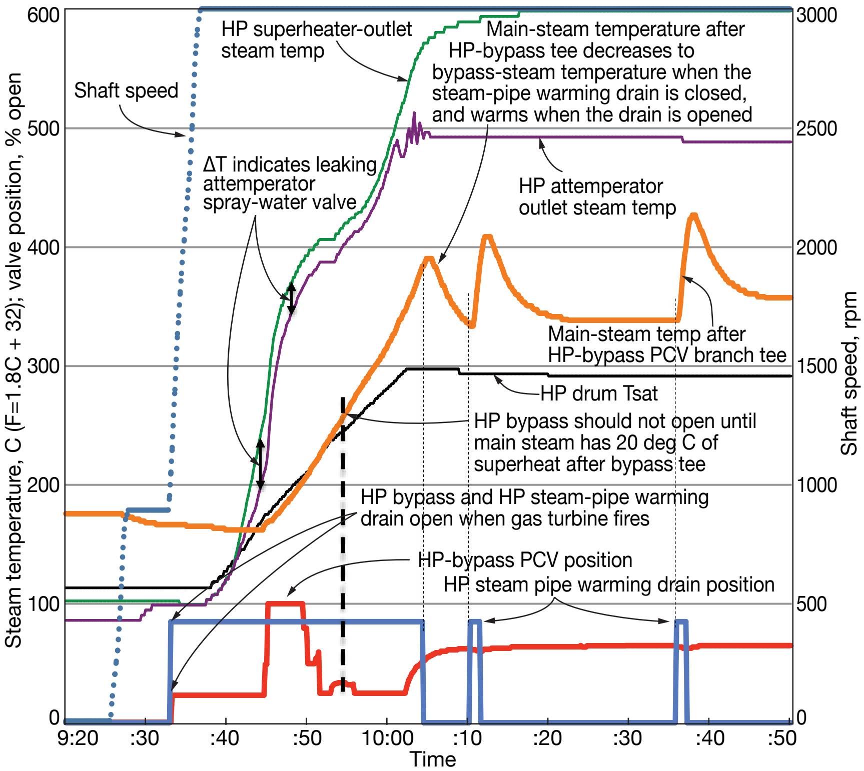
2. A deadheaded main-steam pipe exists in open-cycle service when the gas turbine is operating at low load and the steam turbine is offline. This mode of operation allows condensate to pool along the bottom of the pipe, shrinking it relative to the top of the pipe. Result: the pipe humps upward

The HP-bypass PCV installation arrangement is compliant with the OEM's guidelines. It is located at the top of a 12-ft vertical pipe run directly above the main-steam pipe branch tee and is provided with warming steam both before and after the PCV, as shown in Figs 1 and 2.

Anderson was hired to conduct a root-cause analysis (RCA) of the valve as a subcontractor to Structural Integrity Associates Inc. In addition, he and Dr R Barry Dooley of SIA conducted one of their respected Level I assessments of cycle chemistry, FAC, and undesirable thermal transients (access "HRSG assessments" using the search function at www.ccj-online.com).

Anderson said he and Dooley have conducted these surveys at over 50 combined-cycle plants worldwide and have *always* identified significant previously undetected problems during each survey.

The historical data plot



3. Data plots of critical operating data over time are for a cold start followed by open-cycle service

in Fig 3 identifies three potential contributors to the PCV water-erosion issue repeatedly experienced. While this one plot simplifies presentation of the three problems, selecting the data points to be plotted during the various modes of plant operation, reviewing the plots, rearranging the plots to facilitate analysis, and scaling and annotating the plots require significant experience and practice, Anderson stressed.

Fig 3 presents key historian data for a cold start followed by open-cycle operation. This unit has no GT bypass stack, so open cycle here means the HRSG is producing steam that is routed to the condenser via the HP and IP steam-turbine bypass systems. Below are thumbnails for each of the three operating conditions and system/equipment line-ups considered by Anderson as contributors to HP-bypass PCV erosion.

Note: To accurately determine the relative importance of the contributors to PCV erosion, review of additional data, beyond that provided by the plant's control system, was considered prudent by Anderson. He suggested the installation of additional monitoring instruments for better decision-making, enabling the owner to apply only those corrective actions necessary to solve the problem.

No. 1. The HP-bypass PCV (red line) and main-steam-pipe warming drain (bright blue) open immediately when the GT fires at 9:33. Main-steam temperature (orange) measured 46 ft downstream of the PCV branch tee tracks Tsat (black) until 9:53. As the main-steam pipe warms it forms condensate. When the PCV is open during the warm-up period, some or all of this condensate may pass through the PCV.

No. 2. During early startup (9:41 to 10:03), the HP attemperator block and control valves are closed (not shown in Fig 3), but the HP superheater outlet (attemperator inlet) steam temperature (green) is consistently higher than the attemperator outlet steam temperature (purple). This is characteristic of spray water leaking into the main-steam pipe.

There is a small-bore drain located on the main-steam pipe after the attemperator that is open during startup; but once steam flow begins pushing the leaking spray water along the pipe it likely will bypass the drain and some may be ingested by the PCV.

No. 3. The main-steam pipe, from the HP-bypass branch tee to the ST inlet valves has a 1% downward slope, as shown in Fig 1. A drain pot is located 58 ft downstream of the bypass branch tee; it has a 3-in. automatic drain valve (bright blue) and serves as the main-steam-pipe warming drain.

When open-cycle operation begins at 10:04 this valve closes, and the main-steam temperature measured about 46 ft downstream of the bypass tee (orange) begins to cool to the steam temperature measured after the HP-bypass PCV and its desuperheater.

At 10:11 and 10:36 the warming drain valve automatically opens for a couple of minutes. This indicates that sufficient condensate has formed in the section of deadheaded pipe between the HP-bypass tee and the ST inlet valves to trigger the warming drain-pot level switch. Each time the warming drain valve opens, main-steam temperature measured 46 ft downstream of the bypass tee quickly heats up to more than 400C.

The main-steam pipe thermocouples installed 46 ft downstream of the bypass tee are located on top of the steam pipe. Data suggest condensate forming and pooling in the bottom of the deadheaded main-steam pipe causes a top-to-bottom temperature difference that bows the pipe upwards, overcoming the 1% downward slope and causing condensate to run back towards the bypass branch tee where it is ingested by the PCV.

Corrective actions:

- Delay opening the HP-bypass PCV until the main-steam temperature measured downstream of the bypass tee increases to 20-deg-C above Tsat.
- Repair the leaking HP attemperator spray and block valves.
- Leave the main-steam-pipe warming drain open during open-cycle operation. This may require modulating the drain valve's position to limit steam flow while avoiding condensation in the deadheaded section of pipe.

Additional short stories that could come from this case history:

- The main-steam warming drain has an orifice installed; it is not on the drawings and is of unknown size. This slows warming of the main-steam pipe and increases the time before the HP-bypass PCV achieves 20-deg-C of superheat and can be opened safely.
- The attemperator valves leak because the control logic treats the block valve as "martyr" and the control valve as "master." This is backwards and ensures both valves will begin to leak.

Wrap-up. Pearl Street President Jason Makansi, a consultant who specializes in controls/diagnostics/prognostics, concurred with Anderson's decision to request instrumentation beyond that provided with the plant. "The importance of the foregoing analysis to me," he said, "is that the models used by the DCS to control/automate the plant, especially starts, normally don't factor in the level of data analysis required for sophisticated troubleshooting. Anderson's work uncovered some interesting flaws in the original design." CCJ

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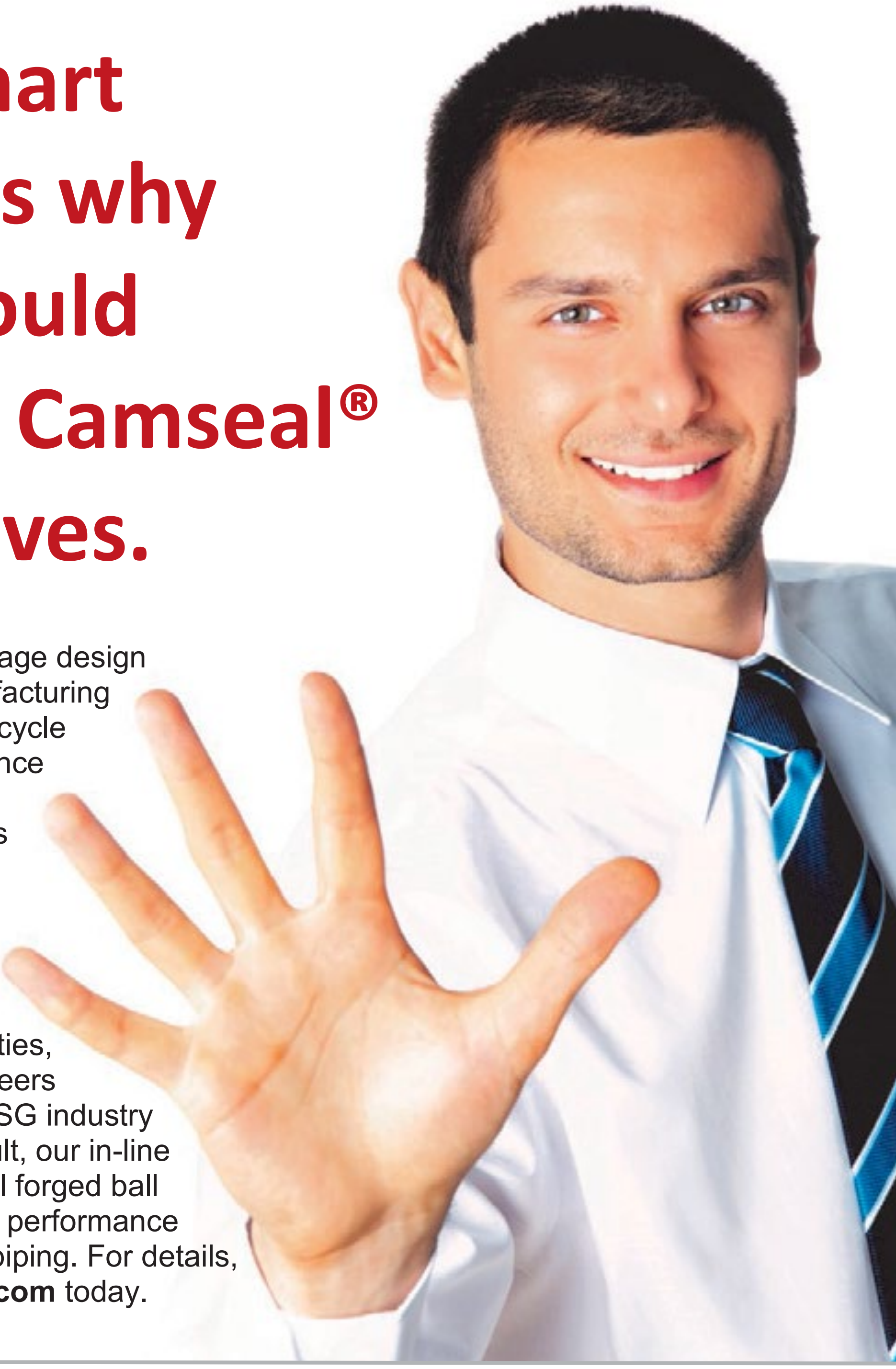

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The ABCs of blade-tip clearances

By Lee S Langston, professor emeritus, UConn

For an axial-flow gas turbine to operate without wear and tear caused by rubbing between rotating and stationary components, clearances between rotating blades and casing shroud, and between stationary vanes and hub, must be adequate—but not generous.

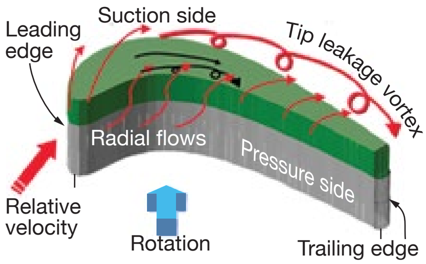
Fig 1 shows the general characteristics of leakage flow over a turbine blade with a flat tip. Leakage along the blade chord is caused by pressure-side axial flow migrating over the top of the airfoil to the lower-pressure suction side. A characteristic of both turbine and compressor blades is the formation of a suction-side vortex attributed to tip leakage; it interacts with the three-dimensional flow within each blade-to-blade passage. Tip leakage flow causes a loss in gas-turbine performance.

A cross-sectional view at a given chord location of tip leakage for a turbine blade and a compressor blade is illustrated in Fig 2. The general leakage-flow picture is basically the same for both, but differs in some details. For example, the pressure difference between the pressure and suction sides of a turbine blade are higher than that of a compressor blade, so turbine tip leakage flows are stronger.

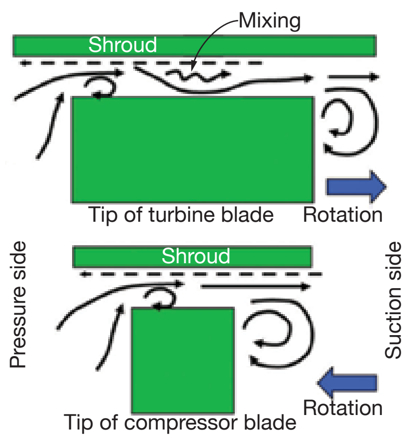
Important to keep in mind is that the axial flow in a compressor stage is having work done on it, so its pressure is increasing while axial flow in a turbine stage is doing work and sees a decreasing pressure. As they rotate, the pressure side of a compressor blade leads, while the suction side leads for a turbine blade.

The two critical parameters for tip leakage are the blade loading (local pressure difference between pressure and suction surfaces, as well as that from leading edge to trailing edge) and the actual tip clearance (expressed as a percentage of blade span or blade chord). Loading is set by the blade designer and the tip clearance is the stepchild to be controlled.

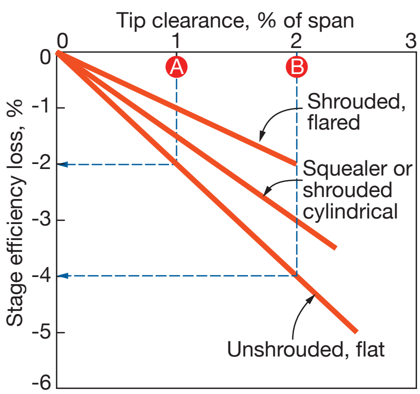
Tightening tip clearances and keeping them under control is a constant worry for OEMs and operators. The author recalls one military jet-engine program back in the 1960s, where efforts were made to "tighten up" compressor-blade tip clearances, to reduce losses. Unfortunately, the tightening went to zero clearance, resulting in a "hard rub" between titanium high-pressure-compressor blade tips and the titanium case. Because the ignition temperature of titanium (2900F) is lower than its melting temperature (3140F) the engine tip-clearance tightening program ended up with a combusted compressor, reduced to a pile of white titanium dioxide powder.



1. Behavior of leakage flow over a turbine blade with a flat tip



2. General leakage flow over the tips of turbine and compressor blades is basically the same



3. Effect of clearance on turbine efficiency is defined for various blade-tip designs

In the mid-1980s, cubic boron nitride (CBN) blade tip coatings for compressors and turbines were developed to prevent tip wear during light rubbing. CBN application to blade tips (or to shrouds) allowed tip clearances to be reduced for increased efficiency without encountering the rub damage experienced during the foregoing 1960's episode.

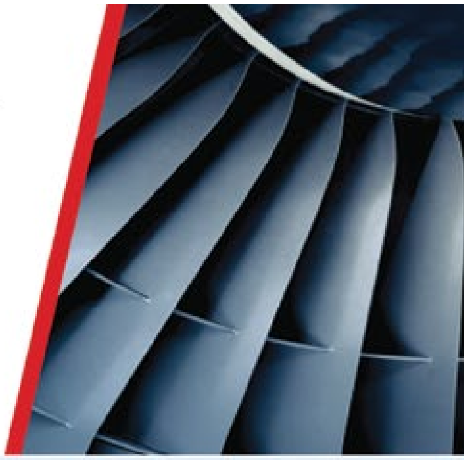
Compressors

Tip leakage losses in compressors can be significant. One study indicated that for every 1% increase in tip clearance (based on chord) there was a 5% decrease in peak pressure rise across a compressor. Another study showed compressor efficiency penalties range from 1 to 2 points for every 1% increase in tip clearance (based on span).

Tip clearance effects can be especially critical in late-model high-compression-ratio aeroderivative (aero) gas turbines with their low-aspect-ratio (Sidebar 1) high-pressure compressor (HPC) blades—airfoils having comparable spans and chords. The low-aspect-ratio blading, and mechanical limitations on the actual magnitude of achievable clearances, could force new HPC designs to accept tip gaps from 1% to 4% (based on span). The result would be reduced efficiency and stall margin.

Turbines

Efforts devoted to tip leakage control in turbines are extensive. The large pressure differences between the



1. Understanding terms

Aspect ratio is the ratio of the span to the mean chord of an airfoil (span/chord).

Chord in gas and steam turbines is the blade or vane width from the leading to trailing edge, as measured in an axial direction, a/k/a "axial chord."

Span is the unsupported length of a rotating or stationary blade extending from the platform to the tip of the airfoil.

Compressor ratio is the total outlet pressure of the compressor section divided by the total inlet pressure.

Component efficiency: Power in (compressor), or power out (turbine), divided by ideal (isentropic) component power.

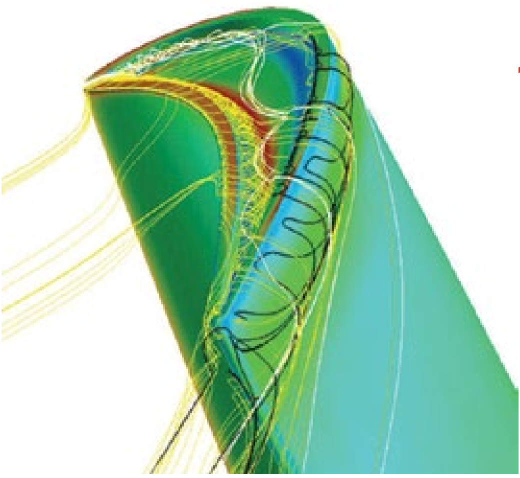
Thermal efficiency: Power out/costly power in (the fuel).

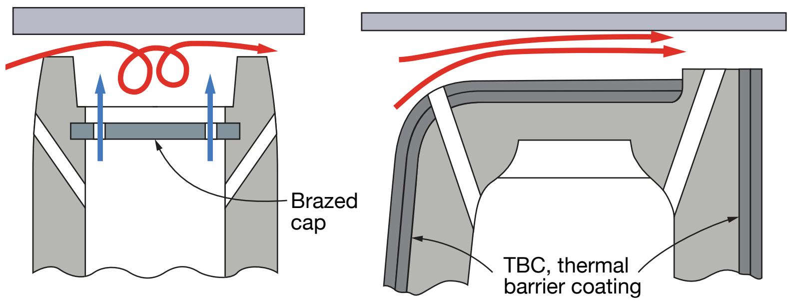
pressure and suction sides of, say, a single-stage aero HP turbine, promote detrimentally high tip-leakage flows. But, most important, these flows are at high temperature, contributing to shorter blade lifetimes.

GE's Ronald Bunker says blade-tip durability in aero HPTs is a critical area, accounting for about one-third of HPT failures. Here, "failure" is defined as the loss of the part from service inventory (unrepairable), or the accelerated degradation of efficiency/output in service.

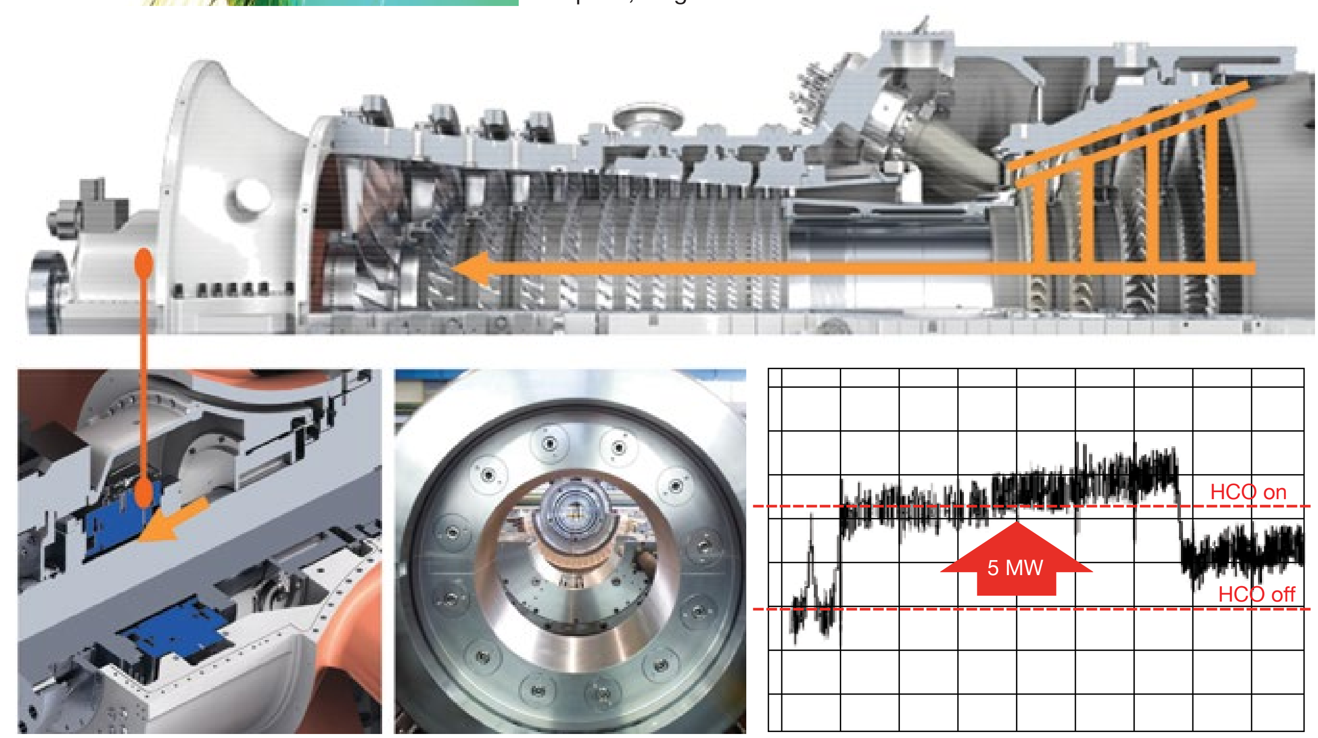
The plot in Fig 3 shows the effect of blade tip clearance (as a percentage of blade span) on turbine efficiency for various blade-tip designs. Unshrouded flat tip refers to a simple untreated tip blade, such as shown in Fig 1. A shrouded cylindrical tip is one where a shroud (integral with the tip) is part of the blade, providing a bounding outer radius surface to the blade passage. A flared shrouded tip is the same, except that the mean radius of the shroud increases in the axial direction.

How to use the Fig 3 chart: Assume





4. Computer modeling of tip leakage for turbine blade with conventional squealer tip is at left. Squealer tip design for original 501F first-stage turbine blade (center) caused turbulence conducive to cap cracking and oxidation. Elimination of the squealer tip on one side of the 501F blade (right) smoothed out the flow, contributing to fewer repairs, longer life



5. Hydraulic clearance optimization feature available on some Siemens gas turbines controls blade-tip clearances automatically by way of hydraulic pistons located behind the compressor thrust bearing

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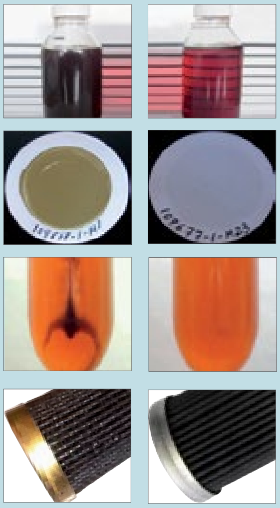

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2. HCO improves operational flexibility, boosts output

The Hydraulic Clearance Optimization feature provided on Siemens H-class engines, and offered as an option (for new units and as a retrofit) on V gas-turbine models 84.3A and later, promises performance benefits—including greater operational flexibility and increased power output and efficiency.

According to Siemens literature, performance enhancement is achieved by shifting the rotor against flow direction to optimize turbine clearances during steady-state operation. The axial shift of the rotor is performed automatically by hydraulic pistons behind the compressor thrust bearing. The gain in power quoted is up to 5 MW on the SGT5-8000H and up to 2 MW on a simple-cycle SGT6-4000F; efficiency improvement is up to three-tenths of a percentage point on qualifying simple-cycle V units.

The power boost and increase in efficiency are made possible, it is said, because of the conical shape of the turbine sections on these machines. Note that the performance gains in the turbine section attributed to repositioning of the rotor are greater than the losses incurred in the compressor section. The HCO feature is in full function when the differential thermal expansion of rotor and casing components has equalized—about an hour after the machine is started.

Performance improvements aside, the greatest value provided by HCO may be as a rubbing solution to keep clearances from closing up on shutdown, thereby eliminating the need for cooldown before restart in some situations. The product has been most popular in the 50-Hz V94.3A fleet with several score engines so equipped since 2003. At least eight 50-Hz machines have been retrofitted with the HCO worldwide. The first time use of HCO on a V84.3A was in Korea, March 2009. No retrofits have been sold to date in the US.

Korean experience. The writer, Lee S Langston, in Korea for ASME's 2016 Turbo Expo conference, visited Korea Midland Power Co's (Komipo) 1450-MW Incheon Thermal Power Site, home of the V machines with HCO experience, to get a first-hand account of how the clearance optimization system has performed since installation.

The site includes two nearly identical 2 × 1 combined cycles powered by V84.3A engines; only one (Unit 2) is equipped with the HCO system. Unit 1 is rated 503.5 MW; Unit 2, 508.9 MW. To evaluate the differences between the two combined cycles, Prof Langston—accompanied by Junho Kim, a Seoul National Univ PhD engineering student of Prof Seung Jin Song—met with three Komipo senior staff members: Youn-Kwang Kim, VP engineering and operations; Jung Hwa Kim, assistant manager—gas turbines; and Gi Tae Kim, service manager—steam turbines.

No hard data were available so the three plant employees spoke in general terms. They said the HCO-equipped engines were more efficient than the gas turbines for Unit 1, and Unit 2 produced power at less cost than its sister combined cycle. Further, that the plant has not experienced any problems with the HCO upgrades since commissioning.

The HCOs operate automatically through the Siemens control system. Operators are alerted when HCO is in operation, but don't have to take any action. The bottom line: A happy customer.

501F clearance control. HCO is not adaptable for use in the Siemens 501F fleet popular in the US. However, all of Siemens' advanced F designs (F4 and later) are equipped with the OEM's Direct Air Injection System (DAIS) for better control of clearances and to avoid rubbing. It relies on "cool" compressed air injected into the turbine section on shutdown to prevent lockup between the casing and rotating components. For earlier engines (up through FD3) Siemens has developed process changes to better accommodate spin cool and hot restart. DAIS also can be retrofitted to these earlier 501Fs.

a near-zero-clearance, 90%-efficient turbine stage for the Fig 3 unshrouded flat-tip design. If tip clearance is increased to 1% (Point A), observe that the stage efficiency drops by 2 percentage points, reducing it to 88%. Similarly, for a tip clearance of 2% (Point B), efficiency drops about 4 points to yield a disappointing 86%.

The squealer tip, most commonly used in aero HPTs and in the first turbine stage of frame engines for reducing leakage flow, has a short rim surrounding a shallow cavity to provide a simple two-tooth labyrinth seal. Fig 4 shows the tip leakage flow field for a squealer tip, as predicted by computer modeling.

The illustrations at the right in Fig 4 show how Mitsubishi eliminated cap cracking and oxidation caused by turbulence in the squealer-tip area. The left-hand sketch describes the original squealer-tip design, the one at the right has a squealer only on one side of the airfoil. This allows hot gas to flow smoothly across the blade tip. Also, note that the height of the squealer for the redesigned tip is less than that for the original blade.

Dealing with transients

During transient operations (for example, start up, load variation, or a sudden trip condition) gas- turbine blade tip clearances will change based on blade/disk centrifugal loads and the different response times of engine parts to thermally induced expansions and contractions.

Designers have perfected active clearance control (ACC) systems to accommodate these transient conditions. ACC uses cool or hot gas path at appropriate times during transients to control the rate of expansion or contraction of internal parts adjacent to the gas path and outer casings.

In 2012 the author visited a new combined cycle in Irsching, Germany, equipped with a Siemens SGT5-8000H gas turbine—the world's most powerful engine at the time (375 MW). Siemens has a unique blade tip clearance system (Fig 5), called hydraulic clearance optimization. With the daily load variations, and startups and shutdowns, rotating-blade tip clearances may increase or decrease. To control the clearances, Siemens' HCO has hydraulic pistons that can shift the rotating gas turbine rotor along the axis of rotation (Sidebar 2).

The outer case of the gas path is conical in the compressor (apex downstream) and in the turbine (apex upstream). Thus an HCO rotor shift towards the gas turbine inlet decreases the blade tip clearance in the turbine but increases those in the compressor. However, since turbine power is twice the power to drive the compressor and the conical turbine case is four times steeper than that of the compressor, compressor tip losses are only one-eighth of the turbine's power and efficiency improvements. Fig 5 shows data illustrating a gratifying 5-MW increase in output when HCO is applied in an SGT5-8000H engine. CCJ

Intermission control: Reducing downtime risk to HRSGs

By **Steven C Stultz,** Consulting Editor

The trend from baseload to cycling service (and short- or long-term layup) in the "renewables era" seems inevitable and universal. Regardless of original HRSG design, the physical stresses and atmospheric impacts become more hostile with age. It is all too common to overlook these forces until significant damage is done. For older units (Fig 1), it can be even more troubling.

1. Fredrickson 1 is a 249-MW 7F-powered combined cycle with a vintage HRSG

2. Typical stack balloon slopes toward the access for moisture drainage

The need for caution

Any amount of downtime can hurt most equipment. At last year's Australasian HRSG Users Group (AHUG 2015) meeting, while discussing layup at Stanwell Corp's 375-MW Swanbank E power station in Queensland, Dr Barry Dooley of Structural Integrity Associates Inc, San Jose, Calif, added a post-presentation comment: "Any storage above three days poses a critical risk to the LP steam turbine." The topic was corrosion (see CCJ 4Q/2015, "Deep dive on HRSG and cycle chemistry make this meeting special," p 8).

For most attendees, three days seemed a short time for critical risk. And what about the HRSG? Industry experts generally recommend maintaining relative humidity in both the LP turbine and on the gas side of the HRSG at less than 40%. So even a short cooling of HRSG components calls for caution.

Consider also the temperature differences between night and day. Metal temperatures lag, so tubes cooled overnight condense the warmer daytime humid air, leading to corrosion. In this reverse-draft scenario, air enters the stack and exits through the gas turbine.

Corrosion, in turn, adversely affects HRSG performance and can soon increase backpressure and de-rate or trip the plant. Air likes to move. Tube, fin, header, casing, piping, and hanger corrosion all are probable outcomes.

Ambient conditions (whether seasonal or geographic) compound the need for protection. In most locations, spring and fall coincide with higher ambient humidity and precipitation. The important point is that as temperature and humidity cycle, HRSG system components can attract condensation. This can be considered another form of dewpoint corrosion, but now entire sections are at risk.

And if not removed, corrosion products compound their damage and can become particulate emissions at restart.

Thumb rules

A recent industry event offered some rules of thumb, along with definitions, for both gas-side and water-side components in cycling service:

- Short-term wet storage, less than seven days.
- Long-term wet storage, seven to 30 days.
- Dry storage, more than 30 days.

Some units, like the one discussed below, exceed the 30-day shift to dry

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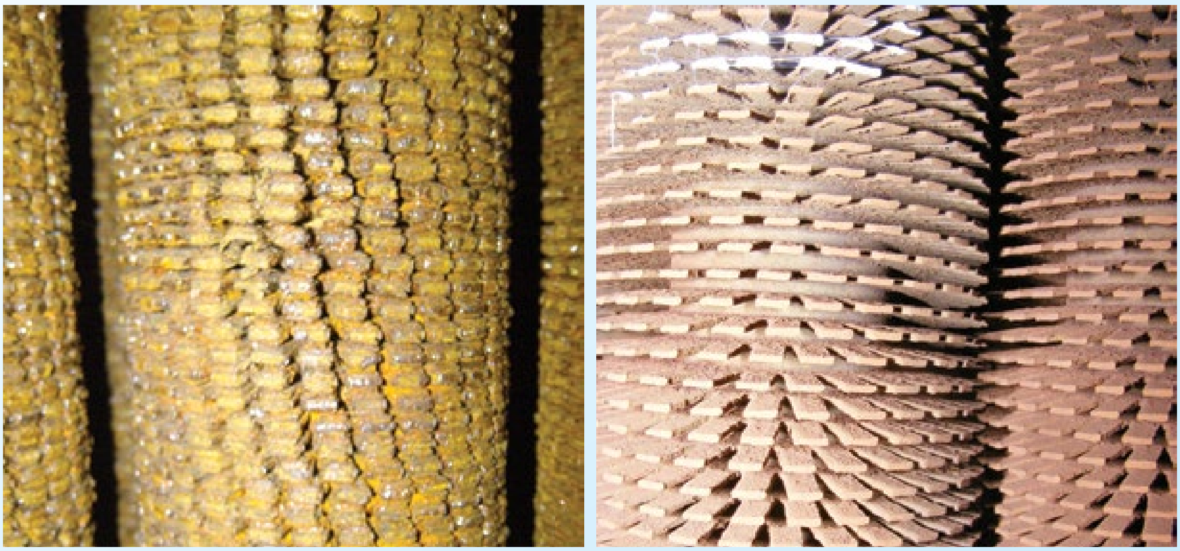

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3. The GT exhaust-duct balloon, a multi-purpose isolation barrier, was installed first at Frederickson (left)

4. Desiccant dehumidifier maintains humidity at less than 40% on the gas side of the HRSG (above)

storage with nitrogen capping, pH checks, and by circulating water and filling as required.

Each time period has specific requirements, but the fundamental owner/operator goals are the same:

- Reduce the potential for gas-side and water-side corrosion.
- Allow restart as quickly as possible (and achieve proper chemistry on the water side).
- Retain maintenance access (and attention).

Isolation barriers

Whether short term (bottling up) or longer term, the first rule is to impede draft. One such strategy, either partnered with or as an alternative to stack dampers, is custom-manufactured balloons (Fig 2). When also used at the HRSG's turbine exhaust inlet (Fig 3), these become the first line of defense against corrosion (CCJ 1Q/2010, "Preservation program works for outages from one month to several years," p 92).

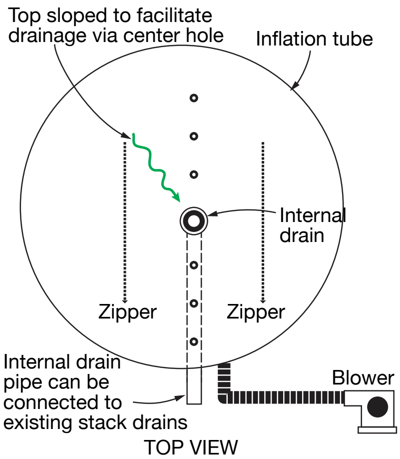
According to Gary Werth of G R Werth and Associates Inc, North Riverside, Ill, "stack and duct balloons are increasingly common and highly effective methods of creating isolation barriers to reduce offline corrosion issues in both HRSGs and gas turbines. For various reasons, primarily high dewpoint and high humidity, corrosion can become significant within days of a shutdown. Potential corrosion carryover at next startup complicates the issue and adds to potential system damage."

Werth is the exclusive distributor of the Duct Balloon™ product line.

Balloon drain enhancement

In the stack balloon design used successfully at Frederickson 1, the top balloon surface is tilted toward the access door opening to permit water runoff. Collected rainwater then runs down the outside of the stack. It does the job; there are more than 100 installations of this type operating around the world.

Although effective, designers have developed an improvement applied recently in Thailand. This latest design (drawing) lets the plant connect the new stack balloon drain line to the existing stack drains. The balloon's top surface is pitched toward the middle to funnel rain water towards the center drain hole. Once the water is collected, it is transported through the internal PVC drain line to the perimeter edge and the stack drain system.



The standard stack balloon has two basic objectives:

- Prevent precipitation (rain, snow, ice) from traveling down the stack and affecting the HRSG.
- Block the natural air flow that would occur because of the pressure differential between the GT inlet and top of stack.

And there are more, all related, including but not limited to:

- Eliminate daytime condensation on HRSG components whose temperatures lag behind those of warmer ambient air (by reverse draft).
- Maintain HRSG heat for more efficient startup. Formerly wet-storage cold starts can become warm starts and formerly wet-storage warm starts can become hot starts.

Example. Use of balloons in, for example, a combined cycle during a weekend shutdown in cold weather can, according to published reports:

- Retain residual heat in the HRSG and prevent freeze-ups.
- Hold temperature below the balloon at 100F when the outside temperature is 20F.
- Reduce or eliminate sparging requirements.
- Reduce offline corrosion potential, fuel use on warm startups, equipment stress fatigue attributed to cold starts, opacity at startup, and/or tube and fin cleaning needs before startup.

Case history

Frederickson 1 Generating Station is a 7FA-powered, natural-gas-fired 1 × 1 combined cycle located near Tacoma, Wash. This rejuvenated and upgraded

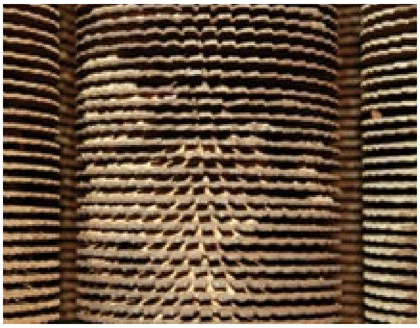
facility began commercial operation in 2002 and can produce up to 275 MW with supplemental duct firing. A nearby peaking unit, similarly named, can provide an additional 147 MW.

The refurbished plant features a 1992-vintage HRSG packed with finned tubes in the back end, originally meant to compete with coal-plant steam capacity and heat rate. Maintenance was secondary. Although somewhat unique in its age, Frederickson typifies many of the risks that all owner/operators need to target in their inspection, maintenance, and planning cycles.

Frederickson LP, part of Atlantic Power, holds power-purchase agreements (PPAs) with three public utility districts in the state. The area's power-generation environment (Puget Sound Energy, which owns just under half of the plant's output) lists, in order of preference for its "diversified portfolio strategy," hydroelectric, wind, natural gas, and imported coal-fired power from Montana. Hydroelectric is dominant (with seasonal peaks); gas-fired power is about 20%.

Therefore, Frederickson is faced with both short- and long-term cyclic operation.

Ric Chernesky, plant manager, explains the benefits of the stack balloon added in 2013, "We first looked at installing stack dampers, mainly because of all the rain in this area. Instead, we bought two balloons—one for the stack and one for the turbine exhaust. This made our HRSG a nice enclosed vestibule."



5. The tightly packed LP tubes are subject to both corrosion and fouling by ammonia salts

The plant also modified the roof penetrations to avoid standing water and moisture seepage. As Chernesky explains, "If moisture hits the ammonia deposits you get a change in pH right away and it turns into stalagmites; it's ugly." The changes have also reduced moisture damage to the SCR catalyst.

In late 2014, Frederickson worked with Applied Systems Northwest to design and purchase a Munters desiccant dehumidification system to use when offline, controlling humidity to 40% or less (Fig 4). This part of the program included the dehumidifier, a new motor control-center breaker, conduit and wring runs, supply and return ductwork, and HRSG access doors.

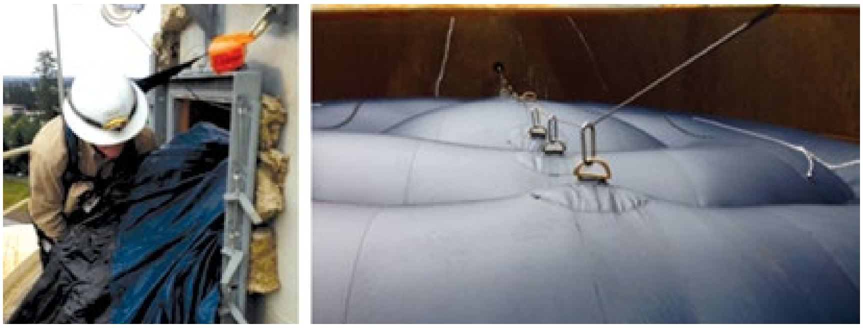
With the HRSG's congested back end (Fig 5), the plant had experienced severe buildup of ammonia salts beyond the SCR. "Now that we can close off the HRSG and control humidity," explains Chernesky, "the tensile strength of these ammonia salts has gone down and they're more brittle (less moisture). They come off a lot easier."

Balloon handling

Chernesky notes that "'Freddie' normally averages 35% to 50% capacity factor depending on the amount of rain. We usually get nine to 12 starts per year, some with short downtime, and we'll run anywhere from one week to three months. We put the balloons in six or seven times each year."

Inflated, the duct balloon is slightly larger than 18 ft in diameter and 5 ft deep. The stack is 18 ft in diameter and required a new stack door and platform at elevation (Fig 6).

"Balloon installation is much faster than we thought it would be," he states. "We can generally have them both installed within about two hours, with a crew of two."



6. Access door and platform were added to accommodate the stack balloon (left); guy wire (right) holds the balloon during placement and is retracted during plant operation

"We've learned a lot over the last 10 years or so," he continues. "We know a great deal now about corrosion control of the carbon steel, including the casing. These balloons, along with the dehumidifier, have helped us immensely."

Tube cleaning improves

The overall HRSG protection program has shown good benefits over time, says Chernesky. "We did our own cleaning for a few years, and even had special hoses and nozzles. But our LP sections are 14 rows deep, and we could only get four or five rows in," he explains.

Working with Precision Iceblast Corp, Peshtigo, Wisc, which was supported by HRST Inc, Eden Prairie, Minn, Frederickson can now get eight rows in from the access lanes. Chernesky notes that this progress results from tube-spreading techniques—including staging, improved media nozzle designs, and improved mixing of ice and air (at the nozzle) for maximum cleaning efficiency. Pressure has increased from 250- to 350-psig air at the nozzle.

"This has reduced backpressure by a couple of inches," he notes, "primarily from our LP preheater and evaporator."

His use of the term "protection program" is appropriate. In Frederickson's case, it is taking on older unit and applying attention and technology improvements to make it operate extremely well, even by new-unit standards.

Continual improvement

During its 2016 outage, Frederickson 1 continued its technical move forward by replacing the SCR catalyst bed and adding a sampling grid for fine tuning. This work was done by Groome Industrial Service Group Inc, Waldwick, NJ, within an 11-day outage window and included the removal and disposal of the existing catalyst plus installation of new Haldor Topsoe A/S catalyst.

"Flow through the SCR is not laminar," explains Chernesky, "and we can now sample across the catalyst bed, not just at the sampling blocks. We can add ammonia to specific areas. This way we have less unreacted ammonia slipping through the SCR." In a further advancement, Frederickson can now back-blow the catalyst at low pressure to extend its life.

Frederickson 1 continues to improve because Chernesky and the lean staff continually look for opportunities. He sums it up perfectly: "You've got to share information and learn from others. I'm interested in anything that can help make us better here. Every little bit helps." CCJ

By invitation only: The dangers of confined space

By Steven C Stultz, Consulting Editor

Today's powerplants are complex engineering triumphs with attention-grabbing geometries, curious nooks and crannies, and sealed entryways.

Approaching, and perhaps peering into, a not-normally-accessible area seems attractive. Going further suggests a challenge. But many plant visitors (as well as some full-time employees) may not appreciate just how dangerous these spaces can be.

Today's heat-recovery steam generators (HRSGs) have many such areas, from the gas-turbine exhaust flange to the stack on the gas side, and from the LP drum to the steam-turbine exhaust hood and condenser on the steam side. Several are (or should be) marked clearly as **Confined Space.**

Look in all directions

For those authorized to enter, even that first reach or step inside can pose unexpected hazards, as highlighted during a safety session at HRST Inc's HRSG Academy (January 2016) in San Antonio. Take, for example, Fig 1. The outside opening allows access to an upper crawl space of this HRSG. But looking in beyond the casing, then immediately down, reveals a vertical drop of 60 ft along a finned tube wall (Fig 2).

It's not just gravity that could cause the damage. Air moves around, fumes rise, noise travels, and sources of light change, so the unexpected cavity poses many variables and potential dangers to the untutored visitor.

Further on, inside this upper crawl space, vulnerability lurks again between sections (Fig 3). A quick look down shows another 60 ft drop, with finned steel tubes along both sides (Fig 4).

So for even the seasoned HRSG worker, short-term lack of attention (or complacency) can lead to catastrophe. The bottom line: Always expect the unexpected.


HRST Inc

1, 2. Upper crawl space 1, looking in (left) and looking down (right)


HRST Inc

3, 4. Upper crawl space 5, looking in (left) and looking down (right)

Horizontal turbines; vertical steam systems

To some staff and contractor personnel at combined-cycle plants, Confined Space designations and regulations might be less than routine. In the US, confined spaces are regulated by the Occupational Safety and Health Administration (OSHA). Under OSHA 29 CFR 1910.146, gas-turbine enclosures normally are not considered confined spaces (although they are considered so in Great Britain). On the HRSG and condenser side, restricted-area rules and regulations are common, and many areas are clearly defined as Confined Space (Fig 5).

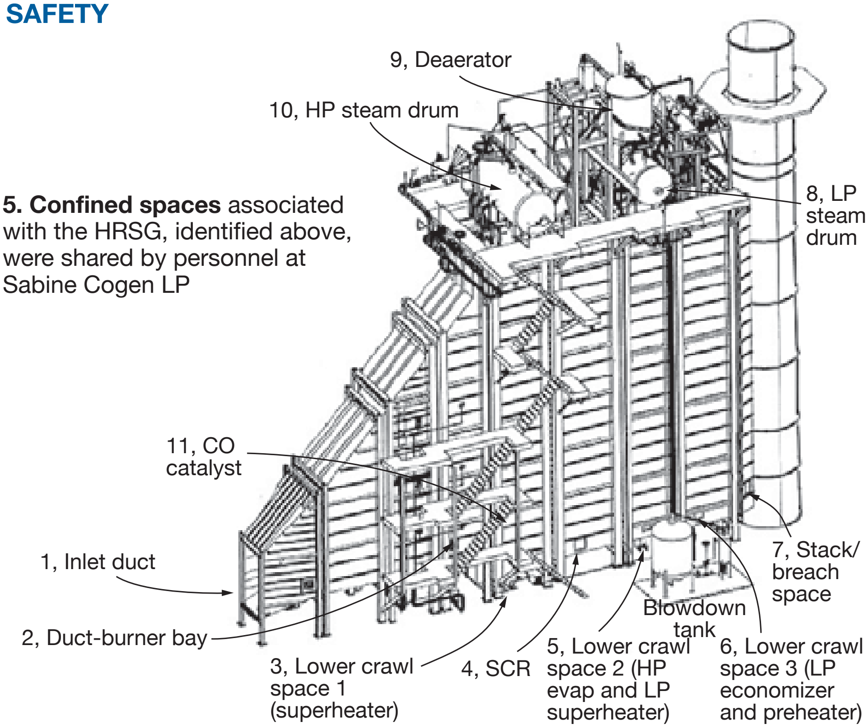
Further, industry experts remind us that:

- Conditions can change within each HRSG.
- Designs differ from OEM to OEM.
- Designs also can differ within the same OEM.

Fire/Safety Specialist Duane Daggers at JLN Associates LLC, Old Lyme, Conn, looks at confined space from a variety of angles, experiences, and training. He is a safety supervisor, rescue team member, and paramedic. Perhaps more important, Daggers holds advanced degrees in safety and leadership, and is well versed in rules and regulations—including OSHA, NFPA, and ANSI. He knows the all-important steps and paperwork.

He also knows that if done properly and with specific purpose, training, guidance, and permits, working within a designated confined space can be a unique and personally rewarding experience.

"Complacency is what can get work-



5. Confined spaces associated with the HRSG, identified above, were shared by personnel at Sabine Cogen LP

ers injured and killed," says Daggers. "And with a new generation of employees entering the industry, these seemingly stringent rules and regulations become even more meaningful."

Confined Space defined

Daggers offers a clear summary of Confined Space: "Any time you unbolt a hatch and have to enter an area not designed for everyday worker activity, it is classified as a confined space." He also gives the two OSHA-supported definitions which are explained in CFR 29 1910.146.

Non-permit-required confined space is one that does not contain or, with respect to atmospheric hazards, have the potential to contain any hazard capable of causing death or serious harm. When there are changes in the use or configuration of a non-permit confined space that might increase the hazards to entrants, it can be re-evaluated and if necessary reclassified as a permit-required space.

Crawl spaces are excellent examples (Fig 6). Under normal circumstances, they pose minimal risk. However, all spaces have the potential to cause injury and often are re-evaluated.

Permit-required confined space is one that is large enough and configured so that an employee can enter and perform assigned work. It has limited or restricted access, and is not designated for continuous occupancy. The space may contain a potentially hazardous atmosphere, it may have limited oxygen content, and it may contain mechanical or electrical equipment, which upon contact or activation may trap, crush, or electrocute the worker.

In Fig 7, the spaces shown are the lower HRSG hatches for the superheater and the HP evaporator. With the doors open a temporary barricade is installed to warn people to not enter, and the various lines for air, welding, and electric are all secured in a corner to reduce trip hazards and keep exit points clear.

A critical first step for all confined areas is an OSHA-approved lockout/tagout program. Lockout/tagout specifically means the control of hazardous energy. It refers to the practices and procedures necessary to disable machinery or equipment, thereby preventing the release of hazardous energy while employees perform service and maintenance. It happens before anyone enters.

Outage concerns

For most lean-staffed combined-cycle plants, an outage brings contractors and others to site who, perhaps, are not familiar with unique areas and configurations, changes made since the last outage, and even site-specific nomenclature and rules. Ongoing plant operations could be in abnormal configurations. There can be moments of confusion.

Service providers like JLN can play key roles in the coordination of such events and personnel during any outage. In a well-planned outage, the full-time plant staff can more easily concentrate on the outage activities, maintenance, costs, and schedules.

Regulations from organizations like OSHA also play a critical role in both outage success and worker safety. Training and awareness are full-time jobs at any site. The more common elements that are implemented and enforced, the less likely the confusion or misunderstanding. OHSA, for example, plays a commonly accepted heavy hand in confined-space rules and procedures.

Permits demand focus

Knowing a permit is required means identifying precisely what is within the space and what conditions the workers will face. It means, first, that

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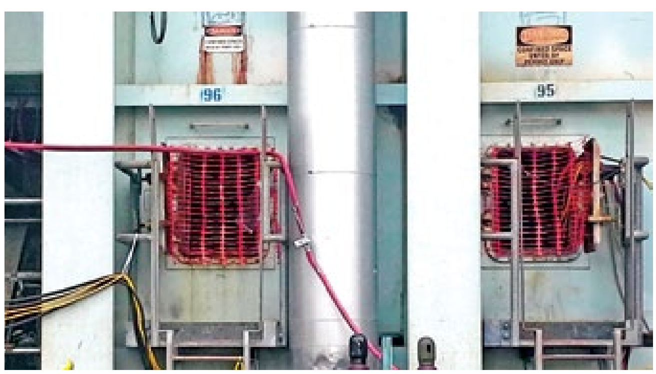
6. Crawl space with no permit required



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7. Lower hatches for superheater and HP evaporator access during outages. Temporary barricades are installed and lines for air, welding, and electric are secured


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CONFINED SPACE HAZARD ASSESSMENT

Space No.: 1 **Description: HRSG Inlet Duct**	**Size of Access Door(s): 15"x18'**	**Classification: Permit Required Confined Space Entry**
Location: "Duct A" section. See HRSG Dwg.	**No. of Access Doors: Two (2). [One on ea. side of HRSG.]**	**Reasoning: Floor slopes downward and tapers to smaller cross-section.** **Approval Date & Signature:**

Potential Atmospheric Hazards	**OSHA Permissible Exposure Level (PEL) 8-hr TWA:**	**Methods of Isolation, Control or Elimination**
• Possible Oxygen deficient atmosphere	Less than 19.5% (or above 23.5%)	HRSG LOTO; Pre-entry atmospheric testing. Continuous atmospheric monitoring; Natural or mechanical ventilation; Respiratory protection as needed.
• Exhaust Gases		
• Natural Gas		
• Ammonia (NH3)	25 ppm by volume	
• Carbon Monoxide (CO)	50 ppm or 55 mg/m^3	
• Sulfur Dioxide (SO2)	5 ppm or 13mg/m^3	
Physical Hazards:		
• Location of Entrance\Exit (height) • Scaffold steps entry \ exit.	Standard railing required if: 4' or more off the ground; 4 or more risers; or less than 44" wide with both sides open.	Scaffold steps (built to avoid additional fall protection) at entry point.
• Size of Access\Exit (15"x18")		Size of entrance cannot be altered. Notify all parties.
• Heat\Temperature		Cool down procedures.
• Steam		HRSG LOTO & cool down procedures.
• Hot Water		HRSG LOTO & cool down procedures
• Internal Baffles		Internal baffles cannot be altered. Notify all parties.
• Floor slopes downward and tapers to a smaller cross-section.		Complete Confined Space Entry Permit. Notify all parties.
• Uneven Walking Surfaces		Notify all parties.
• Sharp objects protruding from floor.		Notify all parties. PPE \ knee pads may be necessary.
• Low or No Lighting		Lighting \ Explosive-proof lighting as needed.
• Low Overhead Clearances		Hard Hat
Other Hazard Considerations:		
• Will air contaminants be introduced into the space (i.e. welding, painting, cleaning, and cutting)? If so what and how?		Confined Space Entry Permit, Hot Work Permit, Ventilation, &/or Respiratory protection, Electric equipment listed Class I, Division I, Group D, Explosive-proof lighting, Non-sparking tools.
• Is scaffolding being built inside or ladder being used inside?		Fall protection Confined Space Entry Permit
• **List other:**		

8. Confined-space hazard assessment sheet provided by Sabine Cogen LP is typical of the documentation made available to plant and contractor personnel working in a hazardous area


JLN Associates LLC

9. Safety technician performs confined-space attendant duties on a condenser hotwell

a hazard assessment is complete. It means, for the contractor, that the host employer can define all elements within all confined spaces, will coordinate entry operations of all work groups (both direct employee and contractor), and will be aware of all permit-space programs implemented on the site.

It also means that all activities should be planned and scheduled in advance. Workers must then complete a work authorization (job safety analysis or JSA) which clearly identifies the scope of their work, potential hazards, and all steps used to control those hazards (Fig 8).

Daggers points out that "the confined space entry permit is specific to the area of work and must contain exact information before any entry." This includes precise dates and durations.

More specifically, Daggers lists the details:

- Entrants by name.
- Attendants.
- Supervisors.
- Specific hazards.
- Measures used (lockout/tagout) to isolate the space and control hazards.
- Acceptable entry conditions.
- Results of all initial and periodic atmospheric tests, including names and dates.
- Rescue and emergency services available including equipment and contact information.

The supervisor has a long list of responsibilities, including full understanding of all personal protective and rescue equipment; all hazards; symptoms and consequences of exposure; procedures for terminating entry and canceling the permit; means of summoning rescue services; and procedures for removing unauthorized individuals from the area. The supervisor is also responsible for all attendants.

Attendants enforce the rules

Attendants do much more than check names against rosters. They are trained in confined-space regulations, OSHA requirements, and atmospheric monitoring. Specific tasks are defined further by OSHA.

As Daggers explains, "Attendants must understand all possible hazards including the mode, signs or symptoms, and consequences of exposure. They must understand, watch for and identify possible behavioral effects, while maintaining a constant vigil outside the permit space, and communicating with those inside (Fig 9). Their primary duty is to protect the entrants. And they are fully authorized to remove anyone."

Atmospheric monitoring is critical. All confined spaces, both non-permit and permit, must have atmospheric testing before any entry, using calibrated direct-reading instruments. Tests include:

- Oxygen content.
- Flammable gases and vapors.
- Potential toxic air contaminants.

Atmospheric testing can be facility-, area-, and operation-specific. Knowing how the facility operates is a key factor in determining what potential contaminants may be within a confined space. Take ammonia for example. The gas side is affected when plants use anhydrous ammonia for NO_x reduction. On the steam/water side, plants using seawater for condensing and cooling need to test for organic compounds including ammonia in the condenser waterboxes.

And consider again the openings in

JLN Associates LLC

10. Confined-space rescue team in standby mode during vertical-pit entry

Figs 2 and 4. Because air and fumes move, knowing the configuration and content of an adjacent space could help determine the type of tests. All areas are then monitored for any changes in the internal atmosphere.

Rescue plan and team

Authorized entry requires an approved rescue plan and certified rescue team. OSHA again has specific requirements for team members, including the following:

- In-depth training and practice.
- Knowledge of retrieval methods, and their consequences.
- Training in first aid and CPR.

The team generally includes a minimum of four medical and rescue trained personnel with a full complement of equipment to establish a safe work zone and perform technical rescue (Fig 10).

Each team member wears a complete rescue ensemble in the event all must enter to assist with the rescue. Each must use a chest or full-body harness, or other approved rescue system with a retrieval line. The retrieval line is attached to a mechanical device or fixed point outside the permit space. Also, a mechanical device must be in place to retrieve personnel from vertical spaces more than five feet.

The confined-space rescue team completes the same entry procedures as every other entrant. The team must complete a JSA, ensure lockout/tagout protection, receive approval for entry, and be logged in and out.

It's in the paperwork

Taking JLN again as an example, trained contractors can become the "eyes and ears" for owner/operators during many tasks and scheduled operations. They can handle confined space permits, serve as supervisors and monitors, and perform other tasks including rescue. And perhaps more important, they know the rules and control the paperwork.

It's called using your resources, and many of these resources have vast and wide-ranging experience. John Nickerson, for example, established JLN Associates LLC in October 1999 following extensive hands-on experience in the power industry as well as general industry and public sectors. He once established and managed a 40+ member nuclear-powerplant fire protection and emergency-response organization. In the nuclear sector, it's all part of the NRC's safety-conscious work environment (NRC 2003).

Bring it home

Safety programs have many names: Safety First, Target Zero, and even Slogans Don't Save Lives. But all include the personal responsibility to know in advance, to stay alert, to know even the best workers make mistakes, and to stop work when problems arise. Regardless of the name, it's people looking out for other people, and for themselves.

Speaking for those who make safety a career, Daggers offers the following: "As safety professionals we make sure administrators and workers all have the same safety culture. We don't stress the importance of safety because it is mandatory, or because we enjoy pointing out mistakes. We make it a point to ensure all workers on the jobsites make it home at the end of their shift." CCJ

Aetos, Mistras Group

Drones facilitate some inspections, maintenance decision-making

By Steven C Stultz, Consulting Editor

Commercially available drones have become much more than a weekend novelty. Some facility owner/operators use them to survey and inspect transmission and distribution systems, pipelines, plant boundaries, or the plant itself. And some have now moved indoors to inspect wall panels, burner systems, and critical heat-transfer surfaces of large fossil-fueled boilers.

Some have moved even further—to the more compact areas of an HRSG.

So these fleets that began as well-controlled eagles and hawks, those soaring surveyors with purpose, might now include a reflection of abnormally large, hovering hummingbirds.

The point is, powerplant engineers are tapping into these *eyes in the sky* to survey, record, analyze, revisit if necessary, and most importantly make critical decisions on the efficient use of personnel, time, and money.

These tools go by various names, including unmanned aerial vehicles (UAVs), and have proven their value in combined-cycle HRSGs. Field engineers have found that drones can reduce the overall time and expense of scaffolding, personnel baskets, and interior lighting systems, and can even reach areas that humans cannot easily inspect.

Take for example perforated distribution plates for the gas-turbine exhaust. In the words of one trained engineer (pilot) who has flown a number of missions in both HRSGs and large fossil boilers, "we looked at the distribution plate area as best we could from the ground, and we didn't plan to scaffold the area for this particular outage. We saw up high a little bit of plate distortion, but nothing that seemed critical."

The two-person crew then prepared a drone with new batteries and a new memory card. (If there's a crash, you only risk losing one memory card.) "At about 40 feet off the floor," he stated "we saw a six-foot crack in one of the seams. It was around the corner, and we could not have seen it from the floor." The 4 × 8 ft perforated steel plate could have come off before the next outage and caused major damage. "So the crew erected scaffolding only where we needed it, got up there efficiently, and fixed it," he explained.

Drones are useful for short outages and for spot checks of nuisance areas. For longer outages, they allow fast and economic inspection even before scaffolding is erected.

Targeting erosion/corrosion and exposed-insulation concerns seems obvious (Figs 1, 2). But operators also have been able to inspect catalyst areas to identify slipping blocks or gas bypass (Fig 3). Another common flight path is duct burners, for baffle and nozzle investigation (Fig 4). Fuel

1. Drones allow close inspection of tubes for rust and other performance thieves

3. Catalyst inspections by drone can pinpoint dislodged seals and other issues

2. Evidence of exposed insulation or parts distress allows targeted repairs

4. A short flight could show locations of burner-tip coking.

nozzles get cracks in them, and you need to get within about 2 ft to see the cracks. Drones can do that.

It is important to note that the FAA has strict and evolving rules for drones, and the wise owner/operator will check with the FAA before any use. There could be some grey areas.

In one example discussion, this editor found an engineer who entered what is perhaps one of these areas, but left with an important discovery. Fully aware he could not exit the top of the stack, he flew to inspect the open stack damper. But with the camera on the bottom of this particular craft, he flew slightly above. The aerodynamic discovery was on the return.

Although open, this four-blade damper offered enough resistance to the drone's rotor wash (and limited battery life) that the drone could not return. Think check valve. So the control room closed the damper to make a landing platform. The drone was retrieved through a stack door. Similarly, pilot engineers have experienced rotor wash pulling the units toward nearby surfaces (catalyst beds, for example).

Basic air currents are also significant, more so than outdoors. Inside a coal-fired boiler or HRSG, pilots lose the benefit of tools like GPS navigation that will let you stay in place even with a 10 to 15 mph wind. In a boiler none of that works. So even a slight draft, like an open stack damper or ventilation fan, can push the unit a few feet. Electronic interference can also occur within these steel enclosures.

So what's next?

Keep in mind that most flights are initial surveys and inspections, but they do provide area focus and a high degree of visual precision. If hands-on personnel are needed, the playing field is narrowed and planning can be much more efficient. Safety and cost-effective mobilization of field personnel become measurable benefits. Drones are a valuable decision-making tool.

EPRI Journal (Jan/Feb 2016) discusses further initiatives like landing on and attaching to boiler tube walls (to conserve power during inspections) and rollers for tube wall climbing. But HRSG applications with finned

Drones, ground robotics advance NDE

The relentless advancement of technology has impacted virtually every facet of electric power generation and delivery over the last decade or so. In the area of nondestructive examination (NDE), for example, there have been many developments in basic inspection tools—such as phased-array ultrasonics.

Recently, NDE developments have expanded to permit "hands-off" inspection by way of drones and ground robotics. For an industry with a focus on safety and cost, this is a big step forward. Unmanned aerial systems (UAS) and robotic crawlers enable inspection of hazardous areas and confined spaces with minimal risk to personnel. Typically, they can do these jobs faster and at less cost than traditional methods.

Aetos, a member company of Mistras Group, an organization known to many gas-turbine owner/operators for instrumentation able to remotely identify fluid leaks and the initiation of cracking in stationary engine components, is a leader in this emerging area. The company was the first to receive Federal Aviation Administration airspace approval to fly UAS in the petrochemical industry.

Today, Aetos' team of licensed pilots is inspecting burners, igniters, and harps on the gas side of heat-recovery steam generators (HRSGs), plus external stacks and structures. In some cases, inspections are conducted when the plant is operating. Typically, only two people are required for such inspections. The benefits are obvious: Reduction in outage time, elimination of scaffolding and at-height work, cost saving.

tubes could present some additional challenges.

EPRI and others also are looking at ultrasonic testing, dye penetrant, and even radiography, and similar tasks not needing extensive surface preparation.

And for confined space planning and possible hazardous conditions, think canaries in a coal mine.

If technology gets to where the drones can attack corrosion, perhaps our opening hawks will turn into vultures. Or in the case of HRSGs, martins. But all will carry that classic resonance. CCJ

A vibrant commercial market for grid-scale storage in the US is at least five years out, despite declining cost curves for the prevalent technology option, a supportive legislative framework in key US markets and ISOs, and so-called mega-factories ready to ship hundreds of units. Shown here is a DOE-funded demonstration project in Pennsylvania

Regulators, ISOs set the table; suppliers served few orders

Editor's Note: The status report below draws broad insight from a consultant's engagement with high-level representatives from countries interested in US grid-scale storage technologies, regulations, and applications—including attendance at the Energy Storage Association's 2016 Conference in Charlotte, NC, April 25-28, plus meetings with US storage system suppliers, California utilities, CAISO, and other stakeholders.

What is clear from being immersed in the grid-scale storage space (here *not* addressing behind-the-meter storage) for 10 days is that state and federal regulators in key states and regions, along with the respective organized-market independent system operators (ISOs) and regional transmission organizations (RTOs), have laid the foundation for grid-scale storage to compete against traditional options for supplying grid services. In California, there is more than a foundation; there is a mandate for a modest amount of storage capacity to be procured, as well as multiple pieces of legislation supporting grid-scale storage.

The importance of this regulatory framework in the electric-power industry should never be under-estimated.

Unfortunately, the viability of storage options—whether technical, commercial, economic, lifecycle, safety, and reliability, or otherwise—is still being called into question by the utilities charged with integrating storage into the grid. And the market for new grid assets, in general, is questionable in the near term given persistent and historically low electricity demand in most regions and lackluster economic growth.

Bottom line: Storage still lacks *replicable, compelling payback-driven* applications to attract either private or regulated-rate-of-return financing. The goal, after all, isn't a market the size of one or two typical combined-cycle plants annually, which is what the total market size is today. This, despite the fact that cost for the prevailing technology, the variety of batteries classified as lithium-ion, keeps plummeting and, according to one report, only 40% of the world's manufacturing capacity is currently being utilized.

One California utility specialist conceded that, if not for the mandate, there are less expensive ways to provide the same services. Another utility in the state, involved in multiple distributed and bulk-storage pilot, demonstration, and assessment projects, reported that storage "is not expected to be an attractive commercial investment until the 2025-2030 time frame." Yet the mandate requires the state's three investor-owned utilities (IOUs) to install over 1300 MW of storage by 2020.

If that's the sentiment in what everyone agrees is the *most* attractive state for grid-scale storage, system suppliers which have invested in hundreds of thousands of square feet of manufacturing space may be sitting with idle assembly lines for years to come, unless behind-the-meter installations dominate in the near-term.

Leaders of a pre-conference workshop at this year's Energy Storage Association (ESA) meeting identified and elaborated on the multiple value streams available for developers to monetize a storage asset. FERC has weighed in positively through several rulemakings to support use of storage for a variety of ancillary services among the ISOs and RTOs.

Congressional legislation now allows storage paired with solar to qualify for a generous investment tax credit (ITC). That should have been music in the ears of the prominent solar developers who started pursuing storage with gusto a few years ago, except several of them are facing insolvency and corporate restructuring.

The California ISO (CAISO) offers ancillary-services payments (spin, non-spin), regulation up and down,

DOE-funded demonstration project in Texas pairs wind with large-scale storage

resource-adequacy type capacity payments, and proxy demand response; a flexible ramping product is coming. PJM has Reg-D frequency regulation payments as well as capacity payments for non-generating resources. The Mid-continent ISO Inc (MISO) allows for short duration "stored energy resources" and a flexible ramping product is imminent. Storage is thought to be ideal for providing short- and long-duration cycle ramping.

NYISO and ISO New England Inc both have created means for storage participation. Hawaii wants fully dispatchable solar (accomplished by pairing solar with storage) to displace diesel generation. Oregon has also passed legislation requiring utilities in the state to begin procuring initial storage capacity by 2020; New York may not be far behind.

The seminal challenge is that, beyond the mandates, none of these value streams typically can support a storage asset investment. Even "stacking" multiple value streams rarely vaults the threshold for financial viability.

Broad technical challenges still loom, at least from the owner/operator perspective. System integration is one. Control and communications systems are another. One R&D-oriented stakeholder noted that control systems are "a focus of industry efforts today." An OEM, which supplies everything to a storage system *but* the battery, stated that inverter technology must be optimized. "All inverters respond differently to the grid," a company specialist said, "and the more inverters there are, the greater chance that they will interfere with each other."

Safety and lifecycle issues are paramount with owner/operators. One utility representative reported that the availability of the storage system (including power electronics, telecommunications devices, wireless communications, etc) for an all-solar home demonstration program was "abysmal." That's not a word you hear very often in public-utility presentations on technology.

Another utility hired an independent consulting company to evaluate safety issues for each storage system "offer." Apparently, in California, the CPUC has no authority over a third-party storage provider. Thus, it falls on the utility to make sure a storage asset doesn't take out the grid, or a large chunk of it, or a neighborhood.

One grid-scale storage specialist points to two landmark projects which could accelerate the pace towards a viable commercial market: a 100-MW (400-MWh) battery project in Southern California serving as the equivalent of a peaking gas-turbine unit, and a 52-MWh project in Hawaii serving as "fully dispatchable solar power." Success would demonstrate technical and financial viability in two well-recognized use cases. However, the peaker displacement project is not scheduled to be online for another five years. The dispatchable solar project could be online much sooner.

Other trends present opportunities. For example, in California, the energy portion of the average utility bill is declining or stable, but demand charges are rising. This presents an opportunity for storage to shave peaks and reduce demand charges. One company's business model is designed around reducing demand charges using storage and automated load shedding at the site, and sharing the savings with the customer.

The recently passed Assembly Bill (AB) 327 has removed legacy ratemaking rules resulting from the California energy crisis of 2000-2001, and has rationalized rules pertaining to net metering, renewable incentives, and who pays and how much to maintain the grid for all ratepayers. AB327 also requires the state's utilities to develop and submit plans for developing distributed energy resources—including storage.

Although it is not clear who ultimately wins or loses as AB327 is implemented, what is clear is that the state is driving a distributed-energy paradigm over the traditional centralized "big-iron and long wires" approach of the last century.

Here's another dichotomy: The state's utilities repeatedly find that bulk energy storage, pumped hydroelectric (PHS), and compressed-air energy storage (CAES), are economically viable but the "push," as one director called it, is towards small distributed-energy systems and the "deployment of new technologies." Nevertheless, this utility expects a move to a bulk storage project within five years, although it could be CAES, PHS, or a large flow battery.

Utilities in the vanguard of storage deployments and investment hail the present as the time to "try" new technologies. Utilities use words like "learning," "understanding," "long-term," and "strategic investment" when describing their programs and investments in energy storage. Suppliers, on the other hand, need to feed the beasts of their mega-factories now.

While California's AB2514 legislation (the "storage mandate" bill) requires IOUs to procure 2% of their peak load as storage (1% for the municipals and irrigation districts), there are caveats in the bill regarding cost-effectiveness. One might interpret

this as a potential "off-ramp" for utilities. But it's not that easy, noted one utility spokesperson.

The California Public Utility Commission (CPUC) is obligated to conduct an independent evaluation of cost and benefits as a "second opinion" and reportedly can impose penalties on the utility depending on what they conclude. Also, if other utilities find a technology economic, then the case for the utility which concluded the opposite is weakened.

Those sitting on vast manufacturing capacity, most of them lithium-ion battery suppliers, may have another challenge when the market finally hits that mythical knee in the curve: competition from other technologies. Advanced flywheels, a plethora of flow-battery chemistry systems, better lithium-ion options, advanced lead-acid batteries, and systems which combine batteries and ultra-capacitors are all on the cusp of breaking through the demonstration phase and into commercial applications.

Finally, if a commercial grid-scale storage market is struggling to emerge in the US, then it is embryonic in most other parts of the world, with the exception of Europe, China, and other developed countries like Japan, Korea, and South Africa. Countries like Brazil, Jordan, India, and others with ambitious renewable capacity additions are just now getting acquainted with grid-scale storage.

It might be surprising to learn, for example, that a major utility in India is targeting one-third of its generation to be renewable-energy based within a decade or so. The country in general faces a 2% deficit in energy and 3% deficit between peak demand and capacity. Jordan seeks 10% of its electricity to be supplied by renewable resources by 2020.

Significant wind capacity is being added in Brazil, where in the northern part of the country wind capacity factors can be between 50% and 70%. Unfortunately, the population centers are to the south where, according to a spokesperson, the wind characteristics are "completely different." This creates a potential need for massive amounts of storage, the spokesperson indicating that the logical option would be at least 2000 MW of PHS.

In sum, let's just say, in the US anyway, there are "seams issues" among the owner/operators who have modest expectations and needs *at best* for the next five years, regulators and ISO officials who have diligently legislated the grid-scale storage opportunity over the last 10 years, and suppliers which have built out manufacturing capacity for orders they needed yesterday. CCJ

Where all players in the aero community meet

Annual meetings of the Western Turbine Users Inc (WTUI) open with a series of plenary sessions that extend through the first morning of the conference. All attendees are invited and most come: Witness a cavernous meeting room and an audience of nearly a thousand—including owner/operators of LM2500, LM5000, LM6000, and LMS100 engines, plus suppliers of parts and services for those gas turbines.

The Monday morning program begins with an update on WTUI business matters—president's welcome, treasurer's report, introduction of the group's leadership team (Sidebar 1), new officers/directors, plans for upcoming meetings, etc. Next are short presentations by the OEM-licensed depots so important to the organization's success, a brief message from GE, and the respected Axford Report on the state of the market. All that was summarized last issue (CCJ No. 48, p 80).

After lunch and open time for circulating through the exhibit hall, the technical sessions begin. Over the next two days, users would participate in the breakout session focusing on their engine of interest—about nine hours of presentations and discussions that dig into the nitty gritty of gas turbine O&M. No better place for owner/operators of LM aeros to learn; if you don't understand something, there's always a colleague or supplier willing to help.

LM6000 breakout

Hands down, the most popular of the four breakouts at WTUI is the LM6000, chaired by Andrew Gundershaug, plant manager, Calpine Solano Peakers. More than 200 owner/operators participated in these sessions during the organization's 26th annual meeting in Palm Springs, Calif, March 20-23, 2016.

Gundershaug

[PLEASE INSERT HEADCUT OF GUNDERSHAUG, p/u 1Q/15, p 68]

One reason for this breakout's popularity: There are more LM6000s in land-based electric generation service than the other three engine models combined. Units installed, under construction, and on order total a nominal 1200—about 30% equipped with DLE combustion systems.

Roughly three hours is set aside during each breakout to review depot findings for the year prior to the meeting. Information gathering and presentation are collaborative efforts among key personnel at the participating Level 4 authorized depots—for the LM6000: IHI Corp (Ken Ueda), MTU Maintenance (Jens Arend), and TransCanada Turbines (Steve Willard).

The term "authorized" means qualified by the OEM and approved for access to GE technical documents, parts and service support, and the approved-vendor list for component repairs, etc. For more detail, consult service letter SL6000-15-002.

Significant to note, given the dog-eat-dog world of gas-turbine services, is that although the depots compete commercially they come together as an effective technology team to support owner/operators. One outcome of this effort is a nominal 100-page, full-color, printed summary of the depot findings containing scores of photos. In the editors' opinion, there is no better training program available for O&M personnel.

Depot findings with the greatest cost impacts were selected by the editors for coverage here:

Cracking of LPT first-stage blades. Multiple cracks on the trailing edges (TE, Sidebar 2) of low-pressure-turbine first-stage blades have been found during HGP inspections (25,000 hours) and major overhauls, and occasionally during borescope inspections. The cracks, while relatively slow to propagate, should be reported to your CSM immediately. It was said that approximately three-quarters of the LPT S1 blades scrapped during shop visits are trashed because of such cracking. TE thickness and coating quality of the damaged blades were confirmed within the OEM's limits.

According to one participating depot representative, there isn't much users can do to mitigate cracking other than to operate the engine within OEM guidelines and simply deal with any wear and tear identified.

A user asked if cracking has been found on both peaking and baseload machines. The answer: Yes, but it's more prevalent on peakers. However, no statistics were available. Cyclic operation also was said to impact crack propagation. When a crack gets to a certain point, the group was told, there is no choice but to stop operating and to repair/replace blades as required.

A new LPT S1 blade with a material change reportedly is under engineering review.

IGB gear-shaft pitting. Pitting/scoring outside of the OEM's limits was observed on the gear teeth of the horizontal gear shaft for an inlet gearbox


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1. WTUI leadership, 2016-2017

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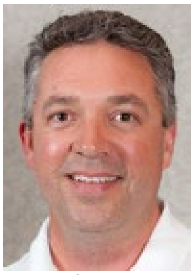
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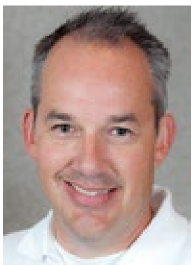
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after about 25,000 hours of service. Experts were concerned that cracks could initiate at pits. Direct cause of the damage could not be determined, although the following possibilities were considered:

- Fatigue damage from repeated force/pressure.
- Contaminated oil.
- Dry condition (lack of oil).
- High moisture.

Primary recommendation was to keep turbine lube oil clean. Also, hand turn the engine before a start after long storage.

HPT N1 leaf seals, SB 306. A borescope inspection of the first-stage nozzle row for the HP turbine in a DLE unit, accessed via the combustion liner, identified burn-through conditions on the leading edges of some nozzles, making an outage necessary. Investigators found the burning associated with the leakage of cooling air, caused by the deflection of inner and outer leaf seals and the loss of some portions of the seals. The coil spring holding the leaf seals in place was ineffective.

Damage to the combustor also may occur with ineffective leaf seals. This was the focus of the HPT N1 discussion at the 2015 meeting in Long Beach.

Recommended action was inspection of the combustion chamber to verify proper seating of the leaf seals. If overheating or burning is apparent, inspect the leaf seals. Any rework required should be done during an engine overhaul, and the recommendations made in service bulletin LM6000-IND-306 implemented.

SB-306 suggests the addition of brazed doublers to the inner and outer seals as well as replacement of the Rene 41 coil spring with one made of Inconel X-750. Manufacturing changes include a different nozzle casting and addition of a lug on the inner band to limit leaf-seal deflection.

HPC S3 to S9 spool damage. Inspection of the Stage 3-to-Stage 9 spool on an engine with more than 50,000 hours of service and 400 starts revealed damage on the upper surface of third-stage dovetail slot rails. The IRM does not address repair limits for damage found in this area, so the spool was removed from service.

During disassembly at the depot, damaged balance weights were found. Investigators believe fragments of broken weights caught between the lower blade platform and upper dovetail slot rail surfaces caused the damage. The depot set aside balance weights with the same part number until a proper engineering review could be done.

HPC blades. Discussion revolved around SB LM6000-IND-310, "HPC Rotor Stage 3 - 5 Blades Dovetail Coating Refurbishment," released Feb 26, 2016—just prior to the WTUI meeting. This portion of the presentation began with a case history carried over from the 2015 meeting offering the following "observed condition": HPC Stage 3 blade lift on a unit with about 12,000 hours of service and 6000 fired starts.

A borescope inspection identified both lifting of several S3 blades bearing the "K" designation on their respective platforms as well as blade movement when the rotor was turned over by hand. Note that the latest production blades (2015), distinguished by an "H" on their platforms, are recommended for peaking and load-following service. At last year's meeting the message was that "K" blades were fine in baseload units and can still be used in peakers if coating repairs are made within a normal interval.

Back to the case history: The top case was lifted for closer inspection and removal of the S3 blades. Heavy wear was noted along the dovetail coating faces, with mating wear in the dovetail slots of the S3-S9 spool. Most of the airfoils removed were scrapped because wear extended into the parent metal; the spool also was removed and declared "unrepairable" based on today's experience. This finding was of considerable interest because of the possibility that one or more blades could fail in service if the wear issue was not addressed.

A user reminded the group in Palm Springs that at the previous meeting in Long Beach, GE said it was planning to publish a SB based on starts. The discussion leader acknowl-

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2. Acronyms to remember

AGB—Accessory gearbox (also called the transfer gearbox)
AVR—Automatic voltage regulator
CCM—Condition maintenance manual
CCR—Customized customer repair
CDP—Compressor discharge port
CFF—Compressor front frame
COD—Commercial operating date
CPLM—Critical-parts life management
CRF—Compressor rear frame
CSM—Customer service manager
CWC—Customer web center (GE)
DEL—Deleted part
DLE—Dry, low emissions combustor
DOD—Domestic object damage
EM—Engine manual
FFA—Front frame assembly
FOD—Foreign object damage
FPI—Fluorescent penetrant inspection
FSNL—Full speed, no load
GG—Gas generator (consists of the compressor and hot sections only)
GT—Gas turbine (consists of the gas generator pieces with the power turbine attached)
GTA—Gas-turbine assembly
HCF—High-cycle fatigue
HGP—Hot gas path
HPC—High-pressure compressor
HPCR—High-pressure compressor rotor
HPCS—High-pressure compressor stator
HPT—High-pressure turbine
HPTN—High-pressure turbine nozzle
HPTR—High-pressure turbine rotor
IGB—Inlet gearbox
IGV—Inlet guide vane
IPT—Intermediate-pressure turbine (LMS100)
IRM—Industrial repair manual
LM—Land and marine
LCF—Low-cycle fatigue
LO—Lube oil
LPC—Low-pressure compressor (not on LM2500; just LM5000 and LM6000)
LPCR—Low-pressure compressor rotor
LPCS—Low-pressure compressor stator
LPT—Low-pressure turbine
LPTR—Low-pressure turbine rotor
LPTS—Low-pressure turbine stator
MCD—Magnetic chip detector
MOH—Major overhaul
NGV—Nozzle guide vane
OEM—Original equipment manufacturer
PB—Product bulletin
PN—Part number
PT—Power turbine (turns a generator, pump, compressor, propeller, etc)
PtAl—Platinum aluminide
RCA—Root cause analysis
RFQ—Request for quote
RPL—Replaced part
SAC—Single annular combustor
SB—Service bulletin
SL—Service letter
SUP—Superseded part
STIG—Steam-injected gas turbine
TA—Technical advisor
TAT—Turnaround time
TAN—Total acid number (lube oil)
TBC—Thermal barrier coating
TGB—Transfer gearbox (also called the accessory gearbox)
TMF—Turbine mid frame and thermal mechanical fatigue
TSN—Time since new
VBV—Variable bleed valve (not on LM2500; just LM5000 and LM6000)
VBVD—Variable bypass-valve doors
VIGV—Variable inlet guide vanes
VSV—Variable stator vane
VSVA—Variable-stator-vane actuator

edged that and alerted to all in attendance that the SB-310 released three weeks before the 2016 conference was that document (thorough reading suggested) and it recommended coating refurbishment after every 1500 starts.

Also reported: The OEM is working on an improved blade, one made of Inconel 718 instead of the current titanium and having a larger dovetail to improve stress distribution. Airfoil geometry of the improved blade—planned commercial release is 2017 at the earliest—will remain unchanged. Benefits of Inconel 718 include increased fracture toughness, a reduction in fretting wear, and no need for a wear coating.

It didn't take long for an attendee to recognize that a new spool would be required to accommodate the new dovetail configuration and ask: Do we keep reblading our existing spool until that time? "Yes" was the reply from the podium. Another user said he has experienced four of the failures described in the last 10 years. The floor leader understood his colleague's frustration and told the group he was not aware of any limits on allowable coating loss. "It's a judgement call," he said.

Discussion continued, prompted by another question: "For fatigue failure, is it better to use a new blade rather than a refurbished one?" A depot representative said generally there is no reason not to use a refurbished blade provided it has gone through the refurbishment process, which includes a health assessment and recoating.

DLE combustor change. DLE combustors come in two styles, the group was told: Those with brazed heat shields, those with threaded. The discussion leader reminded attendees that brazed heat shields are non-repairable because they must be machined out of their locations. The benefit of threaded heat shields is that they would be repairable, to reduce costs.

There was talk that at some point brazed heat shields may no longer be available. However, it was reported that the OEM has not yet confirmed the future will be threaded heat shields only. Nor has a repair process for threaded heat shields been finalized; field trials continue with positive results. Plus, users should not expect there would be a 100% yield on threaded heat shields sent for repair.

Attendees were made aware that a switch from brazed to threaded heat shields would require an upgrade to the combustor dome. Also, that the OEM would not recommend field replacement of threaded heat shields because of possible challenges associated with properly removing the locking pin.

A question from users during this portion of the program concerned HPC S11 vanes, which are addressed by service bulletin LM6000-IND-315, "S11 Compressor Stator Vanes Part Number Identification and Replacement." The attendee asked, "Can these be changed out during a site outage." The reply, "Yes, if you're in there for something."

Peak versus baseload operation. An open discussion on this subject exposes attendees to a wide range of valuable O&M experience. Definition of terms was the starting point both at the 2015 and 2016 meetings:

- Baseload means continuous operation 24/7 for power production, except for inspections at intervals of 4000 hours/450 starts, or annually, whichever comes first. It's important, the presenter said, not to expect that the engine always will be serviceable at the next inspection. It is possible unit condition will progress in 4000 hours to be unserviceable, but unlikely the progression will cause an unscheduled event within the inspection period.
- Peak load refers to engines started whenever power is needed and shut down after the peak is over. Several starts per day are possible. It was said that peaking operation of a ground engine is harder on the machine than commercial aircraft service. The reason: The aircraft engine is at peak during takeoff and at 40% load the rest of the flight.

During fast starts and stops, the presenter said, virtually all engine parts can be affected by thermal distress and material fatigue. Oil leaks are common in peaking service because

of the disproportional pressure ratio between seal air and sump air by fluctuating loads or long-term low-power operation. Small leaks are conducive to build-up of oil deposits, possibly causing bearing damage. Serrations on rotating seals and honeycombs of stationary seals suffer abnormal wear.

A series of photos illustrating the types of damage identified with peaking services included the following:

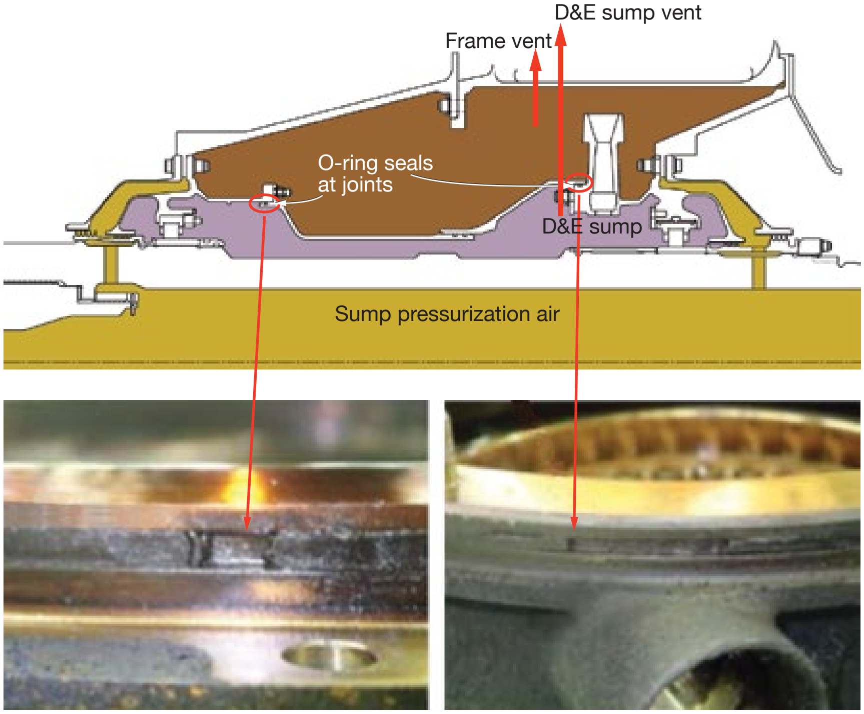
- Trailing-edge cracks on HPT second-stage nozzles.
- HPT shroud and blade-tip rubbing.
- Worn rotating air-seal serrations on the HPC rear shaft.
- Tip rubbing on HPC stator vanes and lands, leading to an increase in clearances.
- Pressurization of the oil sump, contributing to leakage.

The takeaway from this portion of the program was that peak-load operation can be more expensive than baseload operation. Reasons include the following: long-term operation as a peaker increases the wear of engine components, increases heat rate (decrease in efficiency), adversely impacts performance, and raises the cost of maintenance.

A user challenged the OEM, pointing out that "we're in the digital age. Perhaps this could be used to determine the true impact of starts." GE's response was that it has done a preliminary analysis using ORAP® data and was expecting to do more work with Strategic Power Systems Inc on this.

A depot representative said you can't always know the exact impact because it's very site specific and operations specific. Example: When you operate with NO_x water injection you take a hit; same when you run on Sprint™. The bottom line: Owner/operators cannot expect to see the maintenance intervals of 25,000/50,000 hours often sited in promotional literature. An attendee contributed to the conversation by saying that with 16 years of experience behind him, he recommends planning based on 16,000-hr intervals.

LP Sprint damage. The subject of Sprint damage was revisited later in the program. The group was shown photos of abnormally heavy erosion on the leading edges of VIGVs and S0 blades, and on the rub lands of LPC stator cases. Operators were urged to monitor their water flow rates, keeping them within the OEM's recommendations and using even less than that amount of water where possible. Maintaining spray water quality with spec also was stressed. Regular inspection of spray nozzles was stressed, with repair or replacement recommended when tips show signs of wear/erosion.



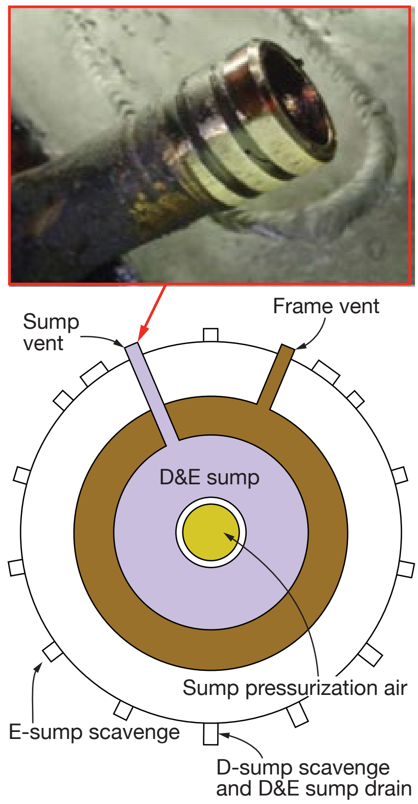
1. Arrangement of the frame, sump, and pressurizing air passage at the back end of an LM6000 shows where O-ring seal damage has been found

How users, depots, OEM interact to solve problems

Users may struggle with some issues for years before viable solutions are confirmed through fleet-wide operating experience of components re-engineered by the OEM. Coking in the D/E sump drain and D-sump scavenge line, located in the turbine rear frame (TRF) at the 6 o'clock position, is one of those. A review of editorial notes indicates coking has been covered in presentations and discussions in the LM6000 breakout sessions the last three years, at least. To review:

At the 2014 meeting (Palm Springs), one of the 2013 depot findings presented was "TRF D&E Sump Drain Coking"—specifically, moderate to severe coking in the No. 6-bearing D-sump oil-scavenge-tube outlet. SB LM6000-IND-244, "TRF Strut End Adapter Gasket Replacement" (Jan 1, 2014), explained that the drain hole could become blocked by the old square seal gasket.

A new gasket, with a larger center-hole diameter was introduced to reduce the risk of blockage. However, early adopters still were reporting moderate to severe coking after implementation of SB-244. The depots acknowledged more work was required to completely



2. Turbine rear frame looking forward helps better understand Fig 1. Inset shows hardening of the O-ring at the sump vent tube

fix the issue.

They recommended that users follow, at a minimum, the inspection and cleaning intervals presented in Table 12-1a, "Recommended Preventive Maintenance and Servicing Checks," of service letter SL6000-05-03 R3. The depot speaker suggested that the pre-

scribed intervals might require adjustment on a site-to-site basis.

At the 2015 meeting (Long Beach), one of the 2014 depot findings presented was Round Two of "TRF D&E Sump Drain Coking." The first slide in both the 2014 and 2015 presentations was the same, except for the photos. The Table 12-1a reference was repeated as well. But research into the root cause of the issue continued, with the following updates presented in 2015:

- Drain-line clogging, together with minor oil leakage into the TRF frame vent cavity from the sump, creates a layered buildup of oil deposits. The presenter attributed leakage of oil in the sump area to (1) a loss of sump pressurization during low power operation, and (2) hardening and embrittlement of O-rings in the joints of the sump components (Fig 1).

  Later in the meeting, during an OEM presentation on the same subject, a GE engineer reported that coking in the units affect typically was observed after two to three years of service. He pinpointed the location of the O-rings of concern and showed some photos of O-ring damage (Fig 2).

  The speaker also mentioned another possible root cause of the coking issue: Insufficient sump drain-line slope such that some oil remained in the line and coked because of the high heat. Attendees were urged to follow the recommendations in product bulletin PB-303, "Turbine Lube-Oil Drain Tubing Inspection." It ensures the slope for the D&E sump drain tubing from the TRF to the unit drain is greater than the 0.25 in./ft cited in the specification.
- Regarding the inspection and cleaning intervals, some users reported scheduling drain-line cleaning monthly.

At the 2016 meeting (Palm Springs), presentation of 2015 depot findings again included moderate to severe coking in the No. 6-bearing D-sump oil-scavenge-tube outlet. Information provided during the previous two meetings on this issue was reviewed. Progress since the 2015 meeting included release of SB LM6000-323, "TRF D- and E-Sump Preformed Packing Material Change for Improved Durability," which changed the O-ring material for the speed probes to AFLAS® to mitigate the hardening attributed to the high-temperature environment.

Regarding the coking issue, a depot representative echoed the advice offered a year earlier regarding more frequent drain-line cleaning, saying


Doing our part to deliver yours.
All of our in-stock aeroderivative and heavy IGT parts are available 24 hours a day, 7 days a week, 365 days a year– all around the world.

"The only thing you can do is clean it, clean it, clean it!" Comments from attendees included the following:

- "We've had this problem. We had a blown gasket. We replaced the gasket and still had the issue."
- "We also had this issue a number of times. We increased the diameter of the line and made the line shorter. Before it would be 8-10 months to see leakage again; now it's been over two years with no leaks." An attendee looking to clarify the comment asked if the machine was a peaker or baseload. It was the latter, which helps to mitigate the problem.
- "We see minor oil leakage in the TRF vent area. We ended up with a completely coked housing. O-ring hardening can be the cause of this."

One user's experience

A user case history closed the presentation/discussion of TRF coking—for this meeting, at least. Two engineers providing maintenance support for a European LM6000 fleet of more than two-dozen engines shared their experiences, beginning with typical findings:

- Oil coking at the 6 o'clock position.
- Oil droplets coming out of the sump drains at part load (not all engines impacted to the same extent). They called this a "bleeding sump," suspecting one or more of the following seals for underperforming: (1) labyrinth seals, (2) No. 6-sump O-ring, (3) TRF vent-tube O-rings, (4) No. 7-sump O-ring, and (5) open-end dynamic seals.

The depot contracted to correct the problem found coking at all but the labyrinth seals. Further, that the seals were hard and brittle with sections missing.

Here's what this fleet learned from its experiences:

- Coking is most severe in engines having the most part-load operating hours.
- At baseload, the VBVs are closed, sump air is at nominal pressure (so-called P25), and the air pressure in the frame exceeds that in the sump.
- At part load, P25 is lower and sump pressure exceeds the frame air pressure.
- Suspected leaking seals are the cause of the bleeding sump, the positive differential pressure across the oil seals having been compromised.

The road to a solution. The original O-rings were made of Viton®, which was limited to 400F service. First replacement material was AFLAS, as noted earlier. However, it was not recommended for applications over 450F. The users presenting said AFLAS was installed in some of their engines and the O-rings degraded after about 25,000 operating hours.

This owner/operator's engineers pursued an independent solution. The choice was Kalrez® 7075, good to 620F, which was developed for chemical and hydrocarbon sealing applications. The jury is still out on this material for LM6000 use, but the speakers said they would update the group at the 2017 meeting.

In addition, this owner/operator found open-end seals installed with the open-end out, rather than open-end in as one might expect—to keep oil from leaking out. The OEM said it didn't matter how the seal was installed because the differential pressure was so low, and the open-end out orientation facilitated installation. The fleet owner decided on changing to open-end in, towards the sump, as the IRM suggests.

Another leak-prevention alternative: The OEM's sump evacuation system (SES)—a/k/a sump sucker—described at the 2015 meeting. It is a good solution, said the users presenting, based on 4000 hours of operating experience. Only minor package mods were required to accommodate installation. These were described by the presenters, who suggested the SES might become obsolete if the leakage issue were resolved another way.

For those unfamiliar with the sump sucker, here are some of the system's highlights:

- Consists of a motor-driven blower

installed in the air/oil separator discharge line.

- Operates when the gas generator is running at low speeds and during load transients.
- Maintains the necessary differential pressure across the oil seals to avoid leaks during low-power operation.

User presentations

Real-time performance monitoring. Important subject, but time constraints prevented dropping below about the 10,000-ft level in terms of detail. The speaker, a US Navy "grad" with three decades of non-military LM experience—including plant operator, plant manager, and performance engineer (last seven years)—discussed performance monitoring in broad terms, touching on the following topics:

- Requirements for real-time performance testing.
- Historian.
- Correction factors/curves.
- Degradation.
- GE apps.
- Data resources—test cell or in-situ.

Starting with the last bullet point, he explained that test cell data are good for verifying engine guarantees but possibly not a realistic benchmark for plant work because the instrumentation and engine configuration may not be the same in the test cell as they are in the plant. In-situ data provide a true "apples-to-apples" comparison for performance assessments. Be sure to gather plant data with all equipment running, he advised—including the HRSG, if installed. Where actual and expected results are not in agreement, send to the OEM to find out what's causing the performance degradation. Example: Is the engine getting dirty?

Remember to correct performance calculations, he continued, for gas-turbine inlet temperature, barometric pressure, elevation, inlet pressure, exhaust pressure, fuel temperature, humidity, etc.

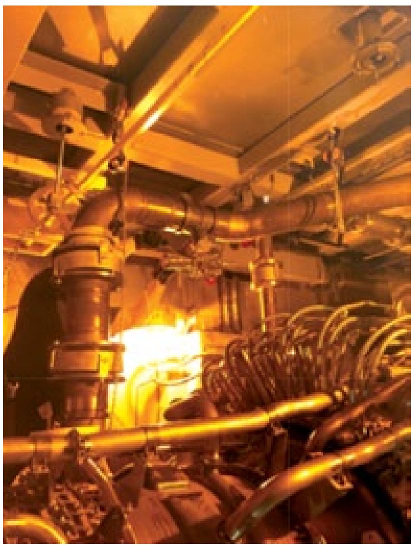
GE apps (applications for packaged power solutions) include a non-guaranteed performance estimator, which can assist in assessing how well your plant is performing. The speaker said your customer service manager should be able to get this for you through the company's Turbine Performance Estimator Portal. The CSM also should have access to runtime degradation curves, another valuable tool.

One attendee asked how to account for water injection/Sprint™. The response: Use GE apps. Measuring washing effectiveness was another area addressed as was the impact of fuel quality and temperature on heat rate. WTUI user members can access this presentation on the organization's website.

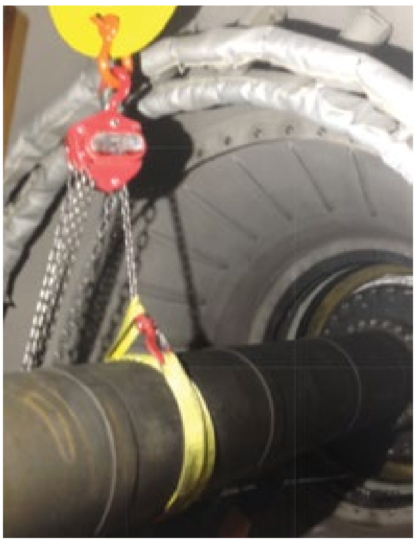
Potpourri of ideas. A plant manager recently assigned to a generating station equipped with two 2 × 1 combined cycles powered by LM6000PF engines, walked attendees through slides prepared by his predecessor. Like the presentation summarized immediately above, it too is posted on the WTUI website. The short presentation offered several best practices/lessons learned, including the following:

- A new monorail system to facilitate engine removal. It enables plant personnel to place the engine directly into the shipping container, eliminating the typical pick from a dolly to the container (see following presentation). The monorail also eliminates interference of the filter house with the crane. Eliminating picks, of course, reduces the risk of damage.
- Bushing changes. The speaker recalled the HPC event on his first day as plant manager when a nut backed off a VSV arm. Corrective action was to put RTV silicone on bolts and to replace all nuts when bushings were changed. The speaker noted that the OEM's manual doesn't mention the need for new nuts or the use of RTV.
- D&E sump drain blockage. (Refer back to the first part of this section.)
- Air/oil separator drains. Plant experienced freezing of both the large and small drains. Corrective actions: Shorten the pipe on the large drain to eliminate a low-point trap and add heat tracing to the small drain. Problem solved.
- Kidney loop filter. High concentrations of water were evident in all oil samples. LP Sprint™ operation got the blame. Corrective action included addition of kidney-loop filter systems on all lube-oil tanks. Result: Water was removed and oil cleanliness improved.

LM6000PF engine swap. The next speaker, representing a 3 × 1 LM6000PF-powered combined cycle, reviewed with breakout session participants lessons learned in changing out an engine. GE provided the technical



3. Air piping over the engine is rigged for bleed-valve removal



4. Generator shaft coupling is supported from fixture. The yellow lifting point for the shaft came with the package. Plant personnel removed the bulkhead in the generator compartment to access to the shaft easily

advisor for the change-out, the owner/operator the labor. The plant has a spare engine to rotate through the plant.

First step: Assure compliance with applicable GE service letters and product bulletins—these in particular:

- SL6000-09-01, "Load Test of Package Crane."
- PB-LM6000-IND-0295, "Trolley Replacement."
- PB-LM6000-IND-0310, "Crane Interlock Assembly."
- PB-LM6000-IND-0238 R2, "PT Perkasa Chain Hoist Replacement."
- PB-LM6000-IND-0284 R1, "Turbine Lift Fixture Load Pin."

In parallel with this effort, schedule an inspection for the package crane using a 10-ton test weight. Keep in mind that the crane hoist can be moved out of the package for inspection and testing once the air piping is removed. Also, remember to thoroughly review your rigging and lift plans, check spares inventory, and order consumables and other parts required.

Next, staging. Preparations include mobilization of H-frame and components, shim material to level beam, engine dolly, lift fixture, rigging, fuel manifold support fixture and bolting, test weights, forklift or zoom boom for handling heavy parts and the H-frame assembly.

Key steps in engine removal, the speaker said, include the following:

1. Offline water wash at shutdown and lock-out/tag-out (LOTO).
2. Disassembly according to GE WP 3010 with the following parallel tasks:
   - Air piping over the engine and bleed valves (Fig 3).
   - Instrument cabling, oil piping/tubing, clutch removal.
   - Generator shaft coupling, VBV boot, and air inlet boot (Fig 4). Be aware that the VBV expansion joint is heavy; use a forklift and pallet skid to remove.
   - Expansion joint, clamshells, slide exhaust diffuser (Fig 5).
   - Fuel supply piping and installation of the fuel-manifold support fixture (WP 3015).
   - H-frame assembly and load test.
3. Position engine lift fixture, loosen mounts, and check the center of gravity.
4. Remove stanchions and keep track of shims.
5. Lift engine with hoist and roll out of package onto the dolly (Fig 6).

When reinstalling the engine, keep these points in mind:

1. Allow the engine lift fixture to support the machine until alignment, shimming, and stanchion torque-up are complete.

5. Exhaust diffuser and clamshells are rigged for removal

6. When rolling out the engine, the speaker's experience suggests having a person at each corner. The challenge at this site was the reduced clearance between grade and maximum engine height because the package was installed below grade

2. Remove lift fixture and return package crane to storage position.
3. Align exhaust diffuser and install clamshells.
4. Reassemble components and remove fuel manifold support.

Lessons learned included:

1. More mechanics and helpers were needed. Plan for the next outage is to have two-man teams to handle the exhaust section, air piping, etc.
2. Have on hand shims of varying thickness to minimize delay time "looking."
3. Exhaust diffuser, clamshells, and expansion joint not shown in the OEM's manual; have spare fasteners on hand.
4. Protection: Have an assortment of plastic plugs and caps readily available to labor.

Special technical presentations

This year the WTUI leadership increased by 50% the number of speakers participating in the group's popular special technical presentations session to expose attendees to more subjects of interest beyond the basic engine. The Tuesday afternoon program in Palm Springs began at 2:30, an hour earlier than had been the norm. This provided time for three one-hour sessions in series, each offering three concurrent presentations.

The diversity of subject matter ensured there was likely something of interest to attendees in each time slot. Here's a sampling: aero control systems, EMI diagnostics for generators, HRSG superheaters, water chemistry, emissions monitoring, performance testing.

The only two speakers focusing on

LM gas turbines, Reed Services Inc's Dale Reed and MT R&O LLC's Rick Kowalski, PE, returned for the second year in a row to continue where they left off at the 2015 meeting in Long Beach.

Importance of LM6000 OEM prescribed maintenance

Reed's primary reference for this year's presentation was the same one he introduced to the group in 2015, GEK 105059, Volume 1/Chapter 12, when his focus was on commonly overlooked maintenance requirements for the LM6000PC (CCJ, 1Q/2015, p 86). He began by suggesting attendees get the latest edition of this publication because GE added to the general checks and inspections in 2016.

Reed's realistic. He noted at the beginning of his presentation that it's not practical to do all the things the OEM suggests in its manuals; you have to pick what's most important to your particular unit and situation. One example he gave is that when it comes to preparing a borescope plan, always do a complete inspection of the HP turbine.

Enclosure inspection was one of the focal points of the presentation. Reed suggested having a copy of the packager's manual for guidance. Anytime the package is accessible and a member of the O&M team is inside, everything that can be done should be done, he said. Confirming the proper functionality and performance of the following systems should be on your list:

- Air and ventilation system.
- Fuel system.
- Sprint system.
- Exhaust system.
- Oil system.
- I&C system.

An inlet and coupling inspection also was suggested as part of the package inspection. Places to check are the external surfaces of the volute and the coupling between the gas turbine and generator. Also, the volute internal surface and above the FOD screen.

Inspection of the engine exterior also can be done at this time. Depth of inspection depends on the time available. At a minimum, look for oil leaks and physical damage. Check both sides of the unit, taking notes on tasks to pursue as time permits. Hands-on wiggle check of components was recommended to review their condition in more detail.

Reed spent quality time on how to inspect the lube oil system and scavenge-pump inlet screen and filter; also on the inspection of liquid-fuel nozzles—including when to consider replacing them. An ensuing discussion on nozzle coking, burning, and wear was well received. Other topics covered included variable bypass-door rig inspection, ignition-system functional check with visual inspection of tip and electrode, fuel metering valves, compressor cleaning, functional checks of fuel, purge, and solenoid valves, compressor cleaning to meet performance objectives, vibration monitoring, replacement of first-stage HPC blades, etc. Qualified users can access Reed's presentation at www.wtui.com.

LM engine component repair and overhaul options for ageing machines

Kowalski, like Reed, is a subject-matter expert in the inspection, overhaul, and repair of aero engines for land and marine applications. Plus, both have complimentary aircraft engine experience. The messages the two experts had for WTUI members were confidence builders, providing especially valuable perspective for "landlocked" plant personnel with little or no access to in-house engine expertise.

As mentioned above, Reed told his audience that OEM-prescribed maintenance was important and vital to the health of their engines. However, most owner/operators cannot afford to do everything the engine manufacturer suggests at the recommended frequency. Priorities must be established by

The Western Turbine value proposition

If your job responsibilities involve the operation and/or maintenance of one or more GE land and marine (LM) aeroderivative gas turbines at a simple-cycle, cogeneration, or combined-cycle generating plant and you're not familiar with the Western Turbine Users Inc, please read on.

WTUI's annual meeting in March (next year at the South Point Hotel in Las Vegas, March 19-22, 2017) is the place to learn what you need to know about your engine—from both colleagues and industry experts—to grow in your job. Knowledge, of course, is the pathway to more responsibility and a bigger paycheck.

A history of the Western Turbine Users, the world's largest independent organization for gas-turbine owner/operators was published by CCJ and distributed at the organization's 25th anniversary meeting in 2015. Learn more about this user organization and how it can benefit you and your company by scanning the QR codes below with your smartphone or tablet.

Major contributors to the commemorative publication included Wayne Kawamoto, WTUI treasurer and plant manager of Corona Cogen; Mike Raaker, WTUI's historian and ambassador, and president of Raaker Services LLC; Sal DellaVilla, CEO of Strategic Power Systems Inc; Mark Axford, president of Axford Turbine Consultants LLC; Jason Makansi, president of Pearl Street Inc, and Steve Johnson, president of SJ Turbine Inc.

QR 1: Before incorporation, *contributed by Mike Raaker*
QR 2: After incorporation, *contributed by Sal DellaVilla*
QR 3: Legislative drivers of GT technology, *contributed by Jason Makansi*
QR 4: The LM engines, *contributed by Team GE*
QR 5: A turbine salesman remembers, *contributed by Mark Axford*
QR 6: WTUI's place in gas-turbine, power-industry history, *contributed by Wayne Kawamoto and Mike Raaker*
QR 7: Aero engine portfolio, *contributed by Team GE*
QR 8: Profiles of ANZGT, TCT, IHI, MTU, *contributed by the depots*
QR 9: User remembrances, *compiled by the CCJ editorial team*
QR 10: Vendor remembrances, *compiled by the CCJ editorial team*

QR 1 QR 2
QR 3 QR 4
QR 5 QR 6
QR 7 QR 8
QR 9 QR 10

the user and they must be based on hard knowledge not a CFO's whim.

Kowalski's message was similar: He encouraged participants in his session to challenge the OEM for information to enable economic decisions on repair/replace, and not just accept as fact that a part may be scrap. His presentation last year focused on possible dispositions: accept/use as is, rework, repair, reject, and scrap. These are terms important to understand and remember. Kowalski reviewed them in his 2016 presentation, which registered WTUI user members can access at www.wtui.com. Alternatively, you can get a summary from CCJ 1Q/2015 on p 87.

The repair expert's goal was to get

LM engine owner/operators to embrace commercial aviation approaches in hardware evaluation and maintenance strategies. He began with a market assessment, which suggests LM users have significant market power that they may not be using to competitive advantage unless perhaps their company owns a large fleet of engines. Kowalski's talking points were the following:

- LM engines maintain a strong track record for performance and reliability.
- Cost to upgrade drives decisions to maintain or replace parts and engines.
- Access to inventory is controlled and can be limited.
- There is a finite availability for replacement parts in the market.
- OEM guidelines and recommendations can drive decisions for replacement versus repair for serviceability.
- There is an expressed need for salvage options with existing engine components.
- Commercial aviation with FAA concurrence is developing working strategies to give engine and system owners greater control of their destiny.

Kowalski's market observations were conducive to his suggestion that WTUI's stated mission (available on the website) could be expanded along commercial aviation's initiatives to support increased engine-owner control of the equipment. Continuing, he said, WTUI's user members, OEM affiliates members, and associates members each have a role in this vision and a stake in the outcome; WTUI would provide the common ground.

He stressed economic responsibility in his presentation, introducing military standards 480 and 1520C, which form the basis for a corrective action and disposition system to identify and correct causes of manufacturing nonconformances, prevent the recurrence of wasteful nonconforming material, reduce the cost of manufacturing inefficiency, and foster quality and productivity improvement. He suggested expanding the use of these documents to engine-run hardware.

Knowing owner/operators would require detailed information to support decision-making, Kowalski pointed out that commercial aviation-engine owners are entitled to technical data and have repair decision rights. He suggested this as a possible WTUI initiative. The FAA, he explained, has formally recognized the rights of airframe, engine, and airframe/engine component owners to manage the repair and overhaul of their fleets and provided access to OEM technical data.

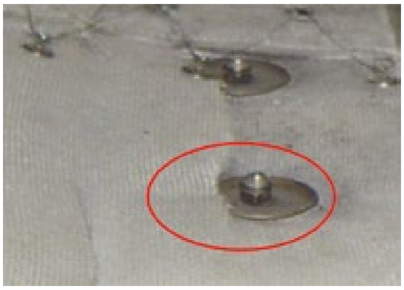
In wrapping up, Kowalski called for improved participation between engine owners and GE for the expanded serviceability of engines and engine hardware.

Vendor fair, a big part of the learning experience

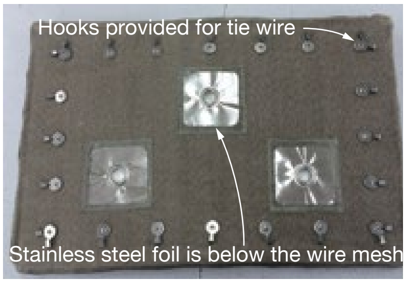
Vendor fairs at user-group meetings are win-win events: Plant personnel learn about products and services they otherwise might not be exposed to and suppliers gain access to those who might benefit from their solutions. Given today's small staffs, and the high cost of visiting plants, such venues may offer the only practical way for buyers and sellers to connect face-to-face. This is particularly true concerning peaking facilities powered by remote-start aeros at locations without permanent staff.

At the Western Turbine Users Inc's 2016 conference, there was the traditional high visibility and robust representation in the exhibit hall by the OEM and the four depots licensed by GE to inspect and repair the engines addressed by the group: Air New Zealand Gas Turbines, IHI Corp, MTU Maintenance Berlin-Brandenburg GmbH, and TransCanada Turbines.

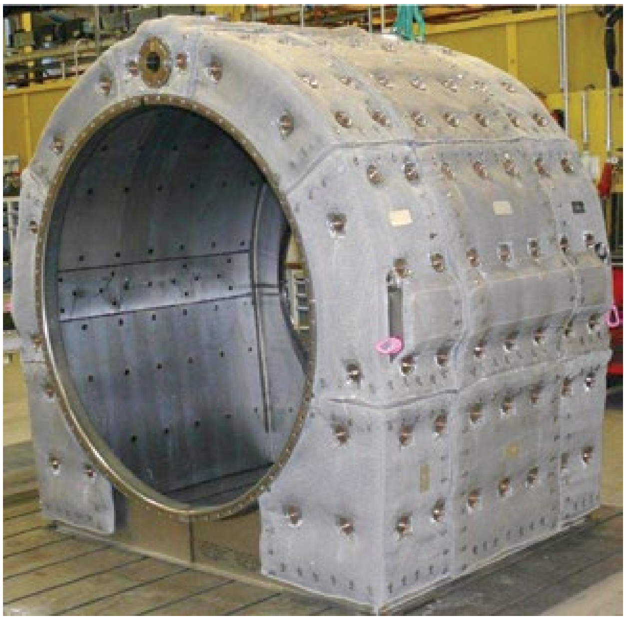
However, these companies were only the proverbial tip of the "exhibitor iceberg" and generally well known



7. Engine vibration and the use of flat washers for attaching insulation to the exhaust casing limit insulation lifetime



8. Stainless-steel-reinforced high-temperature cloth insulation protected by stainless foil and secured to the exhaust casing using stainless mesh is Arnold's recipe for success



9, 10. Tight-fitting insulation system is designed to maximize life

to attendees—at least by name. There were another 150 companies in the hall, many virtual unknowns to plant employees—about one-third of whom were attending their first WTUI meeting.

Sidebar 3 lists the exhibitors at the Palm Springs event, with 2015 CCJ print and CCJ ONline electronic advertisers highlighted in boldface type. You can access information from these companies by simply scanning the accompanying QR code with your smartphone or tablet.

3. Exhibitors in Palm Springs (2016)

QR 1	QR 2	QR 3	QR 4	QR 5	QR 6	QR 7
QR 15	QR 16	QR 17	QR 18	QR 19	QR 20	QR 21
QR 29	QR 30	QR 31	QR 32	QR 33	QR 34	QR 35
QR 43	QR 44	QR 45	QR 46	QR 47	QR 48	QR 49

AAF International (QR 1)
ABB Inc (QR 2)
Advanced Chemical Technology Inc
Advanced Filtration Concepts (QR 3)
Advanced Turbine Support LLC (QR 4)
AGTServices (QR 5)
AGTSI (QR 6)
AHM Associates Inc
Airgas Specialty Products
AMETEK Power Instruments
ANZGT (QR 7)
AP+M (QR 8)
ARB Inc
Arnold Group (QR 9)
Arrow Products Support
ATCO Emissions Management Ltd
Babcock & Wilcox Co
Baseload Power and Generation Parts & Services LLC
BASF Corp (QR 10)
Borri Power (US) Inc
Braden Manufacturing LLC
Bremco Inc (QR 11)
Caldwell Energy (QR 12)
Camfil Power Systems (QR 13)
CEMTEK Environmental
Champion GSE
Chromalloy
CLARCOR Industrial Air (QR 14)
Clean and Science Co Ltd
CleanAir Engineering
Combined Cycle Journal
Compression Source Inc
Conntect Inc
Cormetech Inc (QR 15)
Crown Electric Engineering & Manufacturing (QR 16)
Cullum Detuners Ltd
Cust-O-Fab Specialty Services (QR 17)
Danfoss High Pressure Pumps
DCL International Inc
Dekomte de Temple (QR 18)
Detector Electronics Corp
Diesel & Gas Turbine Worldwide
Doble Engineering Co
Donaldson Company Inc (QR 19)
Drake Controls LLC
Duct Balloon/G R Werth & Associates (QR 20)
ECT Inc (QR 21)
Electrical Maintenance Consultants Inc
eLogger
Emerson Process Management (QR 22)
EMW filtertechnik GmbH
Environex Inc
ep3 LLC (QR 23)
EthosEnergy Group (QR 24)
Evoqua Water Technologies
Exponent Inc
Fossil Energy Research Corp (FERCO)
GARD Specialists Co
Gas Turbine Controls Corp (QR 25)
GasTOPS Ltd
GE
GE Inspection Technologies
Groome Industrial Service Group (QR 26)
GT Ice
W L Gore & Associates Inc
Hach Company
Haldor Topsoe Inc (QR 27)
Hilliard Corp (QR 28)
HPI LLC (QR 29)
HRST Inc (QR 30)
Hy-Pro Filtration (QR 31)
IHI (QR 32)
Innovative Steam Technologies (QR 33)
Inspection Manager Pty Ltd
Integral Cables Inc
Integrated Turbomachinery Inc
Interlink Power Systems

Never has it been so easy to aggregate information.

The organization's officers and directors recognize the challenge of trying to get through the exhibit hall to identify the vendors of greatest interest at the moment and to at least have a brief discussion with each. That's why the WTUI vendor fair is open for nearly 20 hours over three days. Most user groups just allow users and suppliers to connect for three or four hours on one evening.

CCJ editors have attended all the Western Turbine meetings over the last decade and are relatively familiar with the majority of exhibitors and their products. But every year, they'll find a couple of "new" companies. This year, the "surprise" was thermal insulation systems from Arnold Group of Filderstadt, Germany for the exhaust casings of LM2500 and LM6000 engines. The editors could not recall seeing insulation systems in the exhibit hall nor could they remember ever hearing of insulation concerns during the breakout sessions.

But Pierre Ansmann, Arnold's global head of marketing, assured that insulation deterioration on many engines in the LM2500 and LM6000 fleets was causing one or more of the

QR 8 QR 9 QR 10 QR 11 QR 12 QR 13 QR 14

QR 22 QR 23 QR 24 QR 25 QR 26 QR 27 QR 28

QR 36 QR 37 QR 38 QR 39 QR 40 QR 41 QR 42

QR 50 QR 51 QR 52 QR 53 QR 54 QR 55 QR 56

Iris Power-Qualitrol
Jet Aviation Specialists Inc
Johnson Matthey
Karl Storz Industrial-America Inc
Kobelco Compressors America Inc (QR 34)
Koenig Engineering Inc
Maximum Turbine Support Inc (QR 35)
Mee Industries Inc
Meggitt
Metrix Instrument Co
Mistras Group Inc (QR 36)
Mitsubishi Hitachi Power Systems Americas Inc (QR 37)
Montrose Environmental Group Inc
MTU Maintenance (QR 38)
Munters Corp
NAES Corp (QR 39)
Nalco Co
National Electric Coil (QR 40)
Nationwide Boiler Inc
OEM Parts Network Inc
Olympus
ORR Protection Systems
Parker Hannifin Corp (QR 41)
PAS MRO
Peerless Mfg Co
Peter Paul Electronics Co
Petrotech Inc
PIC Group Inc
PME Babbitt Bearings
Pneumafil/Nederman
Powerflow Fluid Systems LLC
PowerPHASE LLC
Precision Iceblast Corp (QR 42)
ProEnergy Services (QR 43)
Puretec Industrial Water
Quality Avaition Inc
Quality Generator Services
Reed Electric and Field Service
REXA
Robinson Fans Inc
Rochem Technical Services USA Ltd
S J Turbine Inc
Score Energy Ltd (QR 44
Siemens Industry (QR 45)
SISU Energy & Environmental
SKF USA Inc
Snap-on Industrial
Sound Technologies (QR 46)
SSS Clutch Co (QR 47)
StandardAero
STIG
Strategic Power Systems Inc (QR 48)
STS Aviation Group
Sulzer Turbo Services Houston Inc (QR 49)
Swan Analytical USA
Sweeney, Hydratight
Switch Filtration
Synergy Catalyst
T2E3 Inc
TAW Miami Service Center
Technical Training Professionals (QR 50)
Teledyne Monitor Labs Inc
Thermo Fisher Scientific Inc
TransCanada Turbines Ltd (QR 51)
TRS Global (QR 52)
Turbine Technics Inc (QR 53)
Turbine Technology Services Corp (QR 54)
TVS Filters
Universal Analyzers Inc
US Petrolon Industrial Inc
Vector Systems Inc
Veotec (Americas)
Vitaulic Co
Weir Specialty Pumps (Roto-Jet)
Woodward Inc
World of Controls Corp (QR 55)
Wunderlich-Malec
Zokman Products Inc (QR 56)

following issues: excessive heat in the package (sometimes demanding increased ventilation), material degradation, excessive noise, damage to electrical and I&C cabling, hot spots, etc.

One of the problems associated with traditional insulation systems for aeros was said to be an ineffective method of attaching the insulating material to the engine. In such cases, Ansmann noted, engine vibration can wear away insulation at the point of attachment relatively quickly—especially when thin layers of marginally effective insulating material are used (Fig 7). He cited instances where insulation blankets have to be repaired or replaced at each outage.

Arnold's solution, Ansmann continued, is a stainless-steel-reinforced high-temperature cloth insulation protected by a layer of stainless foil and secured with a vibration-resistant stainless mesh (Fig 8). Note in the photo that straight washers are not used; they are crimped to avoid a flat surface that could cut through the insulation.

Another feature of the Arnold system, the editors were told, is interlocking steps between adjacent blankets to avoid gaps that occur because of casing thermal expansion. Figs 9 and 10 illustrate a completed project. CCJ

Windscreens improve performance, reduce O&M cost of ACCs

By Steven C Stultz, Consulting Editor

Air-cooled condensers depend on steady air flow created by a properly designed system of axial-flow fans, normally elevated significantly above grade. Induced by the fans, ambient air then flows vertically through the tube bundles above, condensing the steam within those tubes.

During high winds, the condenser outer shell (wind wall) deflects the ambient air, producing a jet stream below, along the fan inlet region. Jet stream conditions (Fig 1) lead to less air flow (suction starvation), reduced pressure, mechanical stress on the fan blades and gear reducers, and increased backpressure on the system, reducing steam-turbine output. An extreme crosswind can mean greatly reduced air uptake, fan stalls, blade damage, and costly motor and gear/drive maintenance and repair.

Although such conditions are both location and time specific, some stations have turned to a system of windscreens (shields) to eliminate, or at least reduce, this jet-stream effect and minimize unfavorable air flow patterns (Fig 2).

Overall ACC performance

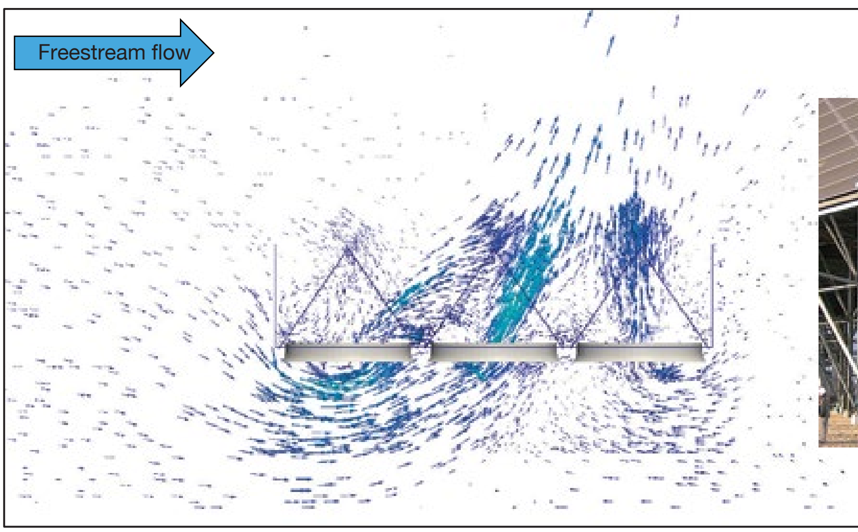
Wind effects vary dramatically from plant to plant, and from season to season. Factors also include ACC orientation onsite, the design sizing of the ACC and fans, and the design of the steam turbine. Nearby buildings, storage tanks, industrial facilities and trees also can have an impact. There is no one-screen-fits-all solution.

If wind is a maintenance or performance factor, the common goal is to design and place screening around the perimeter of the fan system to create uniform air flow into the fans, reduce vibration and stress created by variable winds, and normalize the amperage on the motors driving the fans.

Screens in a cruciform pattern under the ACC will also help enhance air flow into the fans. Balanced and efficient fan operation should then limit equipment damage and improve thermal performance. Service and maintenance should be more predictable.

To date, most windscreen installations are retrofit projects. Many benefits can be measured, but others are still in review. The common parameters studied are:

- Fan performance.
- Blade maintenance.
- Gearbox and motor damage.
- ACC thermal performance.
- System backpressure.
- Steam-turbine output.

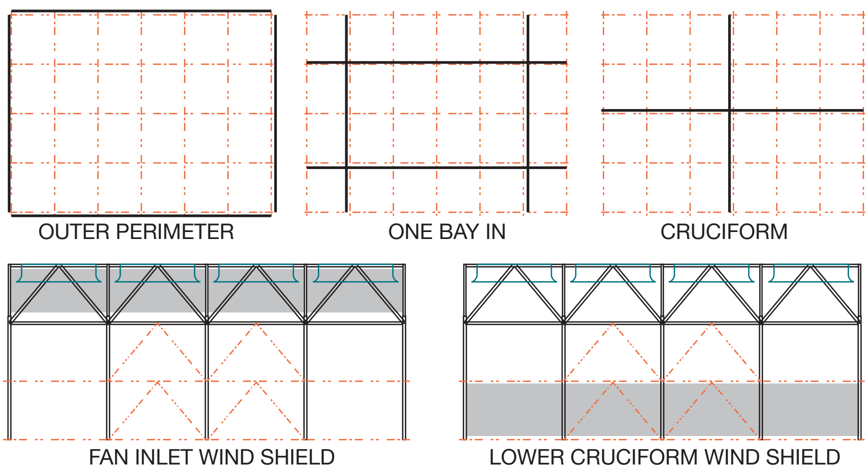


1. Typical impact on ACC of a 9-mph wind without windscreens installed

2. Windscreens and shields are designed to reduce negative airflow patterns. Shown here is an example of a fixed screen

3. Windscreens serving ACCs at a few plants are effective despite being rudimentary. This one was made locally from corrugated sheet steel

4. Mesh screens are designed for specific sites and placement



5. Windscreens come in a variety of arrangements

Perhaps the best summary was presented at the 2015 ACC Users Group meeting in Gettysburg (click on "Presentations" button at www.acc-usersgroup.org); the core information is included and updated here. Plant personnel know that wind effects on ACCs are drawing increased global attention, and that impacts include thermal performance, fan blade damage, and cell-by-cell fan duty, among others. It is difficult, however, to quantify and measure all thermal performance issues, backpressures, cell-by-cell performance, and other specifics.

But with more than 50 ACCs worldwide already using windscreens or shields, wind-effect experience and knowledge are growing quickly through commercial case studies, smoke tests, CFD analyses, and a variety of field and wind-tunnel examinations.

6. Screens are designed to accommodate services and structures

Materials, options

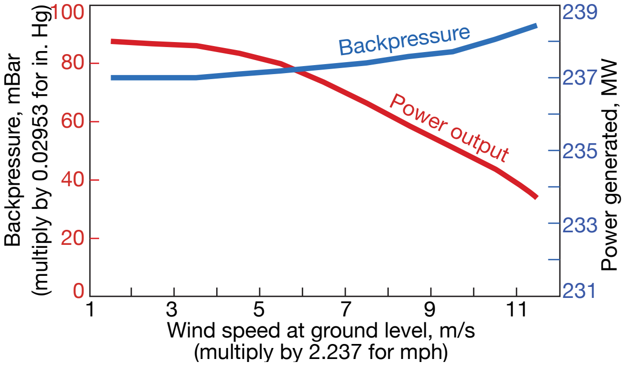
Windscreen and shield materials vary, including local resources as shown in Fig 3. However, most installations use a fabric system in a permeable mesh format ranging from about 40% to 75% solid, and with a range of pressure-drop coefficients (Figs 2 and 4).

Although screen placement configurations vary, typical installations are shown in Fig 5. The outer perimeter location is the most common, elevated around the fan inlet section of the ACC structure on site-specific sides. Such installations must often allow for structural bracing, pipe work, cable routings, and other interferences, especially for retrofit projects (Fig 6).

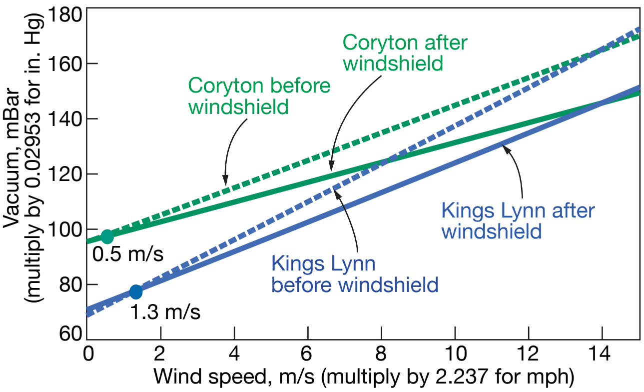
Early British tests, results

ACC windscreen installations began in 1998, in the United Kingdom at the 360-MW King's Lynn combined-cycle station in Norfolk, now owned by Centrica Energy. This installation, by Galebreaker Group (Ledbury, Herefordshire), is cruciform (cross-shaped) with the screens going from grade up to the fan housing.

Of similar design, the first US installation was in 2003 at Reliant Energy Inc's Bighorn Station (now NV Energy's Walter M Higgins Generating Station)—a 530-MW F-class combined



7. ACC performance falls off as wind speed increases. Results are for a 750-MW combined cycle operating at 50F ambient



8. Impact of wind speed on vacuum at two ACC-equipped UK generating plants

cycle in Primm, Nev, about 40 miles south of Las Vegas.

Early studies in the UK determined that high winds under ACCs increased system backpressure, thereby reducing power output. King's Lynn, commissioned in 1997, decided the following year to install the cruciform screens which were fabricated using 55%-solid PVC-coated polyester mesh.

Operators found that with these screens, ACC vacuum improved when ambient winds increased, because of improved fan performance. Measured in 2006 with average winds of 9.6 mph, vacuum had improved by an average of 0.165 to 0.178 in. Hg. In 2011, perimeter screens were added (with one side motorized).

Also in the UK, personnel at Coryton Power Station, a 753-MW combined cycle commissioned in 2002, determined that high winds under the ACC increased system backpressure and reduced power output (Fig 7). Further research at Coryton included CFD modeling. A major concern beyond wind shear under the fans was the adverse impact on LP-turbine vacuum.

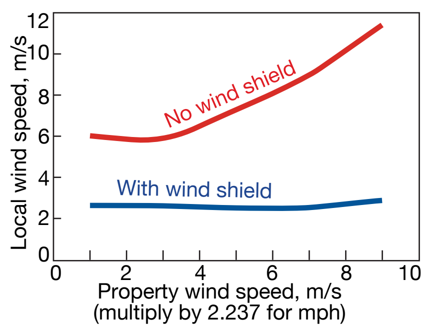
The station added Galebreaker perimeter screens at various heights in 2004. Screen material was identical to that used at King's Lynn. In 2005, based on an average wind speed of 8 mph, vacuum had improved by an average of 0.148 in. Hg (Fig 8).

North Battleford (Canada)

North Battleford Energy Centre, Saskatchewan, Canada, installed screens in 2014—its second year of operation. Battleford is a 1 × 1, 260-MW 7FA-powered combined cycle with an air-cooled condenser arranged in two streets, each with five fans.

Owned and operated by Toronto's Northland Power Inc, Battleford is part of an overall initiative to deliver baseload power to support Saskatchewan's economic growth, and intermediate on-demand power as needed. The unit has been operating more than 8000 hr/yr at from 50% to 100% of rated output.

9. North Battleford, a 1 × 1 combined cycle powered by a 7F.04 gas turbine, relies on perimeter screens for its ACC



10. Influence of wind shield on airflow speed under ACC is dramatic

During its initial (pre-screen) operation, the unit experienced severe ACC fan and platform vibration with up to 20 trips per fan per day. Wind was believed to be a major contributing factor. All equipment at the site was specified with features based on Northland Power's experience with cold-weather applications and freeze protection.

Average ambient temperature at the plant is 40F with low humidity and normal winds of 8 to 12 mph. Because of freezing potential, all fan drives are variable speed. In winter, half of the ACC can be isolated for protection; fan speed can be reduced, and reversed if necessary.

Northland Power decided to install wind shields and permanent wind monitoring equipment. In May 2014, Galebreaker installed 40%-permeable-mesh perimeter screens able to withstand 90-mph winds.

Screens were *hooked* onto the existing structure, on the north, west, and east elevations (south is protected by the turbine hall). This screen design extends down about 21 ft from the bottom of the wind wall, covering about half the grade-to-deck height (Fig 9). By the end of 2014 the unit was experiencing zero fan trips. Air-flow speed below the fan deck was stable (Fig 10).

Asked recently about these modifications, Richard Pratchler, Battleford's maintenance manager, explained "We did not install windscreens to improve performance of the ACC. We installed the screens to try and eliminate wind-induced fan vibration trips.

"Our fans are driven by VFDs and

11. Secondary pinion gear damage suffered at Gateway Generating Station

we can vary the speed from 15% to 100%. At certain rpm and wind conditions we were getting an unacceptable number of fan trips. With a combination of blocked speed ranges and screens, wind-induced fan vibration trips have been eliminated. From this perspective the project was a complete success.

"I do believe that the screens have improved ACC performance," he continued, "but that was not part of the project and we did no testing to determine performance effects." Historically, Battleford has exceeded thermal-performance expectations.

Gateway

Pacific Gas & Electric Co's Gateway Generating Station, Antioch, Calif, achieved COD in January 2009. The nominal 530-MW, 2 × 1 combined cycle, includes a 36-fan ACC (six streets with six fans each), designed for maximum ambient temperature of 104F.

By late 2010, gearbox lube-oil sampling showed metal particulates, and fan vibration readings were increasing on 10 of the 36 fans. When inspection covers were removed, half of those inspected had severe damage to the secondary pinion gear (Fig 11).

All probable causes were reviewed, including:

- Vibration.
- Fan stall caused by wind gusts and high winds.
- Gear-tooth hardness.
- High starting torque.

Strong winds are typical at Gateway, and can be accelerated by the venturi effect of the surrounding area. Average annual wind speeds are 9 to 10 mph, but afternoon speeds of 15 to 20 mph are common. Screens were installed in 2011 to break up the winds. They were placed one bay in, extending from the fan deck half way to the ground. Because the screens also extend to the perimeter, each corner cell is screened on two interior sides (Fig 12).

The screens installed in 2011 have been effective in breaking up the wind. However, any system improvement beyond fan damage has been difficult to measure. Screen design and location were based on existing installations rather than on a concentrated site-specific and unit-specific study (similar to North Battleford). Therefore, the one-bay-in might or might not have been the optimum screen placement.

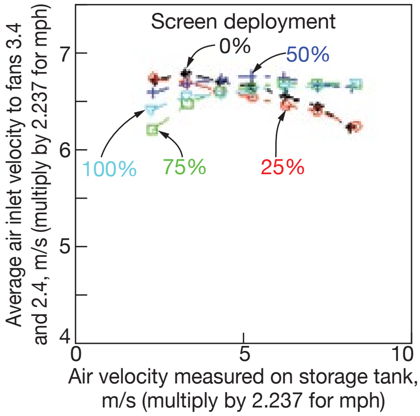
12. One-bay-in screen is installed at Gateway

13. Extensive ACC field tests were conducted at Caithness Long Island Energy Center

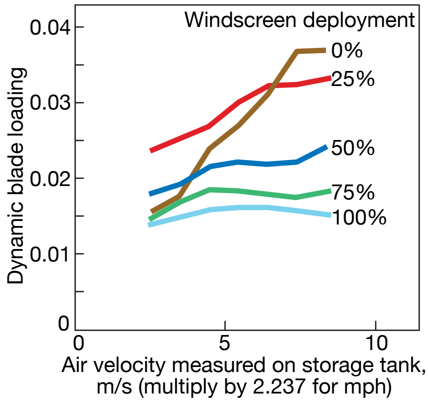
14. Caithness screens are shown retracted (front) and deployed (right side and rear)

Caithness

Perhaps the most detailed and long-term windscreen study is ongoing at the 350-MW Caithness Long Island Energy Center, an ACC windscreen retrofit project and analysis that began in 2012. Caithness was first placed into operation in 2009 (Fig 13).



15. Effects of wind speed and windscreen deployment on the average air inlet velocity to fans 3.4 *and* 2.4 are illustrated in the chart. Note the positive effect of the screen at higher wind speeds and its negative effect at lower wind speeds. Breakeven is about 9 mph (4 m/s). Best results are achieved with 50% screen deployment (up to a wind velocity of 18 mph)



16. Effect of wind speed and windscreen deployment on the dynamic blade loading of fan 3.4 reflects highest loading at highest wind speeds. Screen deployment reduced dynamic blade loading by a factor of from two to three

The Yaphank (NY) facility has a 1 × 1 combined cycle with an 18-cell ACC (three streets with six fans each). During the first period of operation, the ACC experienced cracking of fan blades and vibration issues, as well as a few motor-trip problems.

The aerodynamic impact of wind on fan operations was then studied. Early ACC testing, including fan-intake smoke analysis, was a joint effort by Caithness, Siemens Energy, and Howden Group Ltd. GEA Heat Exchangers supported with structural input and reviews.

The site is subject to high winds, explains Siemens Energy's Bill Wareham. "We are located five miles from the south shore of Long Island, with prevailing winds out of the southwest off the ocean. Wind speeds of 10 to 20 mph are fairly common, and we have had two major storms over the past five years (Hurricanes Gloria and Sandy). On a few occasions each year we get wind speeds approaching 50 mph."

Various screen configurations were evaluated. Following these placement tests, Caithness was outfitted with retractable perimeter windscreens by Galebreaker, a unique *rolling* feature at time of installation in 2012 (Fig 14). The screens can withstand 120 mph winds by design. Also, during this retrofit the six-blade fans were replaced with nine-blade fans to address vibration and loading concerns.

Retractable screens were selected because of the potential hurricane-force winds. With fixed screens in place, such winds could exceed the structural limit of the ACC. Then, because the screens are retractable, the site was selected for in-depth study, and for determining the effects of screens in various deployment conditions. When fully deployed, the screens cover approximately half of the grade-to-deck vertical dimension.

During the next three years, comprehensive research generated a vast amount of data with selected measurable benefits, primarily more uniform inlet velocity and a significant reduction in dynamic fan-blade loading.

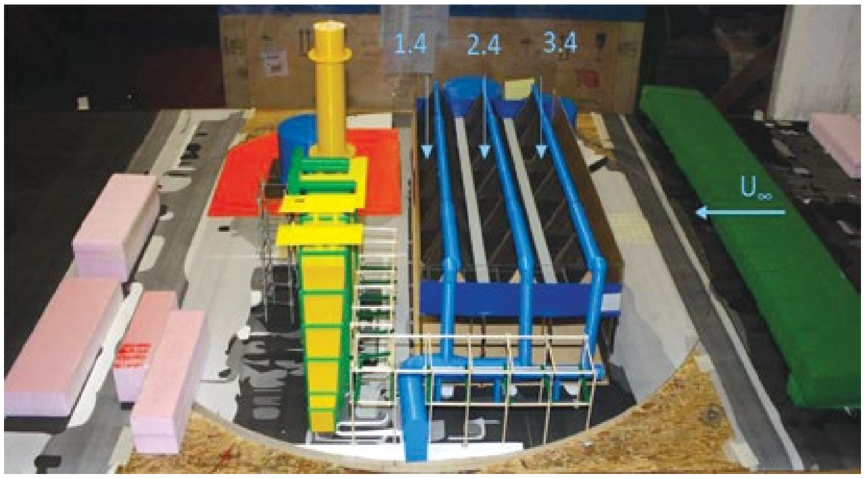
Study participants were Maulbetsch Consulting, Galebreaker (windscreens), Howden (fans), Senta Engineering LLC (CFD), University of California-Davis (wind tunnel), and the Caithness Long Island Energy Center (host site and test operations). The study was funded by the California Energy Commission. A few testing specifics follow:

The immediate impact of adding screens seemed to be improved (more uniform) air flow entering the windward-side perimeter fans and reduced stress on fan blades.

Fan data were collected for 18 months. For a period of two months in 2014, data were gathered for two cells (3.4 and 2.4) at full load and with all fans at full power. Fan inlet velocity was then plotted against wind speed measured at the storage tank wind vane (Fig 15). Data sorting parameters included wind direction and screen position (0%, 25%, 50%, 75%, and 100% deployment).

For the two cells combined, at average air inlet velocity:

1. Screens had a positive effect (fan flow rate) at higher wind speeds.
2. Screens had a negative effect (fan flow rate) at lower wind speeds.
3. A wind speed of about 9 mph was break-even.
4. Screen deployment of 50% offered the best results (up to a wind velocity of 18 mph).



17. A physical wind-tunnel model was developed to advance the depth and breadth of the Caithness studies

Data also were gathered on:

- ACC recirculation (heated plume air back into the inlet stream).
- Steam-turbine backpressure.
- Dynamic fan-blade loading.

For blade dynamics, screen deployment showed significant benefit (Fig 16). Screens reduced dynamic blade load at higher wind speeds by a factor of from two to three. Thermal performance and backpressure benefits were not as clear.

A physical wind-tunnel model (Fig 17) was created at UC-Davis to advance both the depth and breadth of the wind and windscreen studies at Caithness. Study results showed positive correspondence with field data, an accurate physical representation for clarity and understanding, and the ability to explore alternatives. In this case, alternatives were:

- No screens.
- Perimeter screens.
- Perimeter plus cruciform screens.

CFD modeling was created that gave highly detailed representations

18. **ACC serving the 1 × 1 F-class** combined cycle at CCC Saltillo in Mexico currently operates with a combination of sheet-metal wind walls and 60%-mesh windscreens

19, 20. Achieving maximum performance involves thorough inspection and the plugging of the smallest leaks with red gasket-forming silicone (above) and monitoring of fin condition and continually repairing damaged areas (right)

of the ACC and its surroundings. These models qualitatively showed the upstream complexity of the inlet boundary layer, upstream obstructions (trees and buildings), and the impact of adding a horizontal ledge at the bottom of the ACC wind wall.

Quantitative results under windy conditions were not achieved. However, air velocity entering the fans is now more uniform with the screens, and dynamic blade loading has been significantly reduced. Wareham points out that normal operation is now with windscreens 50% deployed.

Saltillo (Mexico)

Central de Ciclo Combinado Saltillo, a 250-MW 1 × 1 combined cycle in Mexico, began commercial operation in 2001. The ACC has three streets with five fans each.

To combat suction starvation caused by occasionally high wind speeds below the ACC, as well as high ambient temperature, the ACC currently operates with a combination of sheet metal wind walls and 60% mesh windscreens. The first sheet-metal walls were added at grade in 2005 (Fig 18). In 2012, perimeter mesh screens were added on the north side.

To maximize air flow through each fan, Saltillo has experimented with variable-speed drives, changes to the fan-blade pitch angle, and even a concerted effort to plug even the smallest air bypass points within the ACC. This includes pinpoint inspections and red gasket-forming silicone as shown in Fig 19. Sheet metal and pop rivets are added when needed. Fin condition is also monitored for damage-induced bypass to ensure effective use of all components (Fig 20).

Daily recordings of electric-consumption values (per fan) are now compared with both ambient temperature and relative humidity. Fan-blade angle of attack is also correlated with air flow and electric current. These data then are used during the most unfavorable weather conditions to maximize air flow. The worst conditions (coldest air with highest humidity) occur in winter.

With blades properly adjusted, the fans show significant increase in air flow and current. In summer, with less dense air, the ACC operates at maximum condensing capacity.

As Leopoldo Duque Baldaras, O&M manager, explained recently, "at first the condenser encountered loss of vacuum during high wind and high ambient temperature. The Codes N3S-AERO (3D) for aerodynamics and TEFERI (1D) for thermal were used to model with and without wind. As part of that, the plant upgraded its fan motors and gears.

"The combination of sheet metal walls and mesh screens contributes to effective ACC operation," Baldaras said, "and we have a lot of improvement now in steam-turbine backpressure."

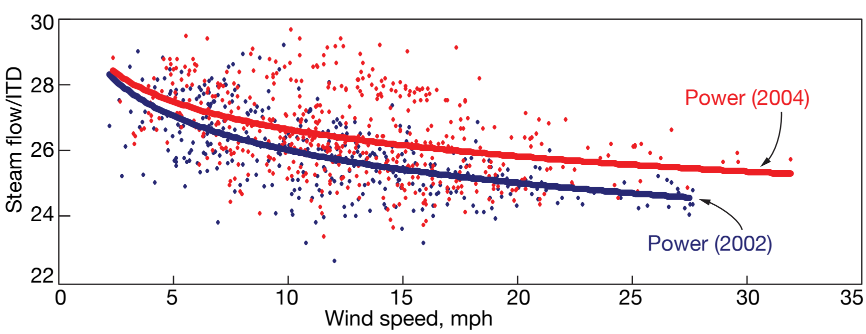
21. Mystic 8's ACC was affected by prevailing southwest winds in summer so the owner installed windscreens on the south and west sides of the unit

22. Obstacles became challenges for south-side screen installation

23. Swing staging was required for some screens

24. Crane assist was necessary for some placements

25. Windscreen porosity at El Dorado varies with the elevation



26. Steam turbine performance is plotted before (blue) and after (red) installation of windscreens at El Dorado, now known as Desert Star

Mystic Unit 8

Exelon Generation's Mystic Generating Station is perhaps a poster child for ACC windscreen retrofits, largely because of its unique location in Charleston, Mass. On a typical summer day the site experiences southwest winds exceeding 10 mph, and average temperatures in the low 80s (F).

Mystic Units 8 and 9 are identical 2 × 1 800-MW combined cycles (steam turbines are rated a nominal 300 MW). ACC configuration is nine streets with four cells per street. Fans are a combination of variable-speed and fixed drive.

The Unit 8 ACC is affected by the prevalent southwest winds in summer. Unit 9 is affected by northwest winds, which are less frequent. Therefore, the owner/operator decided to install wind screens on Unit 8, on the south and west sides (Fig 21). The financial incentive was a recurring reduction in summer output with high cost of replacement power. Screens were installed in late summer 2014.

Unit 8 overall performance then was compared for the summers of 2013 and 2015, revealing similar ambient temperatures, relative humidity, wind speeds, wind direction, and unit backpressure. Based on these data, Unit 8 was able to produce an additional 10 to 20 MW with the windscreens in place. Performance measurements for 2016 are awaiting continual hot days with southwest winds.

The screens were most effective for wind speeds up to 20 mph. Fan performance has also improved, and long-term maintenance has been reduced.

The Unit 8 ACC retrofit was difficult because of obstacles on the south side. The west side was fairly straight forward. Many obstacles had to be incorporated into the site-specific design to allow for existing cable trays, conduit, small bore piping, and structural attachments (Fig 22).

Space restrictions added to the difficulties, requiring creative solutions to normal aerial-lift platform installation methods.

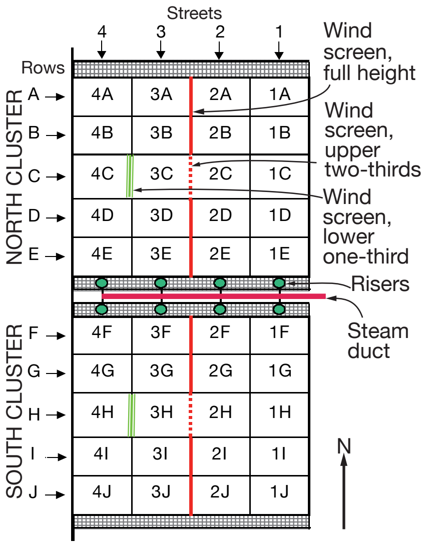
The middle six columns required a combination of aerial lifts and swing staging, and at times swing staging alone (Fig 23). Wind also was a factor and, with limited space, maneuvering of aerial lifts added time to the schedule. At one point, a crane was needed to position a lift (Fig 24).

Exelon's John Ayyvazian says the site is now considering CFD analysis to determine the viability of additional screens to further improve performance.

Desert Star, Higgins

San Diego Gas & Electric Co's Desert Star Energy Center, formerly Reliant Energy's El Dorado Energy, began operation in 2000 as a 480-MW combined cycle in 2 × 1 configuration. The plant includes a 30-cell ACC (five streets with six cells each).

Prevailing summer winds (from the south and southwest) often reach 20 to 40 mph, with gusts to 50 mph. Plant personnel were concerned about the high winds in combination with high temperatures, hot air recirculation,



27. ACC at NV Energy's Walter M Higgins Generating Station has 40 cells, arranged as shown. Note location of screens and their different configurations

and fan-performance degradation caused by non-uniform, crossflow air velocity at the fan inlets.

Screens of porous design from WeatherSolve Structures Inc, Langley, BC, Canada, were installed in a cruciform pattern during the third year of operation. Porosity varies from top to bottom (Fig 25) with the most porous section at the top.

Comparison of ACC and steam-turbine performance before and after screen installation is shown in Fig 26. The performance improvement cannot, however, be precisely characterized because precise field measurements of wind flow patterns and recirculation were not recorded before screen installation.

Higgins began operation in 2004 as Bighorn, as mentioned earlier. The ACC is 40 cells arranged in two 20-cell groups, each with four streets of five cells each.

Screens were installed primarily for aesthetics, as were two wing walls on the northwest and southwest corners (Fig 27). However, detailed measurement of wind patterns in 2005 indicated positive effect for winds not directly from the south. Downwind cells measure some protection against winds from the southeast or southwest.

Dave Rettke, NV Energy mechanical maintenance specialist, explains, "I believe that the windscreens do help our fan and gear reducers in operation. We've never lost a fan blade, and in the highest wind conditions the fans remain fairly stable.

"In most wind conditions," he continues, "the screens help keep the fans stable and well loaded. It is only when we have unusual winds, blowing in gusts against the screens, that I've noted wind-milling issues." CCJ

ACC Users Group steering committee

Owner/operators of ACC-equipped powerplants recognized that critical to solving recurring problems with air-cooled condensers in a timely manner was the sharing of technical information. In 2009, NV Energy and CCJ collaborated on the formation of a user group dedicated to this goal and conducted the first meeting at the utility's headquarters building in Las Vegas. A formal steering-committee structure was put in place shortly after that gathering and today consists of the following members:

Chairman: Dr Andrew Howell, senior systems chemist, Xcel Energy
Dr Barry Dooley, senior associate, Structural Integrity Associates Inc
Oscar Hernandez, manager, corporate engineering, InterGen
Hoc Phung, principal project engineer, PG&E
David Rettke, maintenance specialist, NV Energy

Improving performance parsimoniously

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

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

Such a challenging environment

Committee notes: Geoffrey Kret, Total Petrochemicals USA, an active participant and discussion leader in Frame 6 User Group conferences since the organization's first meeting, recently resigned from the steering committee below because of new responsibilities at Total. Wickey Elmo (photo) resigned from the committee immediately following the meeting to pursue a well-earned retirement.

2016 Steering Committee

Co-chairs: Jeff Gillis, ExxonMobil Chemical (left); Sam Moots, Colorado Energy Management LLC (right)

J C Rawls, BASF Corp (left); John Vermillion, Atlantic Power Corp (right)

Brian Walker, Foster Wheeler Martinez Inc (left); Mike Wenschlag, Chevron Corp (right)

Zahi Youwakim, Huntsman Corp (left); Wickey Elmo, Goose Creek Systems (right) is conducive to a practical solutions-driven mindset that makes doing more with less a way of life. It's not news that some cogen-plant owners consider power production a "necessary evil" and keep O&M budgets lean, opting to spend on process facilities first. Their belief is that end-product investments will produce a better return—at least until a gas turbine is forced out of service.

Adding to the financial challenge is that many cogen facilities are not supported by a corporate engineering staff, and instead rely heavily on the talents of very-capable deck-plates personnel. The Frame 6 Users Group contributes to success by providing a "technical solutions lifeline" for its membership and the reason many of these people continue to attend meetings year after year—some since the group was founded 30 years ago.

Annual Frame 6 meetings begin on Monday evenings with a welcome reception and dinner. Tuesday, reserved for open discussion sessions among users plus presentations by owner/operators and invited providers of equipment and services, is a long day. It concludes with a vendor fair that runs from 5 p.m. until 8:30. Wednesday is GE Day. Thursday morning (the formal meeting concludes at noon) has the same format as Tuesday. This year the Thursday program was extended to accommodate a special tour of PSM's Jupiter (Fla) facilities in the afternoon.

The 2016 conference was conducted at the PGA National Resort, in Palm Beach Gardens, Fla, June 13-16. No time for golf, however; all business.

Co-chairs Jeff Gillis, ExxonMobil Chemical, and Sam Moots, Colorado Energy, called the meeting to order, made a few announcements, and reviewed the hotel's emergency evacuation plan—a perfect segue to the opening roundtable discussion on safety. Gillis may be the ideal session leader on this topic given his global perspective. He has engineering management responsibilities at ExxonMobil for generating equipment worldwide, which requires learning how other countries and cultures assure worker safety and learning their regulations. OSHA is not global, and America does not have all the answers.

Safety roundtable. Session focused on fire protection/prevention. By show of hands, most attendees rely on CO_2 systems for package fire protection. Here's how these systems typically work: Initial release floods the compartment to quickly reduce the amount of oxygen. Injection of the inert gas then continues, to guard against re-ignition.

Point was made that it takes time to put out a fire and cool down the package to prevent re-ignition. Be sure there's a sign like this on the door: "Do not open door when CO_2 is being released." Drive that point home in training, a user suggested to his colleagues. At the recent 7F Users Group conference it was mentioned that operators believed an insulation fire was out and opened the door only to have flames appear once again.

One attendee stressed the need for positive shutoff of the CO_2 system when work is being done in the compartment. He mentioned a near miss as motivation for a piping modification at his plant. One way to prevent an accidental discharge, he said, is to install a gate valve in the CO_2 line to the compartment and chain it shut as part of the lock-out/tag-out (LOTO) process.

Two more ideas:

- Remove the heads of the CO_2 cylinders and replace them when package work is completed.
- Put a time delay on CO_2 release—say 30 seconds—with lights and alarms. This should allow enough time to get out of the package before CO_2 introduction.

Attendees were reminded to train operators to be sure doors are closed and gas-tight before a unit restart. However, testing of door seals may have a downside during a time-constrained outage. It takes about a day to run the test, a couple of days to fix leaks, and another day to re-test. That's about four days if leaks are not found during the second test—which is not unusual.

Also important is to exercise package louvers regularly to verify they are in working order. Example: Weekly use a test blow of compressed air to see that louvers close properly.

Testing of the CO_2 system should include all piping, another user said. He recalled an incident in which CO_2 piping passing through the control cab (which didn't have or need CO_2 protection) leaked, forcing personnel to evacuate. CO_2 bottles often are located inside and can pose a danger if connections leak. An attendee said his plant uses a scale to determine if CO_2 is leaking.

Point made: Sometimes too much "safety" creates an unsafe condition and/or impedes reliable operation. For the plant, he said, concerns go beyond the gas turbine; for the OEM it doesn't. Example: OEM might want to trip the gas turbine if a sensor says the door is open or if ground faults are identified in detector wiring. But the owner certainly doesn't want to trip the refinery unless an unsafe condition can be confirmed.

Another concern brought to the floor: Possible conflict between European and US safety standards regarding the Frame 6B, which now is made in France. Be sure to do your homework.

Water mist technology was discussed as an alternative to CO_2 because of its inherent personnel safety aspects. One participant said his company had installed a mist system on one unit to gain some experience before making a decision on whether to replace its CO_2 systems on all units. Here are a couple of things to keep in mind if you think water mist might be a good fit for your plant:

- The failure of a solenoid valve can compromise reliability.
- Water pump should be powered by compressed air or nitrogen. Electric pumps are not recommended because electricity may not be available.
- Icing is a possible problem in cold climes during the winter months.
- Demin water was recommended by a couple of users.
- Water storage tank should be sized to allow misting for at least 30 minutes.
- Annually, change water in the tank "to keep things from growing." At the same time, check the entire system to be sure there are no leaks and the fog nozzles are performing as expected.

One attendee questioned the logic of spraying water at ambient temperature on a hot casing. He was told a fine mist would not be harmful, but streaming water and drips could be (see last bullet point above).

Suppression system reliability was the next discussion point. Interesting was that no one in the room had experienced a fire in the last five years, although several were impacted by suppression (CO_2) dumps. Thus attendees couldn't comment regarding the effectiveness of either system for extinguishing a fire.

Filter-house fires got a quick mention—including the fire caused by contact of a halogen lamp with dry filter media. This had been discussed at several conferences previously. The safety message regarding lighting was obvious: LED is the way to go. Another safety message regarding inlet houses: Provide egress on both sides of the house and at all levels to avoid being trapped in the event of a fire. Industry experience confirms that a filter house with dry media can be totally consumed within few minutes after a fire starts.

Discussion of safety during outages came at the end of the session. Most plant managers say they empower their personnel to stop a job when they believe they see a safety issue. That's all well and good, but you generally don't want the person stopping the job to suggest how to mitigate the issue observed.

Reason is that most observers are not sufficiently familiar with the situation/equipment to offer a successful on-the-spot solution. The user commenting said the changes proposed by the observer might be—often are—more unsafe than the original plan. Best plan of action: Stop the work and bring the job supervisor and other experts into a room to review the reason for calling a halt to the activity and to agree on a solution.

Formal presentations

There were three formal user/vendor presentations in addition to the Wednesday OEM program summarized later in this report. They were the following:

- Inlet-house air filters, based on the collaborative work between AAF International and a Gulf Coast user.
- Emergent 6B compressor findings, compiled by Florida-based Advanced Turbine Support LLC.
- Six steps to successful repair of Frame 6B components, based on the experience of Hans van Esch, founder, TE Services, Houston.

The first and third presentations are available on the website at www.frame6usersgroup.org.

Air filters. It seems like no meeting of gas-turbine users is complete without an air-filter session. The engineer presenting for the owner/operator opened with a slide that outlined his game plan for filtration success. It was based on answers to these questions:

- How do we select the correct filter for our site?
- What do we need to do to keep the compressor clean?
- What is the frequency of filter replacement?
- What information is required to make the proper decision—including cost of replacement filters, operating profile, ambient conditions, filter-house design, velocity of air through the filter house, etc.

Goal was to retrofit a filtration system that would ensure at least a three-year interval between replacements of AAF's E-12 HEPA-grade filter. Coalescer filters and pre-filters were tested and selected to support this objective. Here's what was decided:

- Install Merv-9 coalescers and

replace them quarterly. Existing coalescers were Merv 6 and replaced every other month.

- Install Merv-15 prefilters and replace at 18-month intervals. Existing pre-filters were Merv 8 and replaced annually.

The first of the plant's two gas turbines was equipped with the new filters after the fall 2015 outage, which included a thorough cleaning of the compressor. Average power increase over the ambient temperature range of interest (45F to 80F) was 2.4 MW—significant for a nominal 35-MW machine. The second engine received new filters after the spring 2016. Plan is to run three years and then replot data to see how well the filters do over time. Information will be shared with 6B user-group participants at a future meeting.

The speaker mentioned that horizontal cylindrical/conical filters may sag over time because of weight and suggested that manufacturing tolerances for tripods might have to be upgraded to prevent filter bypass caused by the sag. This is important: A 1-mm (40 mils) gap between the filter frame and the inlet-house structure holding the filters in place causes a Merv 15 to perform as a Merv 14.

6B compressor findings. President Rod Shidler of Advanced Turbine Support conducted a rapid-fire luncheon workshop on recurring problems the company's technicians are finding during their inspections. Although the 6B is considered a dependable workhorse with relatively few compressor issues, he began, recent findings suggest semiannual—or at least annual—borescope inspections should be conducted to maintain high availability. In the process world, that's particularly important.

Shidler said the company's inspectors have identified mid-chord cracking in first-stage vanes in the lower half of a 6B compressor and stator Row 17/EGV1 liberations in three other machines. While TIL 1352-2R2 (original release in 2003) discusses aft-compressor damage, he continued, the S1 vane cracking is a "first." The cracks and the reasons for the cracking are not yet addressed by any Technical Information Letter and appear to be identical in nature to the cracks found in 7EA compressors both with and without clashing (TIL 1884-R1).

Component repairs. Van Esch, one of the industry's leading experts on inspection and repair of hot parts for industrial gas turbines (IGT), conducts a well-respected three-day training course on "Metallurgical Aspects of IGT Component Refurbishment" twice annually. He developed a primer from this material, "Six steps to successful repair of GT components," which was published in consecutive issues of **CCJ** between 2Q/2005 and 1Q/2006. He updated that work for publication in 3Q/2014; it is easy to access at www.ccj-online.com.

Van Esch boiled down and tweaked his material for a one-hour presentation focused on the needs of 6B users, which is, as noted earlier available at www.frame6usersgroup.org. Here's an outline of the subject matter presented:

- Assessing the condition of GT parts onsite.
- Preparing meaningful component repair specs.
- Selecting the appropriate vendor to refurbish turbine parts.
- Key stages in the repair process.
- Verifications during the refurbishment process.
- Verifying final inspection.

User discussion sessions

Discussion sessions, chaired by members of the steering committee, run about an hour each. At previous meetings, discussion leaders began at the compressor end of the machine and moved aft. The order was changed for the 2016 conference because all the discussion time often had been consumed before the "small stuff"—instrumentation, for example—got air time. This year, the lineup was: auxiliaries, generators, and excitation; instrumentation and controls; compressor section; combustion section; turbine section.

What follows are some of the discussion highlights captured in the editors' notes:

Controls. Chevron Corp's Mike Wenschlag, who looks big enough and strong enough to be a lineman in the NFL, is not the person you would expect to lead an I&C discussion, but he is the steering committee's go-to person on control systems and related equipment. Wenschlag began by putting up on the screen a long list of possible topics and said something like "Pick one and we'll talk about it."

Discussion began with chatter on the types of control systems, from Mark IV through VIeS. Based on a show of hands, a couple of plants were equipped with each of those "bookend" systems, but the most popular product for this group was the Mark V. However, there also were several Mark VI and Mark VIe owner/operators in the audience.

The VIeS designation was not recognized by a few in the room, so one attendee offered that the "S" was for "safety." This system, he continued, is a safety management system engineered for enhanced cybersecurity in critical process applications—such as plant emergency shutdown, burner management, critical process control, fire and gas detection, and turbomachinery safety.

Another attendee said safety critical protection devices—such as an overspeed trip—are designed with a SIL rating (Safety Integrity Level) to ensure a level of protection against "tampering" that might disable a safety feature or change settings when the safety device initiates "this or that."

Technical Information Letters (TILs). A particularly helpful portion of Wenschlag's overview was a checklist of TILs pertinent to Frame 6 operations issued by the OEM since the 2015 meeting. Anybody can miss something of importance, but this allowed everyone to catch up to the same level. Here's the checklist the discussion leader presented:

- 1420-2R1, "Lube-Oil Logic Enhancement," Oct 30, 2007.

  Purpose: To change the Speedtronic control panel to protect turbine bearings following a plant AC power loss by maintaining continued operation of the DC lube-oil pump.

  Reason for revision: Added logic block with 30-min timer. Specifically, the new control software extends the operation of the DC lube-oil pump by 30 minutes following a turbine trip caused by loss of AC power or loss of lube-oil pressure.
- 1963, "Mark VIe ControlST Firmware Update Notifications," May 6, 2015.

  Purpose: Notify users of impactful recent ControlST releases.
- 1968, "Inlet Guide Vane Trip Solenoid Compliance," Aug 11, 2015.

  Purpose: To notify select users of a non-compliant electric trip solenoid installed on certain Woodward IGV actuator assemblies.
- 1939-R1, "Improved Mark VIe Network Switch Availability," Oct 16, 2015.

  Purpose: To inform users of the availability of an alternative IONET network switch.

  Reason for revision: GE-IP has stopped working on failure analysis of N-TRON switches for tracking. No need to ship the failed N-TRON.
- 1881-R2, "Network Security TIL for Mark V, VI, and VIe Controller Platforms, Jan 21, 2016.

  Purpose: To advise sites of new recommendations to help improve control-system robustness to potential cyber attack.

  Reason for the revision: To update the reference documentation to reflect migration of GHT-200042 to GEH-6808.
- 1988, "Z420 HP Hard-Drive Failures, BIOS, and RAID Updates," Feb 16, 2016.

  Purpose: To notify customers of a potential issue with Z420 HP engineering workstations running BIOS versions before 3.87 and INTEL® RAID drivers before 4.1.0.1046. TIL describes the problems reported by some customers and the recommended actions.

Compressor section. J C Rawls, an engineer at BASF Corp's Geismar facility, put up a list of possible discussion topics from drift eliminators on the air inlet house through the compressor—including how to deal with practical operational issues such as icing and hoar frost.

One of the discussion points concerned getting filter-replacement intervals to match the hot-gas-path schedule—now at 32,000 hours (four years for many gas turbines in this fleet). One question in the users' minds: Should HEPA filters be installed to achieve this goal? An attendee championed the idea that each plant should put in place a testing program and do the engineering to ensure the optimal choice of filters for its location.

Interestingly, the Frame 6 group has had several presentations on HEPA filters in the last few years. Previous discussion sessions reflected strong support for hydrophobic HEPA filters from several users. Not so many acolades this year, perhaps because attendance was down by about 20%: The oil-price collapse froze travel budgets at many of the refineries and process plants which rely on the 6B engine.

Also, audience demographics revealed a first-timer population above 40% by show of hands, atypical for a group that normally has about half that number. Perhaps the lack of experience inhibited discussion by some attendees on this topic. However, they benefitted from a review of the group's filter history by members of the steering committee.

Suggestion to all plant personnel attending a user-group meeting for the first time: Do your homework. Conduct a quick review of presentations from the last few meetings posted on the organization's website to gain valuable perspective and to compile a list of questions for the discussion sessions. The better prepared you are, the more you'll benefit from the conference.

That thought was brought to mind during a brief discussion on compressor efficiency and the importance of maintaining a clean compressor. Attendees were reminded that a 1% loss in compressor efficiency actually reduces generator output by 1 MW.

Everyone attending a 6B meeting should know how to calculate compressor efficiency by following the straightforward methodology presented by discussion leader Rawls at the 2013 meeting. Access his presentation at www.frame6usersgroup.org. Eliminating questions that have already been answered (and available) frees up time for new topics.

Combustion section. John Vermillion of Atlantic Power Corp led this discussion session. Remedies for overheating of the combustion compartment and exhaust plenum was one topic. A user reported that the problem at his plant was caused by a "huge" crack in the plenum area. A recommendation for avoiding overheating headaches: Replace aft flex seals and associated insulation at each major.

Other discussion topics included experience with 32,000-hr maintenance intervals, DLN tuning, and primary re-ignition in DLN combustion systems. Regarding the first point, an attendee said there was a tradeoff between maintenance interval and power. More specifically, if your unit is running at 2042F you likely will make the 32K; if running at 2084F to maximize output you will not make it to 32K based on his experience.

Turbine section. Attendees had to wait until Thursday morning for the Turbine roundtable discussion, led by Huntsman Corp's Zahi Youwakim. Morning is the best time for a presentation by, or discussion session chaired by, Youwakim. Plant personnel have to be alert and at the top of their game to benefit from the rapid-fire delivery of rich content by this member of the steering committee.

Fit-up of replacement transition pieces (TP) to first-stage nozzles was the first item discussed. It is wise to verify fit-up four to six weeks in advance of the outage so if there's work to do it won't impact the outage schedule. Full engagement of TPs to first-stage nozzles is necessary to avoid the adverse performance impacts of leakage. Be sure to check the floating seals, the group was told.

First-stage shroud blocks come without cooling holes drilled, attendees were reminded. You have to drill holes after marking their locations with the blocks in place. The axial and radial holes should be drilled in a qualified shop.

A caution on first- and second-stage buckets: Flow test after repairs to identify cooling holes plugged as a result of grit blasting or other reason. You don't want to fail buckets because of insufficient cooling.

There was a significant discussion around the lifecycle of first-stage buckets. It began with the observation that the OEM's change from a 24K to 32K hot-gas-path (HGP) cycle is not in synch with today's typical maintenance cycle for strip (stripping of the coating), HIP (hot isostatic pressing, a heat treatment for restoring material properties), and replace (coating).

Do you do this at every HGP? If so, you'll likely need an extra set of buckets on the shelf. A user said the GT-33 coating was much improved over the GT-29 coating and, in his opinion, you can make the 32K interval with it. The alternative is to just run the parts for 48K or 64K and toss. The optimal lifetime for your engine is an economic decision involving risk analysis. The user cautioned that every repair cycle removes some base metal and this has to be factored into your analysis. If the trailing edge gets too thin, he noted, you could be getting into problems.

Nozzles were another discussion topic. It began with a user saying the OEM expects 72K on first-stage nozzles; 96K on second- and third-stage nozzles. The current alloy for first-stage nozzles was said to be GE's FSX-414, a cobalt–base alloy cited for its superior strength at very high temperatures. GTD-222, a nickel-based alloy, was developed by the OEM to provide improved creep strength in second- and third-stage nozzles; plus, it's weld-repairable.

TIL 1523, "Exhaust Temperature Modifications," spawned another discussion topic. Attendees were in general agreement that if an exhaust thermocouple (t/c) fails it should be jumpered out. At this point, a user interjected that third-party thermocouples installed at his plant are performing better and lasting longer than the OEM's. That certainly was of interest.

Back to the main subject. If you jumper out a failed t/c, be sure *not* to make the connection to the same processor as the surviving t/c for that can. Recommendation to the attendees: Have a procedure for jumpering to avoid creating a trip condition and when you come down you can quickly change out the t/cs bypassed. Also, move the junction box to an area unaffected by heat.

One attendee said he wouldn't jumper out more than two t/cs; he'd either live with the condition or shut down the engine to replace the defective instruments. A couple of users said they change out t/cs every HGP and major, acknowledging that there is an infant-mortality risk in doing this.

GE Day

It seems like hardly a week goes by without an announcement from one of the OEMs on the sale of an advanced machine (late-model F-class, plus G, H, and J series engines), commissioning of a new combined cycle, efficiency gains—sometimes down to relatively few Btu—touting gas-turbine model X as the world's most efficient, etc.

How much of this blather means anything to someone with O&M responsibility at an operating plant? Very little. What's important is how your plant is performing *today*. If your 6B is not meeting expectations—efficiency, availability, reliability, etc—what can you do to turn the tide? Looking ahead, what does the future hold for your equipment? If you're planning to run "forever," are you considering life extension, boosting output, improving performance, etc? User group meetings provide the background and contacts to help you navigate the alternatives available to make your plant the best it can be.

From the editor's perch, GE's participation in the 2016 Frame 6 Users Group meeting reflected the notion that true collaboration between OEM and end user was the goal and progress was being made in this regard. Everyone knows you catch more flies with honey than vinegar and the sales person concerned with your plant's success will sell more product. That's called win/win if you're an astute buyer.

Frame 6 meetings are all about the Clydesdales that keep industry humming, the engines that can take a beating and keep on running—at the lowest cost possible. GE's "A" team for this frame, which spent a productive day with the owner/operators (all work, no play), was sensitive to this need.

But, at the same time, these engineers offered a view of the industry's digital future (fact not fiction), and the proven advancements from the larger frames available for 6B application to meet tomorrow's demands. Checkbook required? Yes. Expensive in the minds of those typically responsible for managing the finances for a Gulf Coast refinery or chemical plant? Yes. But given the level of experience with the lineup of improvements presented, the benefits and payback period seem quantifiable with a relatively low risk profile.

If you missed the meeting, catch up on what the GE 6B team had to say by accessing the presentation outlines at www.frame6usersgroup.org.

Tour of PSM facilities

Perhaps there is no better way to close out a user-group meeting than with a tour of a nearby manufacturing/repair facility. The typical user learns a great deal from this experience because he or she rarely gets out of the plant and likely has limited first-hand knowledge of what happens to gas-turbine parts after they leave the plant. The two-hour tour of PSM's Workshop and Reconditioning Facility at the company's Jupiter (Fla) headquarters, conducted after the official close of the 2016 conference, provided that opportunity.

Participants "walked" the reconditioning process, a perfect segue to Hans van Esch's component repair presentation earlier in the day, and were among the first plant personnel to see PSM's new fuel-nozzle and compressor-blade manufacturing operations. "Stops" on the tour of the 75,000-ft² shop included the following:

- Compressor-blade manufacturing cell.
- Non-destructive examination (NDE) area: visual check, digital x-ray, dimensional, surface inspections.
- Cleaning: surface blasting and chemical stripping.
- Repair: blending, welding, and dimensional correction.
- Machine shop: conventional CNC machines for milling and grinding, plus special processes for hole drilling, shaping, and material removal.
- Laser cladding: rebuilding of turbine-blade tips and re-establishing hard-face areas.
- Heat treatment and brazing: vacuum heat-treatment furnaces, hydrogen and fluoride-ion-cleaning surface preparation, and high-temperature braze repair.
- Thermal spray coating: robotic application of metallic and ceramic protective coatings on airfoils and combustion parts.
- Final inspection: fit checks, air flow, moment weight.

CCJ

Users glimpse benefits of faster response when analytics are integrated with control

One of the most notable presentations from the 2016 Ovation Users' Group Conference (Pittsburgh, July 24-28) showed that the industry truly is on the precipice of a new era with control systems, one in which analytics and machine intelligence are part and parcel of the control system itself.

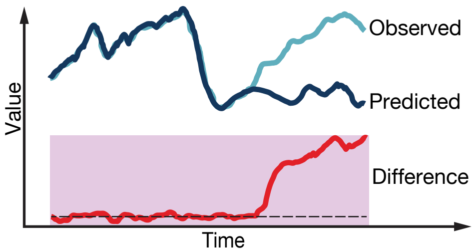
Today, most powerplants pull data from the distributed control system (DCS) into a separate data historian, such as PI. Software applications, including advanced pattern recognition (APR), then take data from the historian, crunch the numbers, and provide indicators around machine health by comparing real-time, actual data trends to historical expected patterns (figure). When a deviation is detected and becomes significant, an operator and/or a specialist is alerted.

One Ovation™ user, a coal-fired plant owned and operated by one of the largest utilities in the country, is pilot-testing a different approach—having the analytics engine *integrated* into the automation system itself. While this has been a topic of discussion at previous meetings of the Ovation Users Group, the important ingredient this time is a solid rationale from a user for doing things differently.

As Emerson Process Management's Azime Can-Cimino and Christine Anselmo noted, "speed is the luxury of Ovation," referring to the fact that traditional APR techniques are based on data rates of one to five minutes, whereas in Ovation, data rates can be one second and less.

The utility is applying APR at faster data rates with coal mills and induced-draft fans and their associated motor drives. Mills and fans at this site experience an abnormal frequency of high motor-current amp readings, and, therefore, mill and fan trips. According to the utility's representative at the meeting, these mill and fan motors are undersized, a hangover issue from original design, and so they are always running too near their trip points. In the case of the fans, this means too near their stall points.

"We need a detection and response capability beyond the commercial APR techniques," he said. In other words, if the motors were properly sized, there would a more comfortable period of time between a normal motor current reading and a gradual trend towards an abnormal reading. At this plant, however, the time interval between "normal" motor amps and a potential trip is greatly truncated. This is why the speed of detection afforded by much higher data rates has real value.



Advanced APR techniques, which detect the difference between actual (observed) and expected (predicted) trends in machine health and performance, are being integrated directly into the Ovation control platform and pilot tested at key customer sites

To date the owner/operator has been suitably impressed: "The Ovation analytics beta test actually predicted a fan failure one month before it occurred!" he reported, privately.

The prediction method or model used to crunch the data is beyond the scope of this article. However most are based on statistical analysis, such as linear and non-linear regression, clustering techniques, decision trees, Bayesian belief networks, and several others.

The benefits of integrating intelligence with control are far-reaching. Avoiding a separate software solution for APR and the digital apparatus that goes with it is an obvious one. Powerplants have been struggling to avoid "islands of automation" for years. In time, embedding many such analytics engines obviates the need for a separate historian and data network.

Beyond the obvious, traditional APR techniques have shown their best success for long-term trending at steady-state conditions, or detecting deviations from a well-established, reasonably constant baseline. With higher data rates, it could be possible to obtain value from APR in short-interval situations—such as plant startup, shutdown, and process upset periods.

For another, with faster detection of, and response to, deviations in key machine parameters, less margin may be needed when a plant is designed in the first place. In the coal-plant example, most large units have six pulverizers whereas full unit load can typically be achieved with four in operation.

Imagine if tighter integration between control systems and monitoring and diagnostic capabilities allowed you to avoid one pulverizer unit. That represents significant savings in capital cost for only a nominal increase in the cost of adding that capability to the automation system.

Most APR capability today is designed to alert operators and specialists of possible developing issues much faster than, say, the alarms built into the control system. Emerson called this a "shirt tug" type of warning. But taking the alert to its logical conclusion, the control strategy can be made "closed-loop," meaning that the automation system itself makes the decision to trip the equipment, *then* notifies the operator that such action has been taken. It may be a while before closed-loop control schemes become standard, but when you think about pilots and commercial aircraft, that's the direction powerplant automation is headed.

One of the challenges with data-driven analytics is that deviations are detected but usually the root cause is not identified. However, with experience, data patterns can also be correlated to root causes through look-up tables, troubleshooting references, or even communicating with a subject matter expert in a pop-up window. CCJ

CO_2: The versatile non-hazardous cleaner

Dry ice in pellet form is used extensively to remove rust, sulfur deposits, ammonia salts, and insulation debris from HRSG heat-transfer surfaces (finned tubes). It's been used to prepare catalyst beds for new blocks. It's non-hazardous with no cleanup or no residuals beyond the materials removed. So what about other areas of a combined-cycle plant? How versatile is this technology?

We brought that question to Plant Manager Ric Chernesky at Frederickson 1 in Tacoma, Wash, who had seen great results with his tight-tubed HRSG (see "Case history," p 18). He also uses CO_2 at reduced pressure to

Advanced Indoor Air Quality Care Inc

Advanced Indoor Air Quality Care Inc

1. Generator core and windings can be cleaned with CO_2 to eliminate most hand work (left)

2. Exciter is cleaned in-situ with dry ice (right)

Advanced Indoor Air Quality Care Inc

3. Turbine fir trees can be cleaned with CO_2 without interrupting outage work

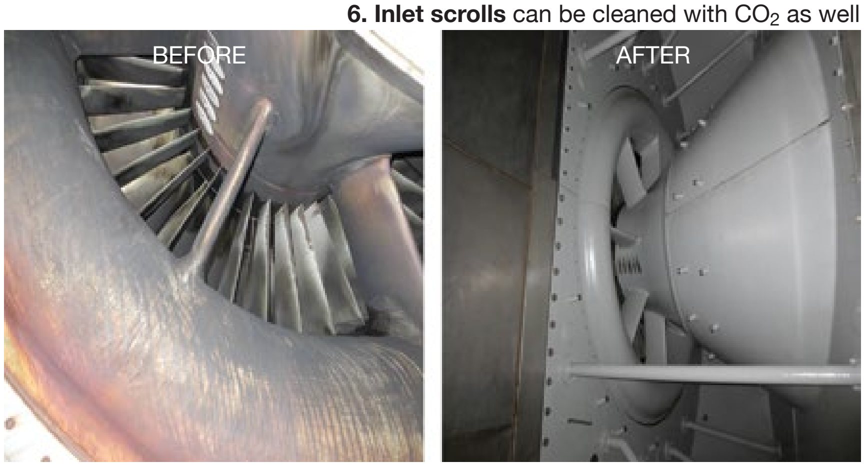
Precision Iceblast Corp

4. Compressor blade cleaning is a common ice application

Advanced Indoor Air Quality Care Inc

5. Compressor stator cleaning is another application (left)

6. Inlet scrolls can be cleaned with CO_2 as well



Precision Iceblast Corp

clean the gas turbine, and says he has heard about all kinds of other plant applications, although not yet tested at "Freddie."

So just how versatile (and useful) is this non-toxic cleaner? With a note that oil-based deposits might still need extra attention, some typical examples follow.

Generators

Generator stator cleaning with CO_2 is becoming increasingly common. With field (rotor) removed, crews will generally blast the core and get any debris or contamination off the laminations. If they feel that solvents have been used in the past, especially on the end windings, they will use CO_2 first to get everything clean, then follow with hand wiping as needed, perhaps using alcohol and Positron.

The point is this entire process was done by hand in the past with potentially harmful cleaners that could leave a residue. Using CO_2 has removed most of the hand work and is chemical-free. The dry ice sublimates directly to a gas (Fig 1).

Rotor work is generally done offsite; exciters have been cleaned on location (Fig 2).

Gas turbines

During hot-gas-path and major inspections, the upper half of the turbine casing is removed to access, inspect, and remove (as needed) any blades (buckets). GT power augmentation (steam or water) and extended time on turning gear can add to the risk of rust and other deposits accumulating in the rotor slots.

Often, because of accumulation, removing some blades can be challenging, as can be reinstalling the blades. The rotor slots must be completely clean, and this is becoming an ideal application for dry ice. In the past this was done by hand—a slow and interruptive process with possible chemical exposure.

CO_2 can do a better job in less time, without interrupting overhaul activities. More than one site reported that all turbine rotor slots can be blasted clean in one shift (Fig 3).

Compressor section cleaning schedules are traditionally site-specific and vary from daily or near-daily water washing to offline cleaning during outages. The outage cleaning methods also differ: from water wash with soap to hand cleaning with an abrasive sponge and cleaner. Some use ice, or if deposits are oily, bead blasting. It seems to be across the board, and inspections determine the extent of compressor-stage cleaning based on dirt buildup and black film.

Ice blasting is a quick and easy option for compressor blades (Fig 4). When CO_2 is used on the compressor stator (Fig 5), cleaning is reported as thorough and efficient. Cleaning of inlet scrolls in place is another application and has been done successfully in the field (Fig 6).

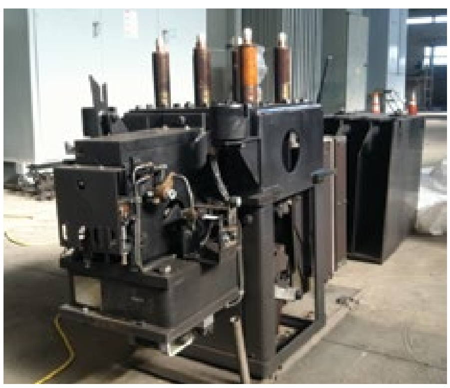
Inside, outside, beyond

So what about plant electrical equipment: transformers, high- and medium-voltage switchgear, insulators,

Advanced Indoor Air Quality Care Inc

7. Substation cabinet fell victim to fire (left) and was restored using CO_2 (right)

Advanced Indoor Air Quality Care Inc



8. Switchgear and breaker cleaning with CO_2 is increasingly common. Before is at left, after at right

Advanced Indoor Air Quality Care Inc

9. This reactor was cleaned with CO_2

Advanced Indoor Air Quality Care Inc

10. Insulator cleaning is fast and effective with CO_2

Groome Industrial Service Group

11. Open-air heat exchanger, severely fouled (left) was restored by CO_2 blasting (right)

and other components that need cleaning?

CO_2 has been used on virtually all distribution equipment including pad-mounted switchgear and transformers, and owner/operators report both unexpected surprise and high satisfaction with the results.

Substation cabinets can become contaminated with dust and dirt or, in an extreme case, flood damage with water carrying silt, salts, and other contaminants. Potentially, all of this can interfere with proper operation. Cabinets also carry the risk of fire (Fig 7). Again, restoration seems to be a logical application for dry ice. One crew member reports removing all soot and debris without any harm to the paper stickers used to identify the wires.

One substation manager reported very dirty 220-kV bushings and lightning arresters and opted for dry ice blasting. Normally, this equipment would be cleaned by hand and this job would have taken two technicians two shifts to complete the work. Ice blasting was completed in half a shift with excellent results. All contaminants were removed and there was virtually no cleanup, the operations manager said, and even that was done by the contractor. Transformer test results showed improvement.

Another utility end user called for ice blasting after a breaker fire (Fig 8). The unit was cleaned and rebuilt at less than one-quarter of the cost of a new unit. Prior to giving ice blasting a try, the breaker likely would have been scrapped.

Reactors (Fig 9), insulators (Fig 10), and a host of other equipment become logical applications as well. As one operations manager put it, "whether it's a fragile surface or non-fragile, whether you are trying to remove paint or contaminant, or just trying to clean it, all things become candidates for ice blasting."

And of course you never know what you will find further out in the field. Take for example Fig 11. This open-air step-down transformer facility included a finned-tube heat exchanger that had probably never been cleaned. Using CO_2, the tubes were cleaned of all condensation, general slime, moss, and other heat-transfer obstructions after many years of operation.

12. Cleaning of generator stator insulation requires care. Photo illustrates what can happen when blast pressure is too high

Versatility, safety, and scheduling

Looking back at Chernesky's workhorse HRSG, ice blasting that began at around 235 psig is now up to 350 psig. Backpressure is low, and he keeps coming back to this cleaning technology.

There are, of course, limits. In these non-HRSG applications, oil and grease (if wet) tend to be moved around rather than removed, and cleaning by hand will still be required in some situations. High-pressure blasting also requires care and attention. Stator insulation, for example, can be damaged when the pressure is too high (Fig 12).

But if you know the right variables, you can adjust CO_2 feed rate and jet pressure. An experienced operator can also play with distance. So even in a sensitive environment, as one owner/cleaner put it, "ice blasting becomes perhaps the only choice." You can just move forward and apply the variables (think School Zone).

JLN Associates LLC, Old Lyme, Ct, reminds us of some unique safety requirements. The jet-cleaning process can be quite loud, and dry ice is extremely cold (-109F), calling proper personal protective equipment. Also, CO_2 released in high concentrations can decrease oxygen content in the work area, meaning strict attention to air quality. Any loose objects must be removed or secured, and static electricity is always a safety concern, calling for proper grounding.

On the positive side, one interesting account described a 150-ft stack that required cleaning to remove peeling paint. In a good climate, water blasting would be ideal. But the work was performed in the north, in December. For both cleanliness of equipment surrounding the stack, and safety of the crew (don't freeze the workers), they chose ice blasting.

During this review the editors also found crew mobilization (usually two), cleanup, and demobilization of both crew and equipment to be heralded as "painless." CO_2 itself is clean, and the process does not make a big mess.

It therefore seems logical that if an ice-blast crew is on site for an HRSG, the owner/operator might consider other tasks, even those hidden from daily view.

Once more back to Chernesky at Freddie: "The bottom line is this: We've had a lot of good experience with CO_2, so we're sticking with it." CCJ

Best Practices Awards

One of the biggest challenges facing owners and operators of generating assets in deregulated markets is the need to continually improve the performance of their facilities—to increase revenues and decrease expenses. One component of this goal of "continual improvement" is best practices. These are the methods and procedures plants rely on to assure top performance on a predictable and repeatable basis.

The Best Practices Awards program, launched in late 2004 by CCJ, has as its primary objective recognition of the valuable contributions made by owner/operator personnel to improve the safety and performance of generating facilities powered by gas turbines. The program continues to evolve by encouraging entries pertinent to industry-wide initiatives.

In 2016, plants were recognized for best practices in water management, O&M, performance improvement, fast start procedures, monitoring and diagnostics, outage management, and safety. One-third of the entries focused on O&M best practices, 27% on performance improvement, 17% on safety.

There are two levels of awards to recognize the achievements at individual plants: Best Practices and The Best of the Best (BoB). The five BoB awards presented this year were profiled in the 1Q/2016 issue (Dogwood Energy, Doswell Energy, Brandywine Cogen, Pleasant Valley Generating Station, and Tuaspring Cogen). Also profiled last issue were three aeroderivative plants recognized for their best practices at the 2016 Western Turbine Users conference (Waterside Power, Lawrence Generating Station, and Worthington Generating Station). This issue features best practices from the eight plants listed below.

In this section:

Armstrong

Improved, expanded GT fire protection system

Armstrong Energy

ENGIE North America (NA)

640-MW, four-unit, dual-fuel, simple-cycle peaking facility located in Shelocta, Pa

Plant manager: Matthew Denver

Challenge. When the gas turbine/generators were designed in 2002, the OEM provided rationale for excluding fire protection for the collector cabinet and load tunnel. Over the last 13 years, though, various insurance carriers have sited this design as inadequate and requested that fire protection be added to these compartments to minimize possible damage in the event of a fire.

Solution. A few options were considered by the plant staff before the decision was made to install high-pressure (HP) CO_2 systems which would work in conjunction with the original low-pressure CO_2 system. The installation of this equipment required an upgrade of the existing control panel to provide ample capacity for additional detection, notification, and control modules.

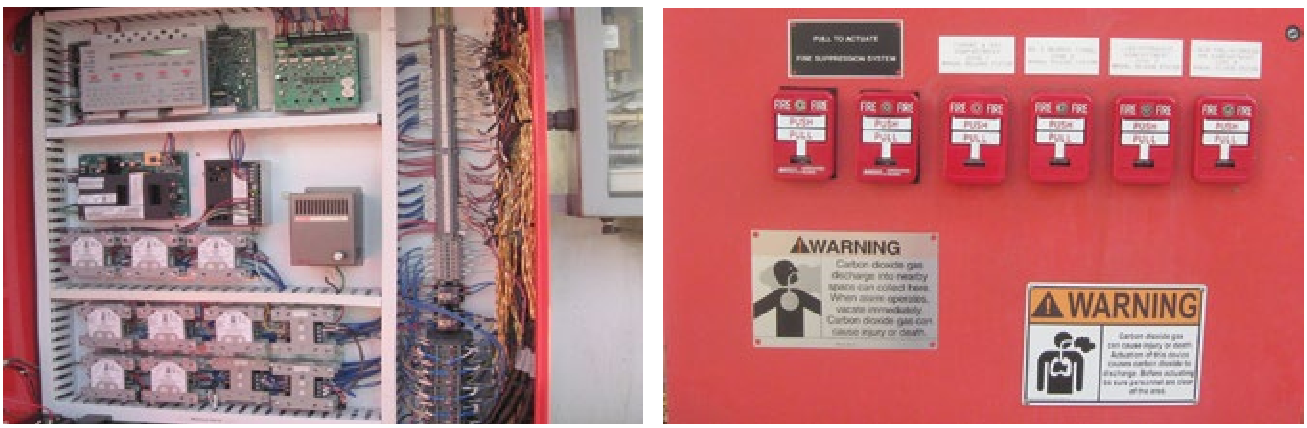
The original fire-protection configuration separated the turbine equipment into four zones:

- GT/gas compartment.
- No. 2 bearing area.
- Accessory module.
- Liquid fuel/atomizing air.

The upgraded CO_2 control cabinet (Fig 1) accommodated addition of two new zones to protect these areas (Fig 2):

- Load tunnel.
- Collector cabinet.

Using NFPA 12 for guidance, HP CO_2 systems were designed and installed. Additionally, several more



1. Upgraded control cabinet is shown inside (left) and out (right)

2. High-pressure CO_2 systems were added to serve the load tunnel (left) and collector cabinet (right)

changes were made:

- Relays were added to provide automatic shutdown and Mark VI control logic was modified to signal the operator.
- The generator automatic-hydrogen-dump logic was connected to the system to provide additional safety margin.
- Two sensors were installed to initiate evacuation of the hydrogen charge.
- CO_2 concentration tests were performed to validate effectiveness of the system design parameters (in accordance with NFPA 12).
- Dampers were installed to effectively isolate air flow.

Results. The load-tunnel compartment was tested to 84% concentration, and required only minimal adjustments to the doors in order to completely seal the compartment.

The collector cabinet doors and soft-patch gaskets required more attention, and the excitation lead box required sealing to reach the required concentration.

Michael Field, ENGIE NA's VP for the PJM/NY region, stated, "With these successful test results, Armstrong Energy has achieved equipment protection and personnel safety standards that other plants will want to emulate. The project was very complicated and needed to adhere to NFPA 12 as well as standards set by ENGIE engineering and the plant's insurer. This will serve as the pilot program for our other plants."

According to Armstrong Plant Manager Matthew Denver, "What we accomplished at Armstrong will pave the way for other ENGIE plants. Superior effort went into this project, which was confirmed by successful test results on the first attempt. This installation will help to further protect our equipment and staff in the event of a malfunction.

"Peter Margliotti, Armstrong's combustion turbine (CT) specialist and the project's overseer and subject-matter expert, researched standards and reviewed prints and documentation in advance to ensure safe and timely project completion.

"From design and installation of project changes to the creation and incorporation of new HMI screens, his depth of knowledge, flexibility, and relentless determination were instrumental to seeing the project to its timely and successful completion."

Magliotti stated, "When this project was first envisioned, I wanted the ability to remotely monitor the gas-turbine fire suppression system, and to also upgrade the systems to current standards. By integrating the fire detection sensors, GT control system, and O&M building fire alarm panel, we have enabled our operators to pinpoint the exact location of a fire and respond appropriately. As a result, our personnel, equipment, and site are now better protected. The next step is to roll out this upgrade to our other plants, and capture the personnel safety and equipment protection benefits across our fleet."

Project participant: Peter Margliotti, CT specialist

Armstrong continues to salute veterans

Armstrong Energy held its 12th Annual Charitable Golf Event benefitting the Wounded Warrior Project and Team Red White & Blue. The event, held on Sept 11, 2015, brought in more than 130 golfers from the local community. What better way to say "thank you" and honor all the brave men and women who serve and have served on behalf of our country. The site alone has five employees who are former US military. Armstrong Energy and ENGIE NA donate 100% of all registration fees and supporter dollars directly to the charities. Last year $55,000 was raised.

MEAG Wansley

MEAG Wansley Unit 9

Owned by Municipal Electric Authority of Georgia

Operated by NAES Corp

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

Plant manager: Timothy Williams

Chain, hoist storage improvements

Challenge. Chains and hoists can be damaged easily. They can collect dust and dirt while lying on a concrete surface or be run over by equipment. At MEAG Wansley Unit 9, the sheer number of chains and hoists also was posing a trip hazard to anyone passing by. Besides that, the required tags and labels can deteriorate and become illegible when left exposed to moisture and possible corrosives. When this happens, expensive equipment can no longer be used and must be replaced.

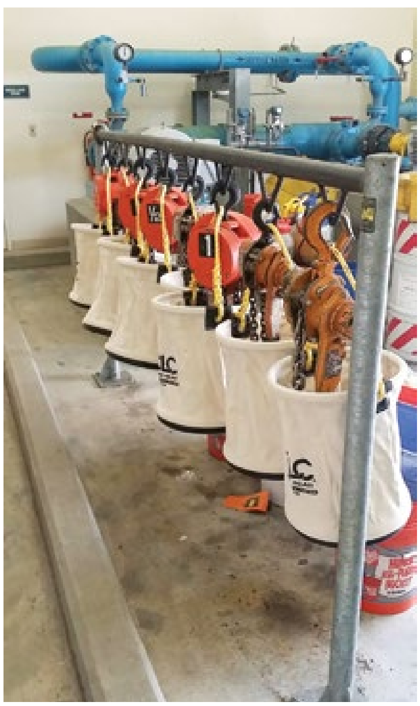
Solution. A couple of our staff had previously fabricated racks to store this equipment in the maintenance area and warehouse, which had relieved the clutter and gotten things up off the floor (Fig 1). However, these too eventually had become cluttered and difficult to organize until recently, when the plant maintenance team came up with a better idea: Canvas storage buckets to be used in tandem with the racks.

They researched the possibilities and ordered heavy-load-rated canvas buckets with plastic bottoms from CLC Work Gear. These work very well for the storage of chains and hoists at manageable cost (Fig 2). As the photos show, the area is now neat, clean, and free of clutter. In addition, plant staff has stenciled pertinent information onto the canvas—such as contents, return location, and weight.

Results. Storing this critical and costly equipment up off the floor in clearly marked canvas buckets will extend its service life and mitigate a possible safety hazard. It also will improve the organization of storage areas and streamline future outages.

Project participants:
William Wright, maintenance manager
James Jensen, maintenance mechanic

1. Chain falls and hoists, as stored initially, created clutter



2. Canvas buckets protect equipment in storage at nominal cost

A better way to document ladder, tool inspections

Challenge. Effective monthly and quarterly inspection and documentation of site ladders and tools can be a challenge. In most cases, these items are routinely exposed to the elements,

3. Traditional tagging was sloppy and short-lived

4. Labeling, color-coded and weather-resistant, lasts and lasts

MEAG / WANSLEY UNIT 9

QUARTERLY LADDER INSPECTION CHECKLIST

Inspector:		Signature:		Date:	

LADDER TYPE		EQUIP No.	QTY	Compliant YES	Compliant NO	COMMENT/LOCATION
2' Louisville step ladder	(300lbs)	M-02-01	1			Shop Storage Rack
4' Louisville step ladder	(300lbs)	M-04-01	1			Shop Storage Rack
4' Louisville step ladder	(300lbs)	M-04-02	1			PDC
6' Louisville step ladder	(300lbs)	M-06-01	1			PEECC 2
6' Louisville step ladder	(375lbs)	M-06-02	1			Shop Storage Rack
8' Louisville step ladder	(300lbs)	M-08-01	1			South of Generator 1
8' Louisville step ladder	(300lbs)	M-08-01	1			Under Steam Generator
10' Louisville step ladder	(300lbs)	M-10-01	1			Shop Storage Rack
10' Louisville step ladder	(300lbs)	M-10-02	1			Shop Storage Rack
12' Louisville step ladder	(300lbs)	M-12-01	1			Between HRSG 1& 2
12' Louisville step ladder	(300lbs)	M-12-02	1			North of Lab "labels are beginning to deteriorate"
12' Louisville step ladder	(300lbs)	M-12-03	1			Circ Water Platform
20' Louisville extension ladder	(300lbs)	M-20-01	1			CEMS 1
32' Louisville extension ladder	(300lbs)	M-32-01	1			Shop Storage Rack

Inspection Criteria

01. Check that all straight or extension ladders are equipped with safety feet (non-skid treads) and a six foot length of 3/8" minimum tie-off rope
02. Ladders are free from oil, grease, or slippery material (on steps or feet)
03. Ladders are equipped with safety feet in good condition
04. All step ladders are no longer than 20 feet, have a step depth of at least 3 inches, and the minimum width between the side rails on the top step is 12 inches
05. Check that there are no broken or worn steps or rung[illegible]

5. Checklist manages inspection results

6. Color-coded signage identifies non-compliant equipment at a glance

so traditional tags and inspection markings can become illegible in short order (Fig 3).

Solution. Plant's objective was to design a quick, durable, easy-to-read inspection process that all site employees, contractors, vendors, and visitors could understand at a glance.

Staff developed a system to address this need: Following each inspection cycle, we now attach color-coded nylon ties that match a quarterly code posted on signage around the site. Also, personnel applied a color-coded, weather-resistant label to each ladder that specifies its length (Fig 4). To keep track of inspection results, a new checklist was developed; it includes columns for pertinent data and equipment location (Fig 5).

To make the system easier to understand, staff developed and posted signage site-wide that can be cross-checked at a glance to determine if a particular ladder or tool has been inspected on schedule (Fig 6).

Results. The new process has mitigated the risk of injury that could result from using a tool or ladder not properly inspected according to the plant's quarterly schedule. It also eliminates the tedium of trying to decipher a faded, handwritten inspection date on one of our ladders, and the new checklist helps keep things stored in their proper locations. This streamlines work processes in outages as well.

Project participants:
Jacob Blickenstaff, ICE technician
Jason Land, ICE technician

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T A Smith

T A Smith Energy Facility

Oglethorpe Power Corp

1250-MW, gas-fired, two 2 × 1 combined-cycle power blocks located near Dalton, Ga

Plant manager: Rich Wallen

Owning safety: Developing an effective outage safety program

Challenge. Safe-work monitoring at a two-block, combined-cycle facility can be challenging with a staff of only 32, especially during outages when there can be over 300 contractors onsite. In the past, the owner's organization had only three individuals in its safety department to cover eight sites in the state of Georgia. However, specific task-oriented safety jobs, like confined-space entry, were contracted out during outages to qualified vendors. This provided good results for individual jobs, but staff believed the plant's safe-work culture could be improved.

Solution. A program developed to solicit volunteers to act as safety representatives during outages. Two plant employees were identified and engaged in developing expectations for this position during the fall 2015 outages. These individuals were completely removed from other site outage duties on the days they were designated as safety reps.

Safety coverage was provided every day of the outage using these two individuals. Expectations included hazard-reduction identification and elimination, plus cradle-to-grave job observations—that is, from the pre-job briefing to task execution in the field and follow up.

The value in observing specific jobs/tasks is illustrated by the hazards identified below during the rewinding of a gas-turbine generator. Actions taken to prevent a recurrence are obvious.

- Spotters identified walking under suspended load.

Plant safety team (l to r): Ryan Andrews, production technician; Chris Estelle, production technician; Frank Henderson, operations manager; Barry Johnson, production technician; Mike Faltesek, maintenance supervisor; Mark Ward, production technician; Tim Lieving, production technician

- Areas not properly roped/barricaded off.
- Staging areas not identified.
- FME exclusion zones not properly identified.

Another benefit of the program: While safety was the primary focus, the enhanced oversight contributed to improved quality of workmanship in certain areas.

Safety lessons were immediately learned as most were identified during equipment disassembly and removal activities. Staff focused on the post-job briefing to assure reinstallation activities would go much smoother. All lost time during removal was gained back in the schedule on the back end because of enhancements made: Tasks were stopped multiple times early in the schedule to improve safe-work practices.

Other jobs observed by safety representatives now include:

1. HRSG recirc-line work.
2. Steam-turbine condenser confined-space entry.
3. HRSG expansion-joint replacements.
4. Condensate-pump motor removal and installations.
5. Manhole entries for pump replacement.
6. Attemperator piping inspections.
7. High-voltage bushing replacements.
8. Cooling-tower repairs.
9. Bleach-tank replacement.

Results included no T A Smith OSHA recordables or first-aid injuries. Also included in this were over 35 cradle-to-grave job observations which have now been included in work-order closures as lessons learned along with a comprehensive safety database. Additional hazard reductions were eliminated during the outage to the tune of over 125 reductions resulting in leading indicator identifications.

One key component for the plant's success in this program was the appointment of a control room operator to oversee activities. The level of associate-to-associate respect existed immediately and was not viewed as the safety department coming to oversee their work.

Project participants:

Rich Wallen, plant manager
Barry Johnson, production technician

Green Country

From baseload to black plant: It's a wild trip!

Challenge. Other than significant natural disasters such as floods, tornados, and hurricanes, one of the potentially most damaging events a powerplant can experience is a black-plant trip. When such a trip occurs, all protective controls must function perfectly, all backup and emergency equipment must start up and operate as intended, and all O&M personnel must perform exceptionally—or significant equipment damage will likely occur.

Most powerplants have good black-plant procedures, and some even conduct routine black-plant drills. But it's doubtful that most facilities plan adequately for an extended black-plant event in which back-feed power cannot be re-established for many hours.

The event: It was a beautiful January day with sunshine, mild temperatures, and all three of the plant's 1 × 1 F-class combined-cycle units operating smoothly at baseload. The employees at Green Country had gathered in the control room after lunch for the plant's weekly safety meeting. And then it happened.

The six generator breakers opened, the control room's lights went out, the steam-turbine (ST) dump valves opened, the HRSG relief valves began to lift, and the fire

Green Country Energy

Owned by J-Power USA

Operated by NAES Corp

800-MW, three gas-fired 1 × 1 combined cycles located in Jenks, Okla

Plant manager: Rick Shackelford

alarms began sounding. The control-board operator announced, "We've lost everything, including the dedicated transmission line into the plant!"

Maintenance technicians moved quickly to inspect the operating condition of all emergency diesel-driven equipment and DC turbine/generator (T/G) emergency lubrication systems. The operations technicians manned the controls to monitor the proper startup of emergency backup equipment as well as the critical readings associated with the six turbines and generators that were coasting down from 3600 rpm.

The cause: One of the transmission-line protective relays had failed, causing the line breaker to open. To make matters worse, the plant experienced a subsequent lockout-switch failure in the switchyard, resulting in an eight-hour delay before electrical back-feed could be re-established to the plant.

Fortunately, Green Country is connected to a highly reliable transmission system, so black-plant events have been very rare over the 15 years since COD. However, in this case, the task of securing and protecting critical equipment following the trip was hampered by the eight-hour back-feed delay.

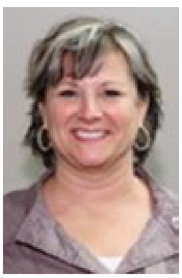
The successes: During the event, all critical emergency backup systems worked as designed, and plant technicians made good decisions. As a result, there was no damage to any plant equipment, or any unpermitted environmental releases.

The complications: Because power was lost to the plant's auxiliary cooling-water and service-water pumps, heat exchangers, including the T/G lube-oil coolers, received no cooling water. Technicians connected firehoses to the auxiliary cooling-water header to pressurize it with potable water. They also started up the portable diesel-driven compressor to supply the plant's main air header, thereby providing control air to most of the plant's pneumatic equipment.

Power was lost to the ST hotwell dump valves as well as to unit sump pumps and various auxiliary systems critical to securing and cooling major equipment. To make things more interesting, darkness was setting in by 6 p.m., and the plant's emergency lighting systems were losing their charge.

Portable radios also were also losing their power, making it difficult for our technicians in the field to com-

Portable gasoline- or propane-powered equipment, hoses for emergency cooling, etc, are necessary for successful recovery from a black-plant trip



1. Black Plant Quick Reference Guide

Immediate actions from the control board

- Verify all GT and duct-burner fuel gas valves are fully closed.
- Verify all DC lube-oil pumps have started properly (ST/G, GT/G, and seal oil).
- Verify all ST/G and GT/G breakers are open.
- Verify that the diesel/generator has started and SB-1, SB-2, and SB-3 are closed.
- Verify AC lube-oil, seal-oil, and vapor-extractor blowers are running from vitals (GT/G and ST/G).
- Break vacuum on STs and secure sealing steam (after control air is established).
- Open vacuum breakers.
- Set auxiliary seal-steam header set point to zero.
- Place steam bypass valves to manual close.
- Continue to monitor coast-down of the T/Gs.
- Verify ST/G turning gear's auto-start after coast-down has occurred.

Immediate actions outside

- Verify lube-oil pressure to ST/Gs and GT/Gs (DC, vital, or both).
- Verify GT/G seal oil pressure, flow, and DP (differential pressure).
- Start and align diesel-driven air compressor.
- Isolate all ST/G seal-steam systems after breaking vacuum (if control air has not been established).

Follow-up actions

- Make appropriate notifications to customer, transmission operator, and balancing authority.
- Notify designated "single-call" recipient, to call for support personnel.
- Monitor ST condenser hotwell levels and manually drain as necessary.
- Monitor HRSG drum levels and manually drain as necessary.
- Secure ST/G DC lube-oil pumps (if lube oil is being supplied from vitals).
- Monitor level in the service-water tank and align manual bypass as necessary.
- Connect alternative cooling-water supply to auxiliary cooling-water header.
- Isolate non-essential coolers to limit water going to the cooling-tower basin.
- Connect cooling-tower-blowdown sodium bisulfite pump to alternative power source and isolate the acid pumps.
- Monitor tower and sump levels; connect portable pumps as necessary.
- Manually open ST/G seat drains if needed.

2. Black-plant emergency equipment checklist

Item	No.	Location
2-in. water pumps	3	N warehouse
Propane-fueled generator	3	N warehouse
2-in. water-pump hose kits	4	N warehouse
3-in. water-pump hose kit	1	N warehouse
Remote-area lighting system	2	N warehouse
Work lights	4	N warehouse
Rechargeable drop lights	8	N warehouse
2½-in. fire hoses (for aux cooling)	9	Three each in fireboxes in front of STs

NOTE: Portable emergency equipment on this list is for black-plant use only

Sharing ideas assures continual improvement at Green Country. Clockwise from Rick Shackelford, plant manager (at left): Danny Parish, operations manager; Daniel Barbee, contracts administrator; Jim Little, operations team leader; Mike Anderson, maintenance manager; David Rose, maintenance team leader; Linne Rollins, compliance supervisor; and Raegan Robinson, plant administrator

municate with the control room. Plus, the computer server went down, so we couldn't send emails or access the plant's shared files.

Solution. Numerous lessons were learned from this event, but the following stand out in importance:

- The exhaustive black-plant procedure previously developed by plant staff provided little value to the technicians who responded to the sudden challenge. A concise, readily available "Black Plant Quick Reference Guide" (Sidebar 1) would have been more useful to ensure that priority concerns were properly monitored and addressed.
- Technicians didn't have adequate time to search the plant for portable emergency equipment. Again, a quick reference guide that listed all such assets and their locations would have been invaluable (Sidebar 2).
- An effective black-plant action plan should allow for an extended back-feed loss; and for such an event happening during an evening, night, or weekend (with only three employees on duty) or during worst-case circumstances such as maximum-capacity operation or adverse weather.
- Plant technicians did not have time to make multiple calls requesting assistance from offsite personnel. It would have helped to have a single-call procedure in place that designated an individual who would receive one call (the operations or plant manager) and would then make additional calls to obtain support.
- The plant should have been equipped with sufficient portable gasoline- or propane-powered equipment (water pumps, light plants, generators, etc) to meet the demands of an extended black-plant event (photos).

Results. We are now much better equipped to respond to a black-plant event—even an extended one. Plant leadership has refined processes and procedures, communicated expectations more clearly, and established and documented priorities.

Project participants:
Rick Shackelford, plant manager
Danny Parish, operations manager
Michael Anderson, maintenance manager
Daniel Barbee, contracts administrator
Linne Rollins, compliance supervisor
Team leaders: Derek Hale, Dave Rose, Ewing Jackson, John Noftsger, Jim Little

Brooklyn Navy Yard

Fuel swapping, starting reliability improvements

Brooklyn Navy Yard Cogeneration Partners

Owned by BNYCP

Operated by NAES Corp

288-MW combined-cycle cogeneration facility with two 1 × 1 power blocks, each equipped with a V82.2 gas turbine, located in Brooklyn, NY

Plant manager: Dan Noel

Challenge. Brooklyn Navy Yard Cogeneration Partners sells electricity, and up to 1 million lb/hr of steam, to Con Edison and the BNY industrial park. In winter, the plant's gas contract allows the supplier to recall that fuel when consumer demand is highest—for up to 19 days annually.

For years, the cogen plant had reliability issues when burning fuel oil and performing fuel swaps on both gas turbines. Two main problems were identified:

1. Hunting of the water injection system.
2. Fluctuating discharge pressure of the fuel-oil injection pump.

Both issues caused several forced outages each winter. During winter 2014, for example, the plant's effective forced-outage rate (EFOR) during the fuel-oil season was approximately 11%.

Background facts:

1. The water injection system is used for power augmentation when burning natural gas, and NO_x reduction when burning fuel oil, making it a critical system. Supply pressure was hunting by approximately 50 psi. This caused damage to the automatic recirculating (ARC) valves and the suction pressure regulating valve incorporated into the skids for both engines.

   Average time between failures for these valves was three months and shop rebuilds cost between $3000 and $5000 per valve—amounting to an approximate annual cost of $36,000.
2. The fuel-oil injection pumps rely on a foreign-made back-pressure regulator known as the startup pressure relief valve. The lead time for parts is long and the manufacturer has no US representative.

The valve, when commanded, ports off sensing pressure through a needle valve and a solenoid valve. This allows a high-pressure (HP) setting, used for normal operation with the solenoid valve closed, and a low-pressure (LP) setting using the needle valve. The

1. Fuel-oil injection pump skids are provided for each engine

2. Viable test plan for the startup pressure-relief valve was critical to reliability improvement

solenoid valve is actuated to temporarily switch the valve to the LP setting. This allows for pump startup and completion of the LP fill step in the fuel-oil injection sequence.

Solutions:

1. Testing of the water injection system was easy, since it is routinely used for power augmentation when the engines are burning gas. However, it was difficult to determine if the hunting was caused by the ARC valves or the suction pressure regulator.

   The first step was to check valve sizes and verify the installation met OEM specs. Ken Engel, maintenance supervisor, found that the valves did meet specs; however, first-hand experience with hunting by this particular pressure regulating valve led Engel to suspect the recommended 10 pipe diameters downstream was not an adequate distance for the pressure sensing tap.

   To further complicate the issue, the pipe was located in an inaccessible area of the overhead pipe run, with no extra fitting locations. Even if access was available, the plant would not be able flush the line after installing a threadolet in order to relocate the sensing line.

   Engel was able to find a pressure regulating valve with internal sensing, the same face-to-face dimension, and appropriate capacity for the application. For the price of only two rebuilds the valve was procured and installed. When it was tested, the suction pressure was rock steady: No more hunting, no more rebuilds.
2. Several problems were noted with the startup pressure relief valves. These included the needle-valve adjustment drift attributed to a worn locking mechanism, and unrepeatability of the settings any time maintenance was performed on the valves. Any time these issues were addressed, the valve had to be tested.

   Jim Sinodinos, senior operating engineer, recommended a way to test the valves. This was a challenge since the control system does not allow a pump start unless the fuel-oil mode is selected. Also, the pump's motor controller does not have a hands-off-auto (HOA) switch.

   Sinodinos developed a plan and coordinated the multi-step effort between the field and control-room operators to force a run on the pump. This enabled the pump to be tested in both the LP and HP modes by actuating the solenoid from the control room.

   This practice allows any air, which causes unrepeatability of the valves, to be forced out after maintenance is performed on the valves. The plant has made this commissioning procedure a standard practice and it has allowed the maintenance team to troubleshoot and correct problems as required.

Results. During the winter of 2015, the plant had its gas recalled the contractual maximum 19 days. This was a record for the plant not only in total fuel-oil run time, but the plant maintained 100% fuel oil reliability for the first time in its 19-year history.

Project participants:

Ken Engel, maintenance supervisor
Jim Sinodinos, senior operating engineer.

Athens

Plant desuperheater mods for cyclic operation

Athens Generating Plant

Owned by Talen Energy

Operated by NAES Corp

1080-MW, gas-fired, three 1 × 1 combined-cycle units located in Athens, NY

Plant manager: Dan DeVinney

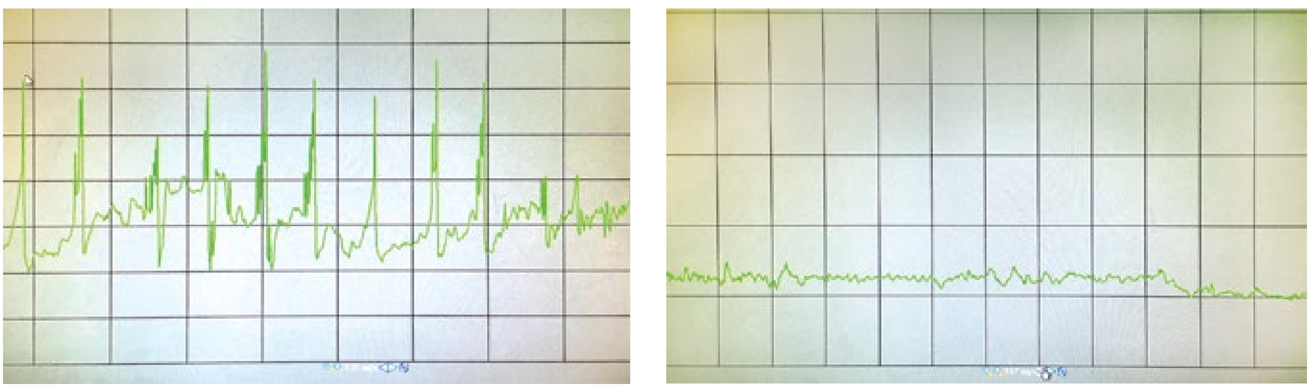
Challenge. Market conditions forced Athens Generating Plant, designed for baseload service, to cycle frequently over the last several years. Cycling has resulted in more-frequent maintenance—for example, to repair desuperheater weld cracks. The high-pressure (HP) and hot-reheat (HRH) steam bypass attemperators have been particularly susceptible to damage.

HP cracks resulted in steam leaks, HRH bypass cracks in unanticipated vacuum problems in the air-cooled condenser (ACC). They have reduced plant reliability and also become a safety hazard.

Cause of the HRH failure was a poorly located desuperheater weld—approxmmately 1 ft downstream of the spray nozzles in a region of high cyclic thermal stresses. Another shortcoming: No liner was provided. Result was a crack in the interior side of the weld (Fig 1).

1. Desuperheater weld crack developed about 1 ft downstream of spray nozzles

2. New HP bypass desuperheater has welds 10 ft farther downstream and includes a liner



3, 4. ACC vacuum swings were dramatic prior desuperheater replacement (left). After replacement, vacuum stability improved dramatically, restoring steam-turbine output to the design spec (right)

Solution. Staff sourced several vendors for possible solutions and settled on CCI, the OEM, to design new HP and HRH bypass desuperheaters. To correct the problem and prevent it from recurring, CCI replaced the original equipment with newly designed desuperheaters that pushed welds farther downstream and also added liners (Fig 2). These two fixes allowed the spray water to adequately mix with process steam prior to coming in contact with piping welds.

Results. The new design has been installed on two HRH bypasses and one HP bypass. Since then, the plant has not experienced any desuperheater cracking.

In addition, vacuum has vastly improved. Before replacement, vacuum would swing from 2.5 to 6 in. Hg abs over the course of several minutes, which significantly diminished steam turbine output (Fig 3). With the new desuperheater, plant vacuum is very stable and ST output has returned to design spec (Fig 4).

Project participant: Hank Tripp, plant engineer

ACC fan shroud enhancement

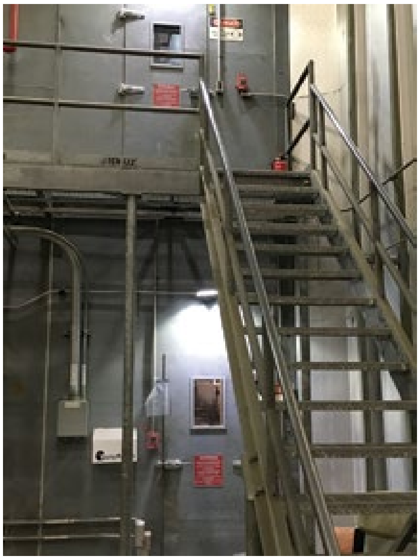
Challenge. The fan shrouds for our air-cooled condenser (ACC) were prone to failure. The original shrouds were made of hollow plastic. A recurring issue with them was the accumulation of water inside the parts, which increased their weight. This in turn put more stress on all of the related support hardware.

As a short-term fix, technicians simply drilled holes in the shrouds to drain the water. However, this weakened them and they began to crack at the hole locations, causing the shrouds to fail.

This presented a safety hazard to our ground crews because the shrouds are located nearly 100 ft above their heads.

The shroud failures also impacted overall system reliability because it took a long time to get replacements, increasing the downtime of the affected fan.

Solution. To address the issue, staff investigated newly designed solid-fiberglass replacements. Solid fiberglass construction increases the weight but eliminates the possibility of water accumulating in this part. A structural analysis revealed the added weight would not compromise ACC integrity. The new shrouds also would not influence air flow to the fans.



5. Low-cost, low-maintenance package door windows allow O&M personnel to assess interior conditions before entering a potentially hazardous situation

Results. Switching to solid fiberglass fan shrouds improved ACC reliability and reduced fan downtime. In addition, it mitigated a safety hazard for the O&M staff because the chances of these shrouds cracking, and pieces being liberated, is virtually nil.

New shrouds installed thus far have not exhibited any deterioration, allowing the fans to remain in service and provide continuous air flow to the ACC. Completion of the retrofit project, which began in spring 2015, is expected by the end of 2017.

Project participant: Steve Cole, lead O&M manager

Safety windows help protect personnel

Challenge. The site is equipped with three Siemens 501G gas turbines, each of which is contained within its own packaged enclosure.

Without opening the enclosure door, plant personnel had no way to view the interior. This presented a variety of hazards to staff entering the package to investigate alarms or abnormal conditions.

With no view of conditions inside, they could potentially walk into a hazardous situation unprepared. In the event of a fire, for example, the fire-suppression system would extinguish the fire with FM200, but staff couldn't determine if it was fully extinguished without opening the enclosure door.

Solution. Personnel researched possible solutions—such as installing cameras within each enclosure that showed conditions in and around the entry way. However, the reliability of such systems in a high vibration environment remained in doubt. Plus there were installation and maintenance costs to consider.

The retrofit decision chosen was package-door windows, which presented a more reliable, lower-cost solution. We sourced the windows through the turbine OEM and had them installed by local contractors (Fig 5).

Results. With the door windows installed on all three units, operators now have an unobstructed view of the package enclosure and can. O&M personnel can now easily view conditions inside the package and evaluate a situation before entering a potentially hazardous environment. The windows require zero maintenance other than occasional cleaning and will help streamline the workflow during future outages.

Project participants:
Joel Shanks, O&M technician
Roger Masse, O&M technician

Effingham

Effingham County Power

Owned by The Carlyle Group

Operated by Cogentrix

525-MW, gas-fired, 2 x 1 combined cycle located in Rincon, Ga

Plant manager: Nick Bohl

Auxiliary-boiler blowdown relocation

Challenge. The auxiliary boiler's superheater had been a continuous problem. It is an electric superheater containing several 480-V heating elements. Over time, a significant reduction in current to the unit was occurring, and damage to the heater element terminals also was apparent.

Initially it was thought that this damage was caused by steam leaks through the gasket of the heater-element head. However, while inspecting the superheater, personnel found most of the damage was occurring at the lower right-hand section.

Monitoring of the next startup revealed that when the aux boiler was being blown down, the steam was being discharged directly into the electric superheater.

Solution. The steam was going directly into the air vents of the casing, filling the entire electrical enclosure. These vents could not be obstructed to prevent steam entry because this would not allow the hot air in the superheater to escape.

To protect the electric superheater from the steam, O&M personnel decided to redirect the blowdown line. The discharge of the blowdown line is now well clear of the electric superheater and steam entry into the enclosure is no longer an issue (Fig 1).

Results. Since redirecting the blowdown path of the auxiliary boiler, the condition of the electric superheater has greatly improved. The total amount of amperage has increased, meaning it is operating more efficiently and at higher capacity. In the past, the amperage would trail off over time, markedly. Now the current is stable for a much longer amount of time eliminating the need to shut down for repairs.

Project participant: Chris Hofer

1. Blowdown discharge location for Effingham's auxiliary boiler was moved to prevent steam entry into the electric superheater

Freeze protection system enhancements

Challenge. The January 2014 record-breaking cold spell shut down the plant because the freeze protection system was not working properly. Process lines and transmitters were freezing. Several transmitters had to be replaced. Insulation, lights, and temporary heat trace were installed to make it through the cold spell.

Some of the damaged instrumentation was not found until months later because of erratic operation. The drawings that were furnished for heat tracing were not thorough or accurate. Example: The heat-trace junction boxes were not marked with circuit numbers making it difficult to trace down the correct circuits.

Every issue had to be investigated and walked down to verify circuitry, making it very difficult and time-consuming to troubleshoot. The plant has seven electrical heat-trace panels with over 60 different circuits. Some

2. Heat-trace system was labeled in detail to facilitate troubleshooting circuits have as many as 13 runs that branch out to heat trace, heaters, and/or indicating lights.

Solution. The complete heat-trace system was walked down, verified, repaired, and labeled (Fig 2). A spreadsheet was created to document the mapping of the heat-trace system and any issues that arise (Fig 3). It contains all pertinent information needed if a repair or replacement is necessary. All circuits have been clearly marked and recorded on the spreadsheet, which is kept on the shared drive for all staff to access.

Results. With the heat-trace system labeled and documented, the plant is now able to troubleshoot and repair the circuits without wasting man-hours. Plant instrumentation has better freeze protection, resulting in fewer costs for replacing it. Most importantly, the reliability of the plant is no longer affected by freeze issues.

Project participant: Cheryl Hamilton

HRSG 1 CKT#6						
LABEL	TAG ID	PART NUMBER				LOCATION
6	1-1.5IN- 480-1519	MISS-K919-014-03	B-9908-3	VOLTS 120 AMPS .5 WATTS 57		AT BFP STRAINERS
6	480-BV-1509	FLAT HEAT TRACE	XX	XXX	FROM 1519	STRAINER DRAIN
6	1-1.5IN- 480-1521	MISS-K919-014-03	B-9908-1	VOLTS 120 AMPS .5 WATTS 57		AT BFP STRAINERS
6	480-BV-1501	FLAT HEAT TRACE	XX	XXX	FROM 1521	STRAINER DRAIN
6	1-3" 480-1015	KN132L-AN-178-03	B-9908-03	VOLTS 120 AMPS 6.7 WATTS 809		BETWEEN BFP STRAINERS HEAD HIGH
6	1-480-PI-1001, 2, 3A	MISS-K919-016-03	B-9908-3	VOLTS 120 AMPS .4 WATTS 50	J BOX 3 TAPS	NORTH SIDE OF BFW PUMP 'A' GAUGE LINES
6	1-1503/1504 DRAIN VALVE	FLAT HEAT TRACE	XX	XXX	FROM 1001A	HP FW FLOW 'A' AT STRAINER
6	1-480-PI-1001, 2, 3B	MISS-K919-016-03	B-9908-3	VOLTS 120 AMPS .4 WATTS 50	J BOX 3 TAPS	NORTH SIDE OF BFW PUMP 'B' GAUGE LINES
6	1-1511/1512 DRAIN VALVE	FLAT HEAT TRACE	XX	XXX	FROM 1001B	HP FW FLOW 'B' AT STRAINER
6	1-480-PIT-1553A	FLAT HEAT TRACE	XX	XXX		POWER OUT OF 1.5IN-480-1521
6	1-480-PIT-1553B	FLAT HEAT TRACE	XX	XXX		SOUTH OF STRAINER HEADER
6	1-480-PIT-1559	FLAT HEAT TRACE	XX	XXX		W BFP STRAINER AREA IP FW PIPING
6	1-480-PIT-1561A	FLAT HEAT TRACE	XX	XXX		POWER OUT OF 1.5IN-480-1519
6	1-480-PIT-1561B	FLAT HEAT TRACE	XX	XXX		POWER OUT OF 1.5IN-480-1519

3. Spreadsheet documents components in the heat-trace system and identifies location, past issues, information to facilitate ordering of replacements, etc

Increasing lube-oil-pump bearing life

Challenge. The original design of the Buffalo Model VCRE pumps that provide lube oil and seal oil to the gas turbine were equipped with a grease-lubricated upper thrust bearing, fitted with a pressure-cup type automatic greaser. To grease the bearings, you tightened the pressure cap on the greaser and the bearing is lubricated.

This original application would have worked, but because the bearing cover was not fitted with grease relief, over a period of time the grease compacted within the bearing cover and eventually blew out the bottom seal. Once the bottom seal was compromised, the grease would leak out of the bearing cover, and bearing, and cause the upper thrust bearing to fail.

A failure occurred about every 7500 to 8000 run-hours. The installation arrangement with tandem pumps piped to a common header made it impossible to remove one pump at a time. In addition, to repair the failed pump bearing, the entire unit had to be shut down and allowed to cool down.

Next, the lube-oil header piping above the pumps would be removed and lastly, the failed pump removed for repairs. Repair costs associated with the foregoing is minimal compared to the costs of missing a full day of power production.

Solution. To extend the run time of the upper thrust bearings and improve unit dependability and reliability, the O&M team decided to retrofit the upper thrust bearings with a forced feed of lube oil.

The forced oil feed to the bearing was obtained from two sources, the first being the lube-oil header just downstream of the pressure regulator. This would provide lube oil, when the unit was running or on turning gear. If the unit was down or off turning gear, the lube-oil feed was provided from the discharge flange of the seal-oil system. These two sources ensured that the lube-oil pumps would have a continuous supply of oil to the upper thrust bearing.

Next, a stainless-steel fitting was installed into the lube-oil header in the same proximity as the lube-oil header temperature switches, along with a lockable-handle ball valve to provide the first source of forced oil feed to the upper thrust bearing.

The second source of forced oil feed was obtained from an existing ¼ in. pipe fitting on the discharge piping of the seal-oil pump. Oil then is pumped through in-line filters, regulating valves, check valves, and individual isolation valves. Finally, the oil is pumped through a 0.040 in. orifice to provide the correct amount of forced oil feed to the two auxiliary lube-oil pumps and the seal-oil pump.

Because of the lower run times of the DC lube-oil pump, the forced oil feed mod was not implemented on this pump at the time of installation. However, provisions were made in the original installation of the forced oil feed tubing to allow for this at a later date, if required.

Results. Prior to installation of the forced oil feed system, the plant was experiencing a pump bearing failure every two years, or less. Since installation in 2005, the plant has not experienced a failed bearing. The replacement of one or two top-bearing cover seals was needed but this can be done without removing the pump and related piping. This means personnel can make these repairs with the units running.

The associated cost of the seals and bearings is minimal compared to the cost of lost production, not to mention the vast improvement in reliability of the facility without a single bearing failure.

Project participant: Alan Sparks

Sensing lines for fuel-gas-train control valves

Challenge. Effingham experienced below-normal temperatures in recent winters causing multiple freezing issues throughout the plant. Among the components affected were the fuel-gas-train monitor and worker control valves. The upstream and downstream sensing lines to these valves accumulated moisture from continuous operation at ambient temperatures below normal.

When moisture blocked the upstream sensing line, the control valve would sense lower inlet pressure and would open more to maintain downstream pressure. This would raise downstream pressure above the design value, causing safety valves on the fuel-gas filter/separators to lift.

Once the water cleared the line, then the valve would sense a higher inlet pressure, causing the valve to close. As long as moisture was present in the sensing lines, the valve would continue to cycle.

If moisture was present in the downstream sensing line, the control valve would see a lower system pressure, causing it to open to increase downstream pressure. Once the moisture cleared the line, the valve would respond by closing, resulting in rapid cycling of the control valves.

This cycling of the control valves resulted in low inlet pressure at the gas turbines. A load runback was initiated to protect the turbine from low pressure in the fuel-gas system.

The relief valves that lifted to protect the fuel-gas system are only designed for one cycle. Typically, the relief valve would not seat properly and result in fuel gas leaking into the environment. Since the plant doesn't maintain spare relief valves in inventory, Effingham would have to shut down to replace the relief valves.

Both the GT runback and relief-valve maintenance prevented the facility from meeting the day's scheduled dispatch and the plant would be unavailable until the relief valves could be replaced or rebuilt. This happened on several occasions and each time the plant would have to shut down, if running, and the relief valves rebuilt.

During the winter, the plant lost approximately $42,000 because of sensing-line freeze-up.

Solution. Low-point drains with a double-block configuration were installed in the sensing lines (Fig 4). With them installed, plant personnel can easily drain the accumulated moisture.

4. Sensing lines for fuel-gas-train control valves were equipped with drains and double valves to mitigate freeze-up in winter

The fuel-gas trains are isolated and moisture is drained prior to the onset of low ambient temperatures. Also, during the winter, plant personnel drain moisture from the sensing lines monthly to prevent freezing issues.

It took approximately two days to install the additional drain legs to the sensing lines in early 2010, during plant downtime. There was no cost associated with the installation other than the tubing, valves and labor. The tab was approximately $1,000.

Results. After installing the low-point drains for the fuel-gas-train control valves in 2010, the plant's freeze protection procedure has plant personnel drain moisture from the sensing line monthly during the winter. The facility has had no further issues with freeze-up of these sensing lines and there has been no loss generation or revenue since installation.

Project participants: Howard Beebe and Michael Gilbert

Paris Energy Center

Owned by Viva Alamo LLC

Operated by NAES Corp

260-MW, gas-fired, 2 × 1 7EA-powered combined cycle located in Paris, Tex

Plant manager: Mark Vest

Trolley system streamlines replacement of collector rings

Challenge. Paris experienced a hard ground on the generator collector shell leads in October 2015. As part of the outage, collector rings were removed, sent to a shop for machining, and then reinstalled. Last step involved heating the rings to allow them to reposition themselves onto the shaft of the rotor.

The process proved ineffective on the first try because the lengthy crane travel time allowed the rings to cool down before they could be moved from the heater to the collector end of the shaft. Result: The collector shell wouldn't slide into place after reinstalling the rings.

Next, plant personnel tried applying source heat to get the rings hot enough to slide into place. But the installation failed again, this time resulting in material defects that required the collector ring assembly be returned to the shop.

Upon inspection, the shop deemed it necessary to open the fit by one to two mils to allow smoother installation. This resulted in 15 days of downtime, during which the plant could dispatch only at partial load (1 × 1).

Solution. Learning from the first trial, a maintenance technician designed and built a trolley system to accommodate reinstallation when the rings returned. The trolley consists of a chain-fall hoist suspended from a set of rollers that travel along an I-beam rail (Fig 1). The heavy-duty legs are bolted to the concrete ground to provide stability during lifts (Fig 2).

1. Trolley system with chain-fall hoist is used to move collector rings from oven to generator for installation

2. Legs supporting trolley system were bolted to the concrete pad to stabilize lifts

3. Collector rings are heated in oven (foreground, right of center), removed from oven, attached to chain-fall, lifted, and trolleyed to the generator

This system allows staff to remove the rings from the heater—an industrial oven designed to heat metal—and convey them to the collector end in a fraction of the time it took using a conventional crane (Fig 3). The rings remained hot during reinstallation and a consistent temperature was maintained across them. The need for a crane was eliminated.

Results. Thanks to the proactive, creative thinking of Maintenance Technician Bud Browning, Paris Energy Center was able to expedite collector-ring reinstallation, reduce outage scope dramatically, and achieve substantial cost savings in shop time and crane support.

Project participants:

Brent Brady, maintenance manager

Bud Browning, maintenance technician

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Falcon Crest Aviation

Distributor of ZOK27 and ZOKmx gas-turbine compressor cleaning detergents. ZOK27 is a single cleaner and inhibitor in one that cleans and protects the engine—and also inhibits corrosion. ZOKmx is a power cleaner formulated to replace solvents providing exceptional cleaning without the health and environmental risks associated with solvents.

Federal Steel Supply Inc

Distributor of seamless and welded steel pipe, fittings, and flanges for power generation. Specializes in large diameter, heavy-walled carbon steel, and chrome-moly tubular products meant for use in extreme temperature and pressure applications. Multiple grades of pipe covered by ASTM, ASME, and API.

Frenzelit North America

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

Gas Turbine Controls

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

Gas Turbine Efficiency

Provides solutions involving the application of electrical, mechanical, and process-related equipment and components for optimizing system performance. GTE's experienced team of engineers and designers has solid industrial process backgrounds with expertise in fluid systems, instrumentation, and system controls.

GP Strategies

Provides training, engineering, and performance improvement services specifically designed for the power industry: The EtaPRO™ Performance and Condition Monitoring System and GPiLEARN+™.

Groome Industrial Service Group

Offers a variety of SCR and CO catalyst cleaning and maintenance services nationwide and has formed strategic alliances with industry experts and catalyst manufacturers to ensure that Groome offers the most widely supported, comprehensive, turnkey service available.

GTC Services

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

Gulf Coast Filters & Supply

Keep your filter house and evap coolers operating at peak condition. GCF provides comprehensive, personalized filter-house products, field service, and maintenance, emphasizing safety, professionalism, efficiency, minimal job-site disruption, quality products, and thorough testing and inspections.

Haldor Topsoe

Our air pollution technology includes a series of unique catalysts for Selective Catalytic Reduction (SCR) systems for the control of nitrogen oxides (NO_X), and the reduction of carbon monoxide (CO) and volatile organic compounds (VOCs), from stationary and mobile sources.

Hilliard

The HILCO® Division cost-effectively brings fluid-contamination problems under control and engineers a full-range of filters, cartridges, vessels, vent mist eliminators, transfer valves, reclaimers, coolant recyclers and systems, and membrane filtration systems.

HRST

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

Hydro

Engineered solutions enable combined-cycle plants to achieve pump reliability and reduced O&M costs. As the largest independent pump rebuilder, Hydro works hand-in-hand with pump users to optimize the performance and reliability of their pumping systems.

Hy-Pro Filtration

Provides innovative products, support, and solutions to solve hydraulic, lubrication, and diesel contamination problems. Company's global distribution and technical-support networks enable customers to get the most out of their diesel, hydraulic, and lube-oil assets. ISO 9001 certified.

Janus Fire Systems

Manufacturer of special hazard fire protection solutions. Designers of engineered clean agent and high- or low-pressure carbon dioxide systems composed of hardware and software tailored to the application.

JASC

Engineers and manufactures actuators and fluid-control components for power generation, aerospace, defense, and research applications to improve operational capability and performance.

KnechtionRepair Tools

Manufactures tools designed to make thread repairs to both the female and male ends of cross-threaded compression fittings. In most cases, the repair will be accomplished without removing the tube from the system. This saves the O&M tech time and avoids additional downtime.

Kobelco Compressors America

Provides robust, high-efficiency fuel-gas compressors for use with all major types of gas turbines—including GE, Mitsubishi, Alstom, Siemens, Rolls-Royce, and Solar. Over 300 of the company's screw-type compressors have been supplied for gas turbines.

Liburdi Turbine Services

Advanced repairs employ the latest technologies and are proven to extend the life of components for all engine types. Company specializes in high-reliability component repairs and upgrades for blades, vanes, nozzles, shrouds, combustors, and transitions.

M & M Engineering

Provides failure analyses and related services to industrial and insurance-company clients. M&M's expertise includes corrosion in boilers, steam turbines, generators, combustion turbines, deaerators, feedwater heaters, and water and steam piping.

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.

Membrana, a 3M company

Market-leading producer of microporous membranes and membrane devices used in healthcare and industrial degassing applications. The Industrial & Specialty Filtration Group manufactures Liqui-Flux® ultrafiltration and microfiltration modules as well as Liqui-Cel® membrane contactors.

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.

NAES

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

National 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.

NEM Energy

A leading engineering company operating globally in the field of steam generating equipment. NEM supplies custom-made solutions regarding industrial, utility, and heat-recovery steam generators for power generation and industrial plant applications.

NRG Energy Services

Backed by the strength and reach of the America's largest independent power generation company, NRG Energy. Company provides plant maintenance solutions to minimize downtime, increase asset availability, reduce ownership costs, and boost profits. Company delivers custom-tailored O&M solutions to meet any generation need, on any scale.

Parker Balston

Develops and manufactures nitrogen generators for all your power generation needs including boiler layup, gas seals, purging gas lines prior to service, blanketing demin water tanks, and LNG terminals.

Parker Hannifin

Reduce costs and optimize performance with the world's leading diversified OEM of motion, flow, process control, filtration, and sealing technologies, providing precision engineered solutions for the power generation market.

PetrolinkUSA

Provides high-velocity hot-oil flushing, EHC flushing, chemical cleaning, lubricant reconditioning, and auxiliary on-line filtration. Preventive maintenance services include equipment assessments and lubricant analysis.

Powergenics

Leading supplier of industrial electronic circuit-card and power-supply repairs to industrial and power generation customers. Company provides a very high-quality repair at a substantial cost savings from the OEM and other competitors while maintaining a warranty service second to none.

Praxair Surface Technologies

Leading global supplier of surface-enhancing processes and materials, as well as an innovator in thermal spray, composite electroplating, diffusion, and high-performance slurry coatings processes. Company produces and applies metallic and ceramic coatings that protect critical metal components such as in gas turbines.

Precision Iceblast

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

Proco Products

Supplies rubber expansion joints to the power industry in sizes ranging from 1 to 120 in. ID. Proco keeps joints up to 72 in. ID in stock at its Stockton (CA) warehouse and works through an agent/distributor network to supply products to combined-cycle plants.

PSM—an Alstom company

Full-service provider to gas-turbine equipped generating plants, offering technologically advanced aftermarket turbine components and performance upgrades, parts reconditioning, field services, and flexible Long Term Agreements (LTAs) to the worldwide power generation industry.

PW Power Systems

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

Real Time Power

Offers smart optimization solutions for power generation. Expertise spans machine learning, predictive modeling, diagnostics, and forecasting. Employs data scientists with unique domain knowledge of gas turbines to create realistic and practical algorithms, providing accurate predictions which improve plant operations.

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.

Sound Technologies

Provides engineered silencers and systems for new and replacement gas-turbine applications—including turbine inlet silencing, turbine enclosures, bypass systems, and HRSG inlet shrouds and stack and vent silencers.

SSS Clutch Company

Clutches enable operators to disconnect generators from simple-cycle turbines for synchronous-condenser service. Clutches also find application in CHP plants and in single-shaft combined-cycle facilities where operating flexibility is beneficial.

Strategic Power Systems

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

Structural Integrity Associates

Powered by talent and technology, SI is a global leader in providing innovative engineering solutions. Using a multidisciplinary approach, our experts bring a fresh perspective and proven solutions for structural evaluation and repair.

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.

Taylor's Industrial Coatings

Highly skilled staff is trained and equipped with the latest tools and equipment necessary to complete coating projects on time and in scope with a commitment to safety, technical support, and quality workmanship.

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.

TEServices

Superior metallurgical experience in managing components, creating repair and bid specifications, selecting the repair and coating vendor, and verifying them during the refurbishment of critical IGT components when your company does not have the resources available.

Texas Bearing Services

Manufactures and repairs fluid film (babbitt) bearings and seals for turbomachinery including gas and steam turbines, compressors, generators, gearboxes, and more. Works with OEMs, distributors, and end-users all over the world and offer 24/7/365 emergency services for critical outages.

Thor Precision

Value-added service center provides reverse-engineered rotor bolting for the gas-turbine aftermarket—specifically for Frame 3, 5-1, 5-2, 6B, 7E, 9E engines—including compressor, turbine, marriage, and load-coupling hardware.

Turbine Generator Maintenance

Provides turnkey field service maintenance for all turbine/generator components. TGM services the turbine, generator, exciter, control systems, and auxiliaries either individually or in any combination. Its service area includes the US, Caribbean, and South America.

Turbine Technology Services (TTS)

Wide range of expert engineering and consulting services, conversion, modification and upgrade services, GT installation and reapplication services, and design and implementation of complete turbine management systems.

Universal AET

Designs, procures, and manufactures OEM and retrofit inlet and exhaust systems including filter houses, inlet duct/silencers, enclosure doors, diffusers, plenums, expansion joints, transitions, exhaust ducts/stacks, exhaust baffle silencers, and stack dampers.

Universal Plant Services

Specializes in the maintenance, repair, and overhaul of gas and steam turbines, centrifugal and reciprocating compressors, as well as all rotating equipment, with qualified millwright and field machining specialists.

Victory Energy

Offers all types of industrial boilers: watertube, HRSG, firetube, and solar-powered units. Company provides unprecedented support with its rental boilers, spare parts, field service, and auxiliary equipment—including water-level devices, economizers, stacks, expansion joints, and ductwork.

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.

Zeeco Inc

World leader in combustion and environmental systems including burners, flares, thermal oxidizers, vapor control systems, aftermarket parts and services, rental systems, scanners, and monitors.

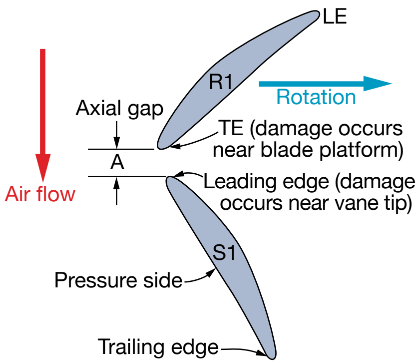
Zokman Products

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.

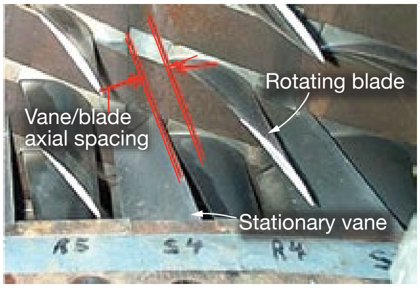
Owner/operators focus on forward compressor issues

Budgets are tight. . .everywhere. But that's no excuse for not attending the 25th anniversary meeting of the 7EA Users Group, November 1-3, at the Hershey Lodge Convention Center in scenic Hershey, Pa.

If you're an owner/operator of one or more GE 7B-EA engines and not yet registered for this conference you missed the 50-buck admission ticket, and the $150 opportunity (expired September 23), but can still get in the door for $250—or about half of what most other user groups charge these



Axial gap (A) at R1 root: more than 0.600 in.
Axial gap (A) at R1 tip: About twice gap at root



1, 2. Clashing occurs when the tip of a stationary vane moves forward more than half an inch and contacts passing rotating blades near their platforms

3. Leading edge of stationary vane was removed by contact with rotating blades days. Think of this meeting as least-cost learning. Register online at http://ge7ea.users-groups.com.

Participate in the 2016 conference and learn how to reduce unplanned outages by upgrading critical compressor components to mitigate clashing and other 7EA fleet issues. Recall that clashing is the term used to describe contact between the leading edge of stationary vane tips with the trailing edges of rotor blades at the platform (Figs 1-3). If you're unfamiliar with clashing, visit www.ccj-online.com and use the search function at the top right-hand side of the home page to access a wealth of information.

When first experienced, clashing was associated with 7EA first-stage airfoils (rotor and stator blades) but later also was identified in the machine's second and third stages. And it has been experienced in 7FAs, 6Bs, and even Frame 5s, according to field reports.

Last year's robust presentation/discussion program on clashing will continue in Hershey, with the OEM likely updating the group on fleet experience with an airfoil coating to guard against destructive corrosion, the value of shorter ring segments and a corrosion-resistant ring material, testing of an IGV schedule to change the characteristic of rotating stall, a fourth-flex retune to minimize the potential for clashing, etc.

A couple of these topics are not typical of the ones you normally find on user-group programs. In some cases they require deep concentration to absorb content critical to reliable operation. The 7EA conference conveys this information in a relaxed setting and provides access to qualified experts—engineers from the OEM, user organizations, and third-party services providers—during breaks, meals, the vendor fair, etc, to answer your questions.

The Nov 9-12, 2015 meeting in Santa Fe, NM, was considered by some owner/operators the most significant 7EA Users Group conference they had ever attended because users finally received meaningful answers

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7EA Users Group

25th Anniversary Conference

Nov 1-3, 2016
Hershey Lodge Convention Center
Hershey, Pa

Steering committee

Jason Hampton, *senior project engineer, EthosEnergy Group*
Joseph Miraya, *CT program manager, Duke Energy TGS*
Syed Mehdi Ali, *GM operations, Karachi Electric Supply Co*
Tracy Dreymala, *facility manager, San Jacinto Peakers, East Texas Electric Co-op*
Ronald Eldred, *plant manager, Rosemary Power Station, Dominion*
Michael Johnson, *powerplant supervisor, Turlock Irrigation District*
Guy LeBlanc, *supervisor, Consolidated CT Plants, First Energy Corp*
Tony Ostlund, *combustion turbine technician, Puget Sound Energy*
Lane Watson, *account engineer, FM Global*
Mirza Hossain, *plant engineer, TransAlta Corp*
Randall Rieder, *mechanical engineer, ATCO Power*

Photo op. Several members of the 7EA Users Group steering committee were having lunch outside during the Santa Fe meeting and the editors captured this informal photo. From the left, Tony Ostlund, Puget Sound Energy; Guy LeBlanc, First Energy Corp; Tracy Dreymala, Ethos Energy Group, San Jacinto Peakers; Pat Myers, now retired; Mizra Hossain, TransAlta Utilities; and Jason Hampton, Ethos Energy Group. Apologies to committee members not present: Randall Rieder, ATCO Power; Syed Mehdi Ali, K-Electric Ltd; Michael Johnson, Turlock Irrigation District; Ronald Eldred, Dominion-Rosemary Power Station, and Lane Watson, FM Global

and guidance regarding the clashing and forward-compressor issues that had dogged the fleet for several years.

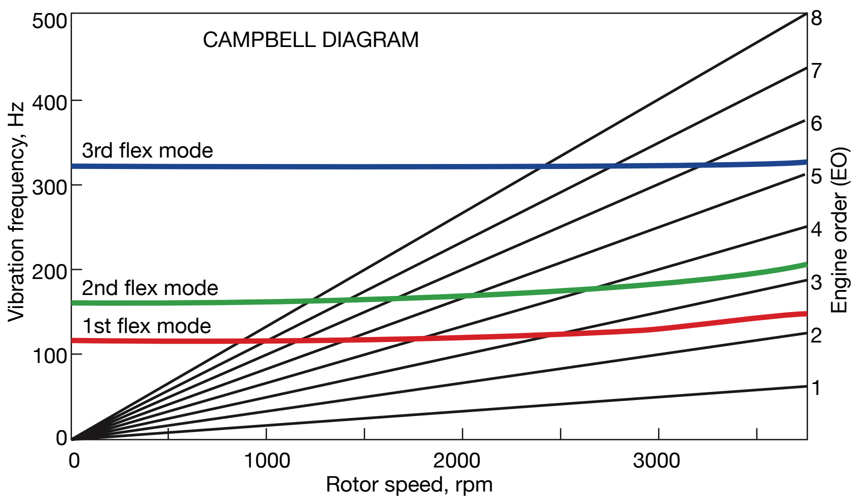
Detailed presentations by GE, four users, Advanced Turbine Support LLC, and EPRI on clashing experiences and investigations, together with open discussion on the topic involving many of

Refresh your knowledge of compressor design

Bechtel Fellow Cyrus B Meher-Homji's presentation at the 27th Turbomachinery Symposium in 1998, "Gas Turbine Blade Failures—Causes, Avoidance, and Troubleshooting," is recommended reading for plant and headquarters personnel wanting to learn more about the GT assets they are responsible for.

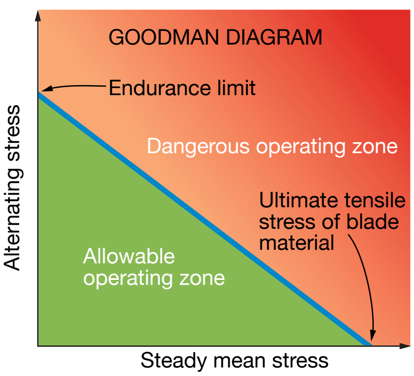
The section of that paper on blade vibration, stress, and life estimation, co-authored with Consultant George A Gabriles, is particularly helpful for understanding the forward compressor issues experienced in the 7EA fleet. The rotating-machinery experts began their dissertation by identifying the two types of compressor-blade vibration of greatest interest to power producers: forced vibration and flutter. The first is the focus here.

Forced vibration, the authors said, arises from movement of the rotor through stationary disturbances—



including upstream rotor wakes, support struts, inlet distortion, etc—or from forcing functions such as rotating stall. Meher-Homji and Gabriles likened forced vibration to rotor critical speed, saying it too can contribute to high stresses, and possibly airfoil failure, when the excitation frequency coincides with the blade's natural frequency.

By way of background, a rotating stall is created when a few airfoils experience stall (that is, air flow separates from the suction side of the blade) and disrupt local air flow in the compressor. The stalled airfoils create pockets of relatively stagnant air (so-called stall cells) which rotate around the circumference of the machine at about 50% to 70% of rotor speed rather than moving in the direction of flow. The impact of local stalls includes a reduction in compressor efficiency and an increase in the structural loads on the affected airfoils.



Almost all sources of forced excitation other than rotating stall are integer multiples of the rotating speed, termed "engine order" (EO), and shown as diagonal lines on a Campbell diagram; the resultant vibrations are known as synchronous.

By contrast, non-synchronous vibrations are not related to engine speed and are indicated by horizontal lines on the diagram. High levels of excitation caused by non-synchronous vibration are possible during transient operating conditions, such as startup and shutdown—particularly when compressor blades are "locked" into ring segments by rust and other foreign matter.

Campbell and Goodman diagrams (illustrations present hypothetical examples) are valuable evaluation tools for troubleshooting blade failures. First provides details on natural frequencies and the forcing functions at different operating speeds, while the Goodman diagram is a visual map of stress levels to estimate gas-turbine operating limits.

the 115 registrants from eight countries, helped attendees better understand what they were dealing with and enabling the formulation of next steps to mitigate the issues.

It had to have been a career moment for Pat Myers, who recently retired as plant manager of AEP's Ceredo Generating Station, a six-unit simple-cycle peaking station powered by 7EAs. Myers was the organization's de facto chairman who relentlessly pursued answers to clashing questions brought to the floor by members of the user group at every meeting since 2008.

The starting point of the Santa Fe presentations and discussion was first-stage clashing, and cracking at the root (and possible liberation) of some first-stage stator vanes (S1). These phenomena were said to be caused by a rotating-stall-driven first-flex (1F) vane frequency response experienced during startup and shutdown (sidebar). Suggestion to attendees: Read TIL 1884-R1, "7EA R1/S1 Inspection Recommendations," on the importance of inspecting R1 and S1 airfoils for possible clashing damage.

The group was told that rotating stall is an unavoidable transient condition on every startup and shutdown. Further, that the stall condition is most likely to drive a response in S1 vanes when inlet temperatures are below about 50F, making engines in North America among the most susceptible. Veterans recalled that the first report of clashing by a member of the 7EA Users Group was on an especially cold December day.

The 1F frequency response, plus the loss of damping attributed to ring-segment corrosion, results in clashing. Recall that the roots of vanes in the first four rows of the 7EA compressor are inserted into slots in the ring segments and the accumulation of corrosion products in that space can lock the airfoils in place.

In sum, evidence to date points to moisture in the compressor case, cold weather, carbon-steel ring segments, and 403cb vane material (pre-1996) as the primary causes of clashing—with starts-based engines most susceptible. Clashing also is in evidence in 7EAs shipped after 1995, but the GTD450 vane material in these units has improved fatigue properties and is more forgiving when under resonance from the 1F frequency response.

Replacement of the existing six carbon-steel ring segments with a dozen segments made of Type-431 stainless steel is recommended by the OEM to mitigate vane lock-up. Increased clearance between the ring segments and casing and the elimination of shims are other positives associated with the upgrade. Roughly 10% of the global fleet reportedly has completed this work, gaining positive operational benefits.

Shortly after the 2015 conference, the OEM released TIL 1980 (Jan 20, 2016), "7EA S1 Suction-Side Inspection Recommendations," to inform users of the need to inspect for crack indications on the S1 airfoil—in particular, units with vanes of Type-403cb stainless-steel—regardless of clashing damage on S1 and R1 airfoils.

Note that the higher-than-normal operating stresses caused by the frequency response and loss of damping described earlier reach a maximum on the suction side of the stator vane near the mid-chord location. Crack indications in this so-called "area of interest" are best identified, according to the leading third-party inspection services firm, by eddy-current inspection. Its technicians found some cracks too tight to bleed dye penetrant as recommended by the technical information letter in cases where fluorescent penetrant inspection is not possible.

In addition to the possibility of S1 liberation at the *root of the airfoil* or in the *mid-chord area,* some units—primarily those operating baseload in corrosive environments (think Middle East)—may be susceptible to S1 *tip* liberation.

The causes here are the fourth-flex (4F) vibration mode, loss of damping, and crack initiation attributed to corrosion pitting on the vane. The findings common to virtually all incidents: GTD450 vane material, carbon-steel vane-segment rings, at least one pit at the point of liberation.

A user said all cracks reported had initiated at the trailing edge of the airfoil between 1 and 2.5 in. from the tip and migrated quickly across the blade to the leading edge, enabling liberation.

One user reported his company's large fleet of 7EAs in baseload service had suffered a total of six individual S1 blade-tip failures in four machines during the 42 months leading up to the 2015 meeting, but no forced outage resulted. There was downstream damage, however. The affected units all had operated from about 55,000 to 65,000 hours; inspection revealed pitting of the uncoated blades and vane-ring corrosion.

The root-cause analysis (RCA) focused primarily on vane design. It pointed to high-cycle fatigue failure from a combination of vane lockup and pitting which shifted the resonant frequency (4F) in synch with the running speed.

The speaker said 38 tip-liberation incidents had been reported worldwide prior to the 2015 meeting (the first in 2006) with only one resulting in a forced outage. He added that no TIL on tip liberation had been issued up to that time. Further, that his company's engineers found tip liberations can occur so fast (in a matter of hours in some cases) they were not aware of any inspection regimen to warn of *impending* cracking.

The OEM's immediate mitigation recommendations to this user: Install shorter stainless-steel vane carrier segments and re-double efforts to maintain the cleanest compressor possible by way of top-quality air filters and/or water washing.

A new first-stage stator vane was said to be in testing, with a 2017 commercial release date planned. It would mitigate 4F effects, but not the 1F frequency response. Addressing the latter is complex, the group was told, possibly requiring a total compressor redesign.

Durability upgrades suggested by the OEM included shot-peening to improve damage tolerance on the first seven stages of the compressor, and coating of S1-S7 stator vanes with the OEM's proprietary GECC-1 formulation to mitigate pitting attack.

An owner/operator with three 7EAs serving a baseload industrial complex was next to report on his company's forward-compressor experience. First engine began commercial operation in mid-1997 with GTD450 S1 vanes, the others went COD shortly thereafter.

Clashing recently had been identified in the lower half of all three units. Eddy-current inspection revealed three cracked S1 vanes (tip area) in one unit that, in round numbers, had operated 155,000 fired hours, had 200 fired starts, and 50 unit trips. Two of the vanes had evidence of clashing, the third blade did not. Each of the three indications was within 2 in. of the tip.

Key shop findings were the following:

- There was no evidence that metallurgical and manufacturing quality contributed to damage mechanisms.
- Cracks were relatively straight and unbranched, indicative of fatigue.
- Cracks were longer on the concave sides of the blades, suggesting they initiated there, and/or the cyclical bending stresses were higher on the concave side.
- The crack in the blade showing no evidence of clashing initiated at a pit.

A user representing a fleet of 20 7EAs in peaking service reported R1/S1 clashing on all but one of those units. Two of the 20 also had R2/S2 clashing. One of those with a 1999 startup date had, in round numbers, 3600 hours of operation, 550 starts, and 30 trips. The other, with clashing damage on 20 second-stage vane tips, went COD in 2001 and had fewer than 300 starts, 1200 hours of service, and 10 trips.

Someone in the audience then spoke up saying that one unit he was responsible for went from clashing on one blade to five blades within five starts. Next, a participant with a solid background in engineering and plant O&M said he wasn't convinced stainless-steel rings were an antidote for clashing—although they might be part of a solution.

A case in point: First-stage airfoils were replaced on one of his compressors and within two years (100 starts) the machine suffered a clashing incident. He asked rhetorically, might this be a result of operating only a few hours in unfavorable environmental conditions with moisture in the front end?

An attendee suggested that perhaps a lubricant would help keep compressor blades from locking up in their respective slots. Another warned against this unless tests showed the blade and disc materials were compatible with the lubricant. He told of an anti-seize formulation that ate away a steam-turbine bolt, causing it to fail.

The Q&A periods following formal 7EA presentations are informative, as they are at other user-group conferences. You never know what fact will pop into public view or how many ways participants can view the same information.

The takeaway from the meeting was that the OEM is working diligently to solve the complex front-end compressor issues. There are no simple solutions. The design margins between having a problem and no-problem are thin and it will take time to make changes to expand these margins. In the meantime, owner/operators are urged to take the preventive measures suggested above.

Considering the forgoing and fleet reports of about five-score clashing events, three-dozen tip liberations, half-a-dozen root liberations, and several mentions of mid-chord cracking over the last six or seven years, how could any conscientious 7EA owner/operator pass on the opportunity to attend the Hershey meeting for a progress report on the issues and their solutions?

Beyond clashing

The OEM's engineering team made several presentations on a wide variety of topics at the Santa Fe meeting. They were objective for the most part and seemed reasonably well received by user attendees. Some of the highlights are below. You can dig deeper by accessing the PowerPoints at http://ge7ea.users-groups.com.

- The OEM's focus is on *total plant solutions:* gas and steam turbines, generators, HRSGs, pumps, valves, piping, consumables, and everything else. GE wants customers to view it as a one-stop shop for equipment and services required by powerplant owner/operators.
- The company's power services and repair network is touting its ability to provide so-called *smart repairs,* defined as repair scope and cycle flexibility to meet a given plant's *specific* needs. Engineering focus is on mature-fleet technology to provide a better customer outcome. Enhanced and transparent communications are part of the promise, too—including more thorough and timely repair reports. A new customer portal, MyDashboard, provides up-to-date information on your jobs in GE shops.
- A focal point of a presentation on next-generation repair solutions was scrap reduction. Mentions included a radial seal replacement for shrouds to improve performance and a new bucket-tip repair procedure.
- A brief commercial in the presentation on repairs with "news" value: GE wants to be your first choice for repairs, regardless of whose components they are and/or who repaired them in the past. Also, the company now is offering certified refurbished parts as an alternative to new.
- LifeSight, a wire-free strain/creep sensor permanently affixed to the surfaces of parts, such as compressor blades, indicates strain beneath the sensor. Data are retained for trending. Users might want to investigate this new offering given increasing emphasis on the digital transformation of electricity and the need for viable diagnostics/prognostics solutions.
- A lack of 7EA jacking provisions was found to contribute to exhaust-frame slippage. Indications of case slippage include displacement of seams at the four-way joint. Not checking the torque of axial bolts prior to breaking the horizontal joint also is a contributor to vibration. Attendees were referred to TIL 1819-R2 and GEK 131700.
- Inlet bleed heat (IBH) is used for compressor surge protection and extended turndown operation. IBH issues often are related to valves installed outside. Rust and corrosion typically impede proper operation. Recommendation: Have spares on-hand given the long lead time for these components. IBH is not normally arranged for anti-icing service. To get this capability some controls work might be necessary.
- OpFlex was described as reliability improvement software with the objective of avoiding trips through runbacks, timers, counters, trends, etc. It also enables extended turndown and fast starting.
- Compressor bleed/extraction valves were said to be experiencing high failure rates. More reliable replacements are nearing commercial availability attendees were told. Recommendations: Install valves tilted away from the GT casing and install heat shields. In particularly hot areas, consider relocating valves outside the enclosure. Plus, service valve actuators every two years.
- Mark V controls are still supported by GE. The OEM offers health checks, revitalization, upgrades, migration to Mark VIe technology, etc.
- Rotor-in inspection was introduced to the group. The speaker said the big benefit is a seven-day reduction in the outage cycle. He said about 30% to 40% of the labor hours associated with a conventional rotor inspection is spent removing/replacing components to gain access. No inspection process is eliminated users were told.

  Other benefits of the rotor-in inspection alternative: higher availability, eliminates risks associated with heavy lifts over plant components, eliminates scaffolding for rotor removal, less heavy equipment onsite, fewer interfaces with other contractors, less laydown required for storing parts, etc.
- Outage planning lessons learned: Define scope a year in advance; develop realistic schedules based on your site and plant needs—for example, one shift or two; identify contingency plans for parts, labor, shipping, storage, schedule, etc. A reminder: Replacement shrouds likely are not pre-drilled so be prepared to line up a local machine shop for this effort.
- Upgrades. The latest performance improvement package (PIP) is the 7E.03, which offers increased output, better heat rate, and other benefits. Might want to consider this option if you're not operating at 2055F, which is said to be the preferred turbine inlet temperature today. The speaker recommended users evaluate firing-temperature and sealing upgrades to get more from existing assets.

Open discussion

Open discussion forums are highly valued by attendees but they can be challenging, particularly when there's a high percentage of first-timers in the room, which is typical of user-group meetings these days as plant managers try to get recent hires trained and involved quickly.

The steering committee has to select discussion topics that they believe of interest to the group and if these don't self-ignite, committee members have to light the fire and keep it burning with their input. Sometimes burning wet hay is easier.

So, you say, why not ask the attendees what they want to talk about. Sounds logical, but the reality is that users with many meeting notches on their belts might ask colleagues one-on-one, and those attending for the first time often are reluctant to raise their hands in a room full of strangers.

It's a given that owner/operators pride themselves on developing solutions for knotty problems. The 7EA UG committee solved this one by placing a large white board at the front of the meeting room, asking those with questions and discussion topics to write them on the board during breaks. They did, but not all the topics proved fruitful.

Committee members Pat Myers and Jason Hampton led the discussion sessions, with the latter feeding questions/topics on the white board to Myers, who had the mic. Hampton jotted down attendee notes for follow-up and put other topics on the board as they arose during the discussion.

A wide variety of discussion topics was brought to the floor during the meeting—some general enough to be of interest to many attendees, others very specific and seemingly beyond the experience, knowledge, and/or interest of most users in the room. Here's a sampling:

- Fifth-stage patch ring. Not viewed as an issue.
- Shaft rotation on loss of hydraulics. Two users reported ratchet failure because of hydraulic issues but a discussion never got going.
- Torque-converter maintenance best practices. Not much was said. Seems like many users just expect problems with torque converters no matter what they do.
- Exhaust-plenum issues (sagging and warping). Welding solutions were highlighted.
- Exhaust-duct liner failure. Inspect and maintain regularly.
- Sticking fuel-oil check valve. One user reported spending more testing than it cost to replace valves. Another suggested buying repair kits and rebuilding the valves.
- Generators generated much interest and discussion. Individual users reported the following:
  - Six generator failures in the last five years. Five of the six were hydrogen-cooled.
  - Owner/operator of 15 air-cooled units reported issues with rotors and J straps.
  - Same rotor failure occurred twice because of high time on turning gear.
  - Re-blocking experience reviewed for a high-hours unit with normal wear and tear.
  - Ground faults attributed to water inleakage.
  - Inspection/testing for peaking units: Only doing quarterly partial-discharge testing, not making any inspections.
  - Borescoping: not many doing this.
  - Greasing reported by several attendees.
  - Rotor insulation slipping and covering cooling-air holes. Result: Unbalance condition.
  - Thermal sensitivity issues and shorted turns contributing to vibration problems. Three machines required rewinding.

User presentations

Presentations by owner/operators are highly valued at all user-group meetings. By the editors' count, there were nine formal user presentations in Santa Fe; key points from four of those are included in the forward-compressor issues discussion above. Two of the remainder are summarized below.

GT O&M technician training. Plant managers at virtually every user-group meeting bemoan the challenges of finding knowledgeable and productive technicians to staff their O&M teams. In many cases, top talent is being siphoned off by new plants offering premium pay to run advanced F-, G-, H-, and J-class machines or by industries with higher pay scales than electric generation.

Experienced replacements are hard to come by. With military cutbacks, the steady stream of trained electricians and mechanics available to the industry when their service time is up are no longer there—at least in the numbers they were only a few years ago. There are a few post-secondary institutions with programs preparing students for careers in the electric power industry—see ads from Oklahoma State University's Institute of Technology, Southeast Community College, and Ft Myers Technical College in this issue (index, p 130)—but they have relatively small enrollments.

In many cases, this assures the plant manager will have to take responsibility for training in addition to all of his or her other duties. Pat Myers, plant manager of AEP's Ceredo Generating Station until his retirement early this year, summarized the realities of training responsibility and explained the program he implemented at Ceredo.

A backgrounder on Myers' plant provides perspective. Ceredo is a peaking station equipped with six gas-only 7EAs. In addition to a plant manager, the facility has one supervisor, three O&M techs, one contract technician, and three contract personnel for security and janitorial services.

Myers is proud of the plant's record, a testament to his management ability and the staff's performance and dedication. Here's the scorecard:

- Safety. More than 5400 continuous accident-free days for plant employees and contractors.
- Starting reliability. In the 10 years since AEP bought the plant from Reliant Energy, total engine starts for the site exceeded 2400 with only two failures; the last 1700 starts were successful.
- Trips from load. Since AEP acquired the facility, there have been five plant-related trips and 11 attributed to outside forces—such as gas-supply and transmission issues.
- Personnel turnover. None, excluding one exit for promotion.
- Outside controls support. Since AEP took over, GE service has not been required. ABB-Bailey was needed one day for BOP controls.

The challenge: How do you maintain this level of success going forward? Knowing he was about to retire, Myers hired two promising technicians and challenged both himself and them to assure the new employees had knowledge, skills, and attitude compatible with plant culture and that they were able to satisfactorily perform the O&M functions required—all within three months.

The facts regarding personnel development, Myers said, are the following:

- The industry doesn't have the time for conventional training progression. The "old school" process is a thing of the past.
- Plants must make time for accelerated, focused training. Today's limited staffing, Myers explained, does not allow "bench strength" and training positions generally are not part of an owner's game plan.
- Use of the best resources to convey information is necessary.
- Plant managers must select job candidates with a proven ability to learn and a good attitude, and have behaviors that mesh with the organization's culture.
- Managers must provide the necessary oversight to reinforce focus and progress, and validate the trainee's knowledge and capabilities.

Effective training is a "system" of deliberate activities, Myers continued. It must ensure effective knowledge exchange, reinforcement, verification, and demonstration (with physical activity) to assure retention and validation. To be time-efficient, the system must be organized—basics first, followed by details, etc.

First and foremost, effective training depends on competent instructors supported by equipment manuals, instructions (policies, procedures, standards, rules, and regulations), visual aids (drawings, prints, photos, videos, etc), 3-D animations, on-the-job training, and demonstrations. Myers believes quality 3-D simulation reduces training time and he supported this contention with a starting system video provided by Technical Training Professionals, based in Overland Park, Kans.

Fuel nozzle failure. A user with engineering responsibility for two-dozen LNG-fueled 7EAs in baseload mechanical-drive service reported on high-temperature damage to secondary fuel nozzles (SFN) serving cans 4, 5, 6, and 7 on one unit. Tip burning caused by overheating, and base burning attributed to C-seal leakage, burned off bolts and forced an outage. The problem occurred in February 2014. Analyses and tests were conducted and a proposed solution was in place by October. Success was declared the following July based on results of a major inspection.

The PowerPoint available to registered users at http://ge7ea.users-groups.com offers important details to owner/operators concerned with this type of failure, which is unrelated to the fuel burned. It includes a detailed drawing of the fuel gas system, timeline of events, laboratory analysis of damage, the RCA process, etc.

The RCA objective, the presenter said, was to learn why retreating flame/hot gas was causing tip and swirler damage. A methodology diagram detailed the approach taken to determine which of the possible damage mechanisms—such as fuel-line blockage, split schedule, dynamics, etc—was to blame. RCA outcomes were the following for the fuel-nozzle tip:

- Melted metal was observed heading into the SFN purge passage.
- Metallurgical analysis pointed to short-duration high temperatures inside the SFN transfer passage.
- Overheating occurs during transfers.
- Damage can occur in approximately 10 seconds of exposure to retreating flame/hot combustion gases.

Outcomes for the base:

- C-seal leakage is heat-induced and the reason behind base burning. A thermal gradient attributed to transfer tip and swirler damage caused the SFN's secondary sleeve to bend, allowing fuel to leak by the seal and burn. The result was more damage.
- Base burning itself is not a cause of tip damage.

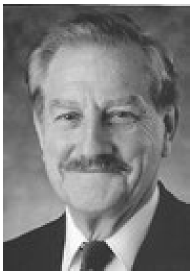
Some of the key actions performed to mitigate the issue:

- Installed instrumentation on transfer fuel gas lines.
- Inspected and tested the fuel gas system; made necessary repairs.
- Replaced fuel-system valves (splitter, transfer, purge).
- Conducted a complete analysis of the fuel gas with a focus on liquid hydrocarbon entrainment, which the OEM believed might have at least contributed to the failures.

Fuel gas was exonerated and attention turned to combustion air. The belief that clean air is critical to reliable operation was reinforced by investigators. Filters were replaced with HEPA cartridges and filter bypass issues were corrected. Engineers found that contaminated air had caused primary re-ignition, requiring the need to transfer in premix, which in turn contributed to SFN tip and swirler melting because of hot-gas backflow. A causal scenario presented in the PowerPoint provides details.

The ultimate culprit was a 4-sec time delay between purge-valve closing and fuel entry into the SFN. CCJ

Eight Bells: Sep van der Linden, 83



Industries are defined by people and their accomplishments. It is the people who are important, not so much the companies they work for. Septimus Strathearn van der Linden, who died suddenly Aug 29, 2016 at home in Chesterfield, Va, was an expert in the area of gas-turbine applications for electric power systems and a tireless proponent for these machines throughout a professional career spanning seven decades.

One might say he and the GT shared a separated childhood. Van der Linden was born Aug 4, 1933 in Vryburg, North Cape Province, South Africa; the first commercial gas turbine, built by Brown, Boveri & Cie, went into service in 1939 in Neuchatel, Switzerland. The physical connection would come some years later when he was employed by BBC.

Engineering degree in hand, van der Linden emigrated from South Africa to Canada, where he joined Worthington International, one of the early developers of gas turbines for generation service. In 1970, van der Linden moved to Curtiss-Wright Power Systems to introduce that company's packaged gas-turbine generating units to the world.

Next stop, a dozen years later, was Brown Boveri Corp to re-introduce BBC into the US gas-turbine market. Along the way to "retirement" in 2002, BBC had to be re-introduced over and over again—as ABB Power Generation, ABB-Alstom, and Alstom. Incidentally, none of the companies mentioned above is in the gas-turbine business today.

Through all this gut-wrenching change, van der Linden took notes, lots of notes. And he didn't throw out "the old stuff" after reorganizations. The result was a one-man reference library on things gas turbines from their introduction (seriously) to the present.

Perhaps most amazing was that he could ferret out facts from all the pre-web materials warehoused in the basement of his home within a few minutes of a request. Van der Linden was an invaluable help to CCJ editors over the years—writing articles, suggesting topics for coverage, correcting errors, confirming facts, providing historical perspective, etc.

He showed up everywhere gas turbines were involved, all the time. During his career, he presented more than 100 technical papers at meetings worldwide and wrote numerous articles for industry magazines. This in addition to volunteering an immense amount of personal time to develop and chair sessions, review papers, etc, for such high-profile industry organizations as the American Society of Mechanical Engineers, International Gas Turbine Institute, Electric Power Conference, Power-Gen International, etc.

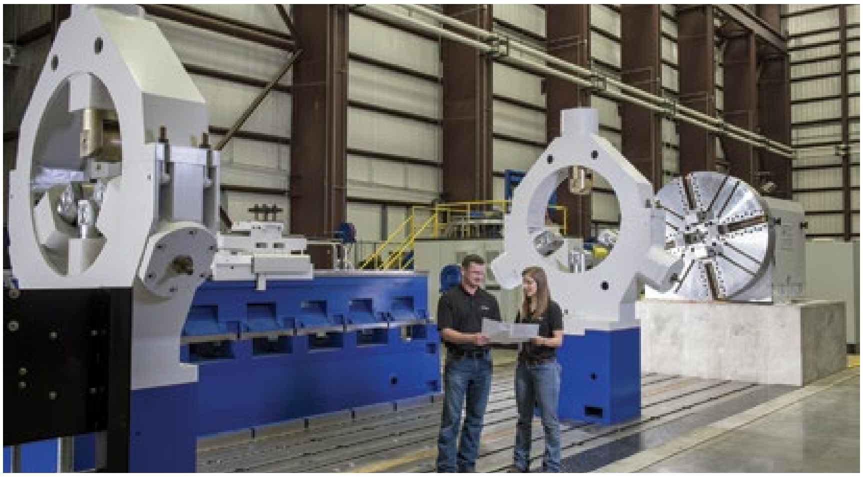
Van der Linden formed Brulin Associates LLC after retiring from Alstom in 2002 to specialize in gas turbines and emerging technologies. He invested considerable effort in the field of energy storage, recognizing its long-term value in a "greener" world. Jason Makansi, president, Pearl Street, and editorial advisor to CCJ, believes van der Linden probably did more to champion the commercial use of compressed-air energy storage (CAES) worldwide than anyone in the industry.

He was involved in the world's first commercial CAES plant in Huntorf, Germany, which began operating in 1978, and helped Makansi, who founded the Energy Storage Council (and later the Coalition to Advance Renewable Energy through Bulk Storage), advance the technology. Over time, van der Linden came to be known as "the father of CAES." Makansi describes him as "an inexorable force in our industry for advanced gas-turbine-based systems who tirelessly shared his data, analytics, and expertise."

PSM's FlameSheet™ a commercial success

Chuck Goodson, a utilities maintenance manager at Eastman Chemical Co, called PSM's FlameSheet™ a "remarkable technical success" in his presentation at the 7F Users Group's 2016 meeting in Orlando, May 9-13. He described the implementation project and early operating experience at Eastman's Longview (Tex) cogeneration plant to an exclusive audience of more than 200 users and made his presentation available online to all 7F owner/operators registered with the organization's forum at www.powerusers.org.

Prior to installing FlameSheet, the plant could operate both of its 7FAs to maximize output, but that exposed Eastman to the consequences of low demand and low power prices. When operating one engine, the plant could satisfy Eastman's requirement but was unable to ramp quickly enough to capture high market pricing. FlameSheet, the speaker said, extended GT turndown, enabling the cogen plant to increase market participation with its full capability while minimizing exposure to unfavorable market conditions.



Sulzer expands its machining capabilities with a state-of-the-art lathe specifically designed for versatility and to accommodate rotors from the latest gas turbines. Capacity is 100 tons, length is 76 ft over bedway, swing is 14 ft

Briefly, FlameSheet is retrofittable in both 7FAs and 501Fs, ideal for minimizing spares in mixed fleets. It enables the F-class GE and Siemens engines to operate down to 30% of their rated outputs while maintaining single-digit NO_x and CO emissions. The combustion system is designed to burn a wide variety of fuels and to operate up to 32,000 factored hours between inspections. For more information use the search function at www.ccj-online.com.

Sulzer's new lathe expands shop capabilities

With H- and J-series gas turbines capturing the hearts and minds of

Keith Boye of Precision Iceblast Corp, a familiar face at user-group meetings, said the North Pole wasn't quite as cold as the dry ice he uses to clean HRSGs, but it was close

key customers, Sulzer expanded the capabilities of its La Porte (Tex) shop facilities near Houston by adding a large state-of-the-art lathe equipped to repair rotors for today's most advanced engines. Billy Bottera, manager of GT rotors at Sulzer Rotating Equipment Services' Big Bay Division, said the versatile lathe was constructed based on current designs of large gas-turbine rotors. Distinguishing features include the following: 200,000-lb capacity, 76 ft over bedway, and 14-ft swing.

The new lathe complements other cutting-edge machines at the facility—including a large, low-speed dynamic balancing machine, also with a capacity of 200,000 lb, and a vertical stacking system designed to protect valuable rotors as well as repair technicians.

Bottera said the combination and arrangement of this new equipment makes the most efficient use of workshop space and speeds up workflow—thereby reducing previous bottlenecks and the time required to make rotor repairs.

Turbine Technology Services announces Lodestar Turbine Parts Management, a technical solution said to organize unprecedented amounts of parts and component data to improve performance by achieving the following:

- Proactive maintenance planning. Enables users to understand the parts histories of their machines and better anticipate the condition of individual components prior to inspection.
- Minimize budget/risk. Provide better information on parts life and unit costs to reduce inventory requirements, improve planning, and reduce operational risks.
- Easy access to data. Lodestar is a cloud-based program that operates via a web browser, allowing personnel to view needed information on desktop, phone, or tablet.
- Fleet standardization. Compare residual parts life across engines in

your fleet to assure optimal dispatch and outage planning.

Mitsubishi Hitachi Power Systems announces that its installed base of J-series gas turbines had accumulated more than 250,000 actual operating hours by the end of June 2016. The company's installed fleet of 20 J engines totals more than 10 GW of capacity and has produced more than 110,000 GWh of electricity; fleet reliability is 99.2%. The fleet leader, in operation since 2011, has recorded more than 26,000 operating hours. Globally, a total of 45 J-series gas turbines have been ordered.

GE update. The OEM, with partner EDF, began operation of the first ever combined-cycle plant equipped with its HA gas turbine in Bouchain, France, in June 2016. The plant was recognized by Guinness World Records as the most efficient combined cycle with an efficiency of 62.22%. In other news, GE appoints Azeez Mohammed president and CEO of its Energy Connections' Power Conversion business.

Siemens update. Siemens was selected to supply six SGT-400-powered compressor trains for the Trans Adriatic Pipeline, which will transport Caspian natural gas to Europe beginning in late 2019. The company also received an order to supply an H-class gas turbine and an SST-800 steam turbine for the 350-MW Altamira combined-cycle cogeneration plant in Tamaulipas state, Mexico. With this order, Siemens has received orders for seven H-class gas turbines from Mexico. In related news, the OEM receives an order from CFE to provide long-term service and maintenance at four powerplants in Mexico. Six of the engines are SGT-8000H units, two are SGT6-5000F machines.

Acquisitions

NAES Corp acquires PurEnergy LLC, an operations and asset management firm that provides services to powerplant owners and lenders to assist in managing their generation assets while optimizing the economic benefit.

Babcock & Wilcox Enterprises Inc acquires SPIG SpA, a global provider of custom-engineered cooling systems and services.

Fondo Strategico Italiano (FSI) and Shanghai Electric (SEC) enter into a strategic agreement that envisages the acquisition by SEC of 40% of Ansaldo Energia (for 400 million euros) and the establishment of two joint ventures between Ansaldo and SEC for manufacturing gas turbines for Asian markets and the creation of an R&D center in Shanghai.

Meetings, training

Design, operation, and maintenance of large turbogenerators, Oct 3-7, 2016, Irvine, Calif, presented by generator specialists Isidor (Izzy) Kerszenbaum and Geoff Klempner. Visit IzzyTech LLC (http://izzytech.com) for details and to register.

Australasian HRSG Users Group, conference and workshops, Nov 15-17, 2016, Sydney, Australia. Details are available on the AHUG2016 website (www.etouches.com/ehome/ahug2016).

Products, services

Advanced Filtration Concepts introduces the EFS Reverse Rigid Pocket Filter (RRPF), built to withstand extreme humidity, high velocities, and turbulence. It is designed for use with final filters where space is limited and is said to extend the life of the final filter when used in lieu of standard pleats. The RRPF

Advanced Filtration Concepts' Reverse Rigid Pocket Filter is designed for use with final filters where space is at a premium

coalesces moisture upstream of the final/static filter. It has no metal parts and the use of a polyurethane header ensures leak-proof bonding of pockets to header. Available in G4 and F5 efficiencies.

Clark-Reliance Corp issues a supplement to its widely distributed "Boiler Inspection Guidelines for Drum Level Instrumentation" to provide guidance on the use of magnetic level gages. Clarifications to the ASME Boiler & Pressure Vessel Code for remote level indicators require a special configuration for MLGs. Although standard use of MLGs from some gage manufacturers may result in a Code violation and create a safety hazard, these instruments can be Code-compliant. Supplement posted at http://www.magsonboilers.com tells how.

US Water presented a workshop on "Biological Testing Methods for Cooling Water—Tests, Interpretation, and Reality" at the Assn of Water Technologies Annual Conference in San Diego, Sept 7-10. If you were not able to attend, access information on the company website at www.uswaterservices.com.

Membrana, a business unit of 3M, offers Liqui-Cell® membrane contactors (www.liquid-cel.com) to remove dissolved oxygen upstream of the deaerator thereby reducing both the vent rate and fuel consumption. Stripping oxygen from feedwater also helps to reduce operating costs by minimizing boiler and piping corrosion, decreasing consumption of chemical scavengers, and extending the interval between blowdowns.

Metso Flow Control USA Inc replaces the name Metso Automation USA Inc, consistent with the company's plan to become a leader in flow control.

Physical Systems Integration and partner Biosolventus Inc advance to the semi-final round of Cleantech Challenge Mexico showcasing PSI's turbine warming system, consisting of electric blankets and a control system, to reduce the startup time of steam turbines thereby saving fuel and reducing emissions.

Ing Giorgio Dodero (right), who provides technical insights on European developments to CCJ's editorial staff, accepts a Best Paper Award at Power-Gen Europe 2016 from Sergio Garribba, Italy's Counsellor for Energy Policy. The title of Dodero's presentation: "CO_2 Utilization within Refineries and Steel Plants, including Synergy with the Power Generation Sector"

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