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CCJ COMBINED CYCLE Journal

User Group Reports

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ACC Users Group.........................56

The first day of the eighth annual meeting featured a tutorial on chemistry and corrosion followed by presentations on airflow management, performance enhancements, gearbox maintenance, tube-bundle cleaning, and air in-leakage testing.

Day Two coverage included film-forming agents, windscreen analysis, direct-drive motors, OEM ACC specs, fogging, external inspection, dry-cooling research, and user experiences.

7F Users Group..........................100

In-depth content is why 250 or more owner/operators attend this meeting. Major segments of the 2016 program were dedicated to technologies offered by the OEM and PSM, while special technical presentations by third-parties addressed a dozen specific topics. More than a dozen user presentations and closed discussion sessions rounded out the program.

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Ring eight bells for Charlie Zirkelback

Register now for 2017 user-group meetings

7F USERS GROUP

26th Annual Conference and Vendor Fair
May 15 – 19
La Cantera Hill Country Resort and Spa
San Antonio, Tex
Contact: Sheila Vashi, conference manager
sheila.vashi@sv-events.net
www.7Fusers.org

D5-D5A Users

20th Anniversary Meeting and Vendor Fair
June 6 – 8
Special West Coast location
Contact: Gabe Fleck, chairman
gfleck@aeci.org
www.501d5-d5ausers.org

Frame 6 Users Group

Annual Conference and Vendor Fair
June 18 – 22
La Cantera Hill Country Resort and Spa
San Antonio, Tex
Contact: Greg Boland, conference manager
greg.boland@ceidmc.com
www.Frame6UsersGroup.org

OVATION USERS' GROUP

30th Anniversary Conference
July 23 – 27
Westin Convention Center Hotel
Pittsburgh, Pa
Contact: Kathleen Garvey
kathleen.garvey@emerson.com
www.ovationusers.com

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Upcoming user-group meetings

2017

April 23-27, CTOTF 42nd Spring Conference & Trade Show, Orlando, Fla, DoubleTree by Hilton (at entrance to Universal Orlando). Chairman: Jack Borsch, jborsch@lakeworth.org. Details/registration at www.ctotf.org. 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. Contact: Sheila Vashi at sheila.vashi@sv-events.net.

May 16-18, European HRSG Forum, Fourth Annual Meeting, Amsterdam, The Netherlands, Courtyard by Marriott Amsterdam Airport. Chairman: Ladislav Bursik, ladi.bursik@bht-gmbh.com. Details as they become available at http://europeanhrsgforum.de.

June TBA, 501D5-D5A Users, 20th Anniversary Meeting, decision on venue pending. Chairman: Gabe Fleck, gfleck@aeci.org. Registration and other details at www.501d5-d5ausers.org as they become available.

June 12-15, V Users Group, 2017 Annual Conference, Nashville, Tenn, Renaissance Nashville Hotel. Contact: Kelly Lewis, conference coordinator, kelly.lewis@siemens.com.

June 18-22, Frame 6 Users Group, Annual Conference & Vendor Fair, San Antonio, Tex, La Cantera Hill Country Resort and Spa. Co-chairmen: Jeff Gillis, william.j.gillis@exxonmobil.com, and Sam Moots, smoots@coloradoenergy.com. Details/registration when available at www.Frame6UsersGroup.org. Contact: Greg Boland, Creative Eventures Inc, conference manager, greg.boland@ceidmc.com.

June 20-22, T3000 Users Group, 2017 Conference, Atlanta, Ga, Hilton Atlanta/Marietta Hotel and Conference Center. Contacts: Bob Lake, chairman, bob.lake@fpl.com; Elizabeth Moore, event coordinator, elizabeth.moore@siemens.com.

July 23-27, Ovation Users' Group, 30th Annual Conference, Pittsburgh, Westin Convention Center Hotel. Register for membership (end users of Ovation and WDPF systems only) at www.ovationusers.com and follow website for details when available. Contact: Kathleen Garvey, kathleen.garvey@emerson.com.

August 28-31, Combined Cycle Users Group (CCUG), 2017 Conference and Discussion Forum, Phoenix, Ariz, Sheraton Grand at Wild Horse Pass. Meeting is co-located with the Steam Turbine Users Group and Generator Users Group; some joint functions, including meals and vendor fair. Chairman: Steve Royall, sgr8@pge.com. Details at www.ccusers.org when available. Contact: Sheila Vashi at sheila.vashi@sv-events.net.

August 28-31, Steam Turbine Users Group (STUG), 2017 Conference and Vendor Fair, Phoenix, Ariz, Sheraton Grand at Wild Horse Pass. Meeting is co-located with the Combined Cycle Users Group and Generator Users Group; some joint functions, including meals and vendor fair. Vice Chairman: Bert Norfleet, bert.norfleet@dom.com. Details at www.stusers.org when available. Contact: Sheila Vashi at sheila.vashi@sv-events.net.

August 28-31, Generator Users Group (GUG), 2017 Conference and Vendor Fair, Phoenix, Ariz, Sheraton Grand at Wild Horse Pass. Meeting is co-located with the Combined Cycle Users Group and Steam Turbine Users Group; some joint functions, including meals and vendor fair. Chairman: Kent Smith, kentn.smith@duke-energy.com. Details at www.genusers.org when available. Contact: Sheila Vashi at sheila.vashi@sv-events.net.

September 17-21, CTOTF Fall Conference & Trade Show, San Antonio, Tex, Hyatt Regency Hill Country. Chairman: Jack Borsch, jborsch@lakeworth.org. Details/registration at www.ctotf.org when available. Contact: Ivy Suter, ivysuter@gmail.com.

October 2-7, ACC Users Group, Ninth Annual Conference, Las Vegas, Nev, Westin Las Vegas. 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.

October 23-26, 7EA Users Group, Annual Conference and Exhibition, St. Augustine, Fla, World Golf Village Renaissance St. Augustine Resort. Details/registration at http://ge7ea.users-groups.com when available.

November 14-16, Australasian HRSG Users Group, 2017 Annual Conference, Sydney, Australia, Rydges World Square Hotel. Visit conference website for details: https://www.eiseverywhere.com//ehome/ahug2017. Chairman: Dr R Barry Dooley, bdooley@structint.com. Submit abstracts for consideration directly to Dooley. Conference contact: Heather McDowell, heathermcdowell@meccaconceptconferences.onmicrosoft.com

2018

February 25-March 2, 501F Users Group, Annual Meeting, Orlando, Fla, Grand Cyprus Orlando. 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.

March 5-7, HRSG Forum with Bob Anderson, Second Annual Meeting, Houston, Tex, Hyatt Regency Houston. Chairman: Bob Anderson. Details/registration at www.HRSGForum.com when available. Contact: Alan Morris, commercial manager, amorris@morrismarketinginc.com.

March 18-21, Western Turbine Users Inc, 28th Anniversary Meeting, Palm Springs, Calif, Renaissance Hotel/Palm Springs Convention Center. Chairman: Chuck Casey, ccasey@riversideca.gov. Details/registration at www.wtui.com when available. Contact: Charlene Raaker, raaker.charlene@prodigy.net.

May 7-11, 7F Users Group, 2018 Conference & Vendor Fair, Atlanta, Ga, Atlanta Marriott Marquis. Details/registration at www.powerusers.org when available. Contact: Sheila Vashi at sheila.vashi@sv-events.net.

CCJ COMBINED CYCLE Journal

Editorial Staff

Robert G Schwieger Sr
Editor and Publisher
702-869-4739, bob@ccj-online.com

Kiyo Komoda
Creative Director

Scott G Schwieger
Director of Electronic Products
702-612-9406, scott@ccj-online.com

Steven C Stultz
Ed Sundheim
Consulting Editors

Clark G Schwieger
Special Projects Manager

Editorial Advisory Board

Robert W Anderson
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Gabriel Fleck
Manager, Gas Plant Operations
Associated Electric Cooperative Inc

Dr Barry Dooley
Structural Integrity Associates Inc

Business Staff*

Susie Carahalios
Advertising Sales Manager
susie@carahaliosmedia.com
303-697-5009

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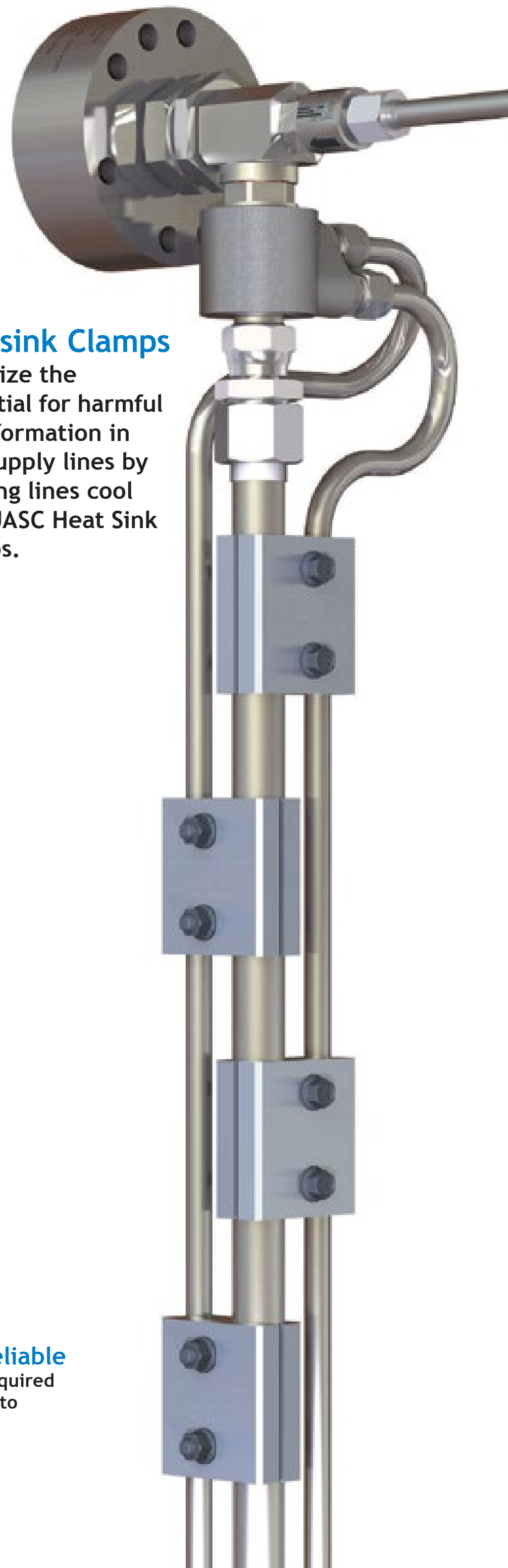

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Presentations by owner/operators dominate annual technical program

Compiled by **Clyde V Maughan,** IEEE Fellow, Maughan Generator Consultants

The second annual meeting of the Generator Users Group (GUG, QR1), today organized under the Power Users Group (QR2) umbrella, was conducted in parallel with the annual meetings of the Combined Cycle Users Group (CCUG, QR3) and Steam Turbine Users Group (STUG, QR4) in San Antonio, Aug 22-15, 2016.

Recall that the GUG was launched in late 2015—a collaborative industry effort with major support from NV Energy, which hosted the first meeting at its Beltway Complex and Conference Center, and Duke Energy (QR5). The steering committee formed to assure success, chaired by Duke's Kent Smith, continues to guide the group (sidebar).

CCJ's coverage of GUG's second annual meeting focuses on three general subject areas:

- Stators.
- Rotors.
- Testing and general.

Topics of particularly high interest in today's powerplants included the following:

- Widespread partial discharge (PD) damage on modern stator windings.
- PD damage and winding failure of global vacuum pressure impregnated stator (GVPI) windings.
- Problems related to severe cracking of rotor forgings.
- Rotor-winding fatigue cracking and thermal sensitivity issues.
- Challenges associated with the operation and maintenance of modern excitation systems.
- Catastrophic failures associated with inadequate ground protection relaying on stator and/or field windings.
- Problems associated with defi-

QR1 QR2 QR3 QR4 QR5

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Vice Chair: Ryan Harrison, P Eng, *ATCO Power (Canada)*

Leopoldo Duque Balderas, *COMEGO (Mexico)*

John Demcko, PE, *Arizona Public Service Co*

Dave Fischli, PE, *Duke Energy*

Joe Riebau, *Constellation, an Exelon company*

Jagadeesh (JD) Srirama, PE, *NV Energy*

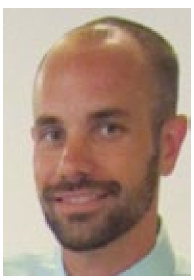
Clyde V Maughan, technical advisor to the steering committee


Smith


Harrison


Balderas


Demcko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cient operation and maintenance of water-cooled stator-winding cooling systems.

- Potentially catastrophic dangers associated with inadequate operation and maintenance of generator hydrogen cooling systems.

Two points to keep in mind as you read through this material:

1. The GUG's mission is to provide a forum for owner/operators of electric generators at coal-fired, nuclear, and combined- and simple-cycle gas-turbine plants to share experiences, best practices, and lessons learned on design, installation, O&M, and uprate/upgrade. Expected outcomes are improved safety, maintainability, availability/reliability, and efficiency, as well as the transfer of industry knowledge from experienced engineers to those wanting to gain hands-on know-how.

   Although CCJ focuses on gas-turbine users, the editors suggest you not bypass the few summaries of nuclear and coal-fired plant experiences incorporated by the editor because they offer valuable lessons learned to all generator users.
2. Several of the user presentations summarized here were made by members of the steering committee, illustrating the depth of knowledge of the GUG leadership and the value of participation in this annual meeting. Follow the website (QR1) for details on the 2017 meeting at the end of August as they are made available; first posting is expected in April.

Users wanting to dig deeper into presentation topics can access the PowerPoints of interest on the Power Users website (QR2). Bear in mind that the presentations are available only to users and you must be registered to access them via the User Forum/Conference Archives button in the horizontal toolbar at the top of the home page. Registration is a simple process if you're not already signed up.

Stators

Stator rewind

As built, McGuire Nuclear Station was equipped with two 1450-MVA, 4-pole generators. featuring water-cooled stators. Within five years of COD in December 1981, both units had been de-rated by about 140 MVA because of operating problems that included end-iron overheating.

There have been numerous maintenance events over the years, including these:

- Stator rewedged in 1998.
- Field rewound in 2007 because of shorted turns and thermal sensitivity.
- Increased oxide fouling in the stator bars.
- Three chemical cleanings conducted in a 10-year period.
- Cracking of aluminum shields in the main lead box.
- Three elevated EL CID indications of about 170 mA each that were slowly increasing between inspections.

A life-extension study was performed in 2010 and it was decided to reuse the generator fields on both units because they had been rewound recently. Relative to the two stators, engineers decided to do the following:

- Purchase a replacement stator with the winding designed for 1550 MVA.
- Convert parallel rings from hydrogen- to water-cooled.
- Upgrade the stator cooling-water (SCW) system to include alkalizer injection for controling pH to address oxide fouling problems.
- Replace the HV bushings with 1550-MVA capability.

After installing the new stator on one unit, the old stator was shipped to the OEM's factory and rewound with upgrades for use in the other generator.

Site acceptance tests of the new stator included ultrasonic measurement of flow in stator cooling-water hoses, EL CID testing of core, and DC hipot. During the site acceptance test the EL CID test failed, with readings as high as 169 mA detected. A loop test conducted to validate EL CID readings was terminated within three minutes because it failed to meet test temperature criteria. Core repairs on the new generator were required.

Numerous problems were identified with the hose water flow on the SCW system, including near-stagnant flow in six parallel rings. The latter is particularly important in that immediate gross overheating of the rings likely would be accompanied by complete winding failure. Corrections of the hose problems identified were complicated and expensive in dollars and outage time.

Dave Fischli is the generator program manager for Duke Energy's fossil generation fleet

EL CID versus rated-flux testing

The generator discussed in this presentation, which offers interpretation and correlation of EL CID results to rated-flux testing, is a nominal 400-MVA, hydrogen direct-water-cooled unit which was installed in a coal-fired plant (COD 1980).

The stator was fully rewound in 2004, during which time a significant core fault (287-mA peak value) was discovered by EL CID test after the new winding was installed. Subsequent rated-flux testing and progressive EL CID flux testing confirmed the concern. Part of the winding was removed and a slot-bottom section repaired (with no root cause determined). After repairs, the core was left with EL CID 65-mA peak.

Top-tooth burning and progressive thermal artifacts have been monitored during subsequent inspections with hot spots greater than 10 deg C noted; however, no EL CID readings exceeded 100 mA. The conditions on this core prompted the following questions:

- Does trending the EL CID results offer meaningful condition trending information?
- Do the EL CID results correlate to the rated-flux test results?

Investigations were conducted to answer these questions, with results discussed by the presenter.

After digitizing select EL CID readings, early minor EL CID indications were corrected to rated-flux hot-spot data with the following mixed results:

- In most cases, EL CID signature correlates to areas where a hot spot exists, but not always.
- Both tests have inconsistencies in results across time periods.
- EL CID was judged "more repeatable," provided the same excitation is used.
- More-frequent EL CID testing is preferred over less-frequent rated-flux testing.

Comparisons were made of various data: pre-rewind, post winding removal, post high-flux testing, and post repair and high-flux test. With adjustments, EL CID historical data were fairly consistent for trending progressive degradation of the core. Attempts were made to correlate high-flux and EL CID data, with mixed results.

At this point, some fundamental questions remain—for instance:

- At what EL CID value should additional steps be taken—is a value below 100 mA appropriate in some cases?
- Is it possible that rated-flux testing can initiate or advance existing damage deep within the core?

Understanding the detail of core-flux testing remains something of a mystery because results cannot always be taken at face value. It appears there is great opportunity for benefit related to efforts such as discussed by the presenter. For example, he is developing digital tools to facilitate fast and easy trending of EL CID results. These will be shared at a later date and users should find them extremely valuable. An update on progress is likely at the 2017 GUG meeting in Chandler (Phoenix), Ariz, Aug 28-31.

P Eng Ryan Harrison is attached to the ATCO Power central engineering group supporting the company's fleet of generators and excitation, protection, and distribution systems.

Issues in hydrogen-cooled machines

The serious problems discussed in this presentation involved a nine-year-old hydrogen-cooled generator rated 193 MVA, 13.8 kV. Its bar design is shown in Fig 1. During a routine maintenance outage, engineers found all the tube-to-copper resistance readings satisfactory, generally above 1000 ohms, with the exception of the bottom tube in the top coil, slot 22, which read 81.8 ohms. The ends of this tube were cleaned and dried and mica inserted, but the reading did not improve.

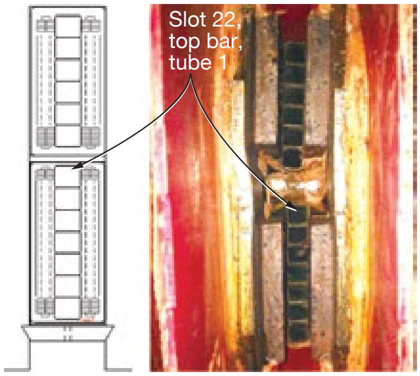
OEM guidelines were the following:

- Less than 500 ohms, investigate.
- Less than 100 ohms, change the affected bar.

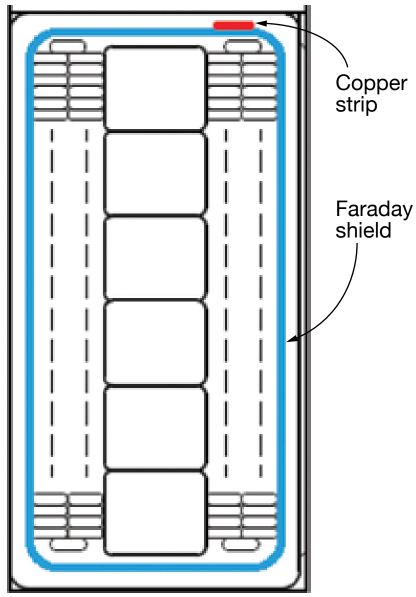
Further investigations—including the removal of series blocking and groundwall insulation—did not reveal the cause of low resistance or improve the low value. The bar was removed from the winding and sent to a non-OEM laboratory for investigation. No additional understanding was found by the initial investigations. Electrical tests revealed the short likely was located from 7% to 10% of the way from the exciter end. Stripping of the groundwall revealed severe localized overheating locations.

After disconnecting the copper grounding strip shown in Fig 2, the tube-to-copper resistance value increased to more than 50 Mohms. This is a complex bar cross section, not well understood. It is clear that the low resistance values were caused by gross overheating, burning (which resulted from circulating currents caused by a short between the copper strip and a strand), and the resulting carbonization of insulation components. However, the root cause of the short remains unknown.

Leopoldo Duque Balderas has many years of powerplant O&M and engineering experience



1. Bar cross section for this hydrogen-cooled generator is illustrated (left) and shown in the photo (right)



2. Faraday shield consists of a semi-conductive tape (blue) around the copper strands. This layer of semi-conductive tape helps create an even ground wall across the tube to copper. A copper strip connects from the semi-conductive layer to a single strand in the copper, ensuring a single path to ground

Continuous EMI monitoring

Motors, generators, transformers, and switchgears typically are monitored with hand-held instrumentation. One informal survey found about half of the nation's powerplants use portable EMI (electromagnetic interference) monitors. EMI also can be tracked with a radio-frequency current transformer (RFCT) placed, for example, on the generator grounding cable (Fig 3).

The speaker told generator users that a new input card had been developed by National Instruments to monitor continuously the output from the RFCT. Duke Energy currently has this instrumentation on 72 transformers and 53 generators at 15 sites. Capabilities of the diagnostic equipment were said to be considerable: full-spectrum scan, live-frequency visual, live-frequency audio, historical-spectrum viewing, power-spectrum trending—five bands with remote access from anywhere on the Duke Intranet.

Fig 4 compares two full-spectrum plots of sister units. The red trace is for a unit that had significant vibration problems, with multiple plant trips from secondary CT wiring being cut. The CT wiring has been stabilized but this trace still shows significant electri-

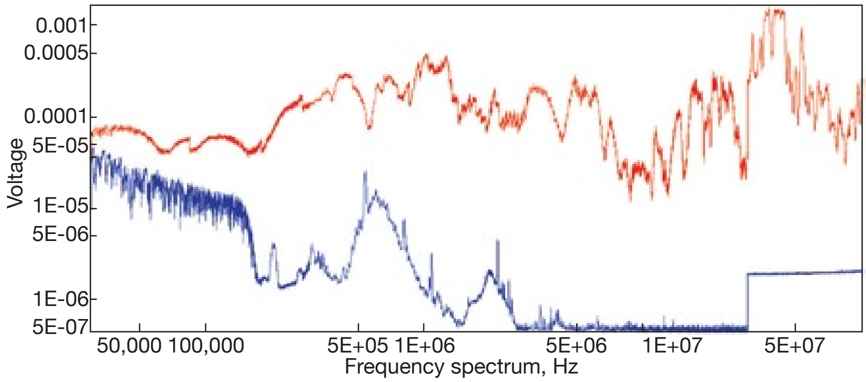
3. Radio-frequency current transformer (RFCT) is coupled to grounding cable to measure electromagnetic interference (left). A field installation of the system is above cal activity. The blue trace is the sister unit at the same location and reveals no signs of any major issues.

The full-spectrum plot in Fig 5 compares scans of the same unit taken approximately two months apart. It shows electrical activity increased slightly over time. The fact that there is significant activity in the high-frequency areas leads engineers to believe there's also significant electrical activity near the isolated phase bus (IPB).

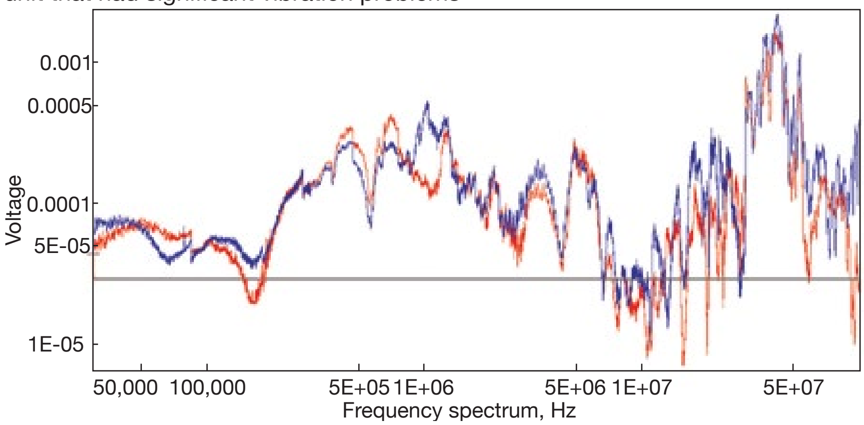
In addition to the full-spectrum scan, plant personnel took local measurements with an EMI "sniffer." It also indicated significant electrical activity in the IPB area. Local measurements show high EMI levels in the bushing-to-bus transition area, as well as in the potential-transformer area. Plans are in place to inspect these areas during the spring 2017 outage.

The diagnostic systems discussed were said to provide plant personnel valuable equipment condition information; interpretation of this information will become better as more experience is gained.

Kent Smith, a 35-yr utility veteran, is manager of generator engineering for Duke Energy



4. Full-spectrum scans of sister units are compared here. Red trace is of a unit that had significant vibration problems



5. Spectrum plot compares the same unit on dates two months apart. Electrical activity increased between the first (red) and second (blue) scans

Connection-ring vibration monitoring system

Intermountain Power Project (IPP) went online in 1986/1987 with two hydrogen-cooled generators rated 991 MVA, 26 kV. By the 1990s, leaks had started in the generator windings and both units usually failed leak tests after 1994. A global strand header repair was performed on Unit 2 in 1996 and on Unit 1 in 1997. Leaks continued even after the epoxy repair, with the leaks usually found at joints in the connection rings (Fig 6).

Plant management decided to rewind both generators, including replacement of the connection rings and use of the OEM's new vertical strand header braze procedure. Unit 2 was rewound in fall 2010, Unit 1 in spring 2011. In December 2011, Unit 1 suffered a massive winding failure, attributed to a failed bolted joint in the neutral connections in the dome. (A similar joint that had not failed is shown in Fig 9.)

Immediately after Unit 1 failed, Unit 2 was taken offline. The flexible connections were examined and arc indications found after only six months of service (Figs 7, 8). The replacement connection rings included additional bolts on the lower tang (Fig 9). But the root cause of Unit-2 arc indications and of Unit 1 failure was use of improper bolting techniques for the stainless steel bolts.

IPP personnel remained concerned with whether the problem had been fixed—in particular because there was no advance warning for the failure. The OEM recommended installation of fiberoptic vibration probes and this was done in January 2012; vibration started to increase in January 2013. Analysis and interpretation of data gathered have not provided definitive results— partially because of little industry experience on connection-ring terminals; plus, weak technical support.

A second vibration probe system has been installed on Unit 1 and a second system will be installed on Unit 2. The trends of the second systems will be compared with the output from the present probes.

Mike Nuttall is assistant superintendent of technical services at IPP

Stator ground in a GE 390H generator

The subject generator is connected to the steam turbine serving a large

6. Leak location in connection-ring braze is identified by arrow

7. Arc damage on connection-ring flexible connectors is significant

8. Arc damage on connection-ring tang is easy to identify

9. Replacement connection rings (right) feature double the number bolts on the lower tang compared to the original five-bolt design at left

F-class combined cycle. Plant began commercial operation in 2004 and ran reliably until 2014, accumulating nearly 45,000 operating hours and 1000 starts. During a startup in fall 2014, the unit tripped on volts/hertz and ground relays.

Visual inspection of the external components revealed no problems, but A phase was grounded. This is a three-circuit winding, and two of the three circuits were grounded. The OEM recommended a full rewind, and each bar was checked using a Megger™ before being removed. The bottom bar in slot 1 was found grounded, with its insulation heavily cut by outside space block (OSSB) migration inward.

Many other bars showed damage from OSSB movement (left and center photos in Fig 10). The core damage at slot 1 is shown in the right-hand photo. Burning is much greater than would be expected from the >5 amps of a single ground and probably resulted from core lamination shorting.

The repairs performed included loosening belly bands, rounding the corner of the compression ring (flange), replacing OSSBs one at a time, adding a punching with master bond coating, reinstalling the compression ring, compressing the core to a higher level (2000 ft-lb increased to 2500), retightening of the belly bands, and rewinding the generator with all-new bars.

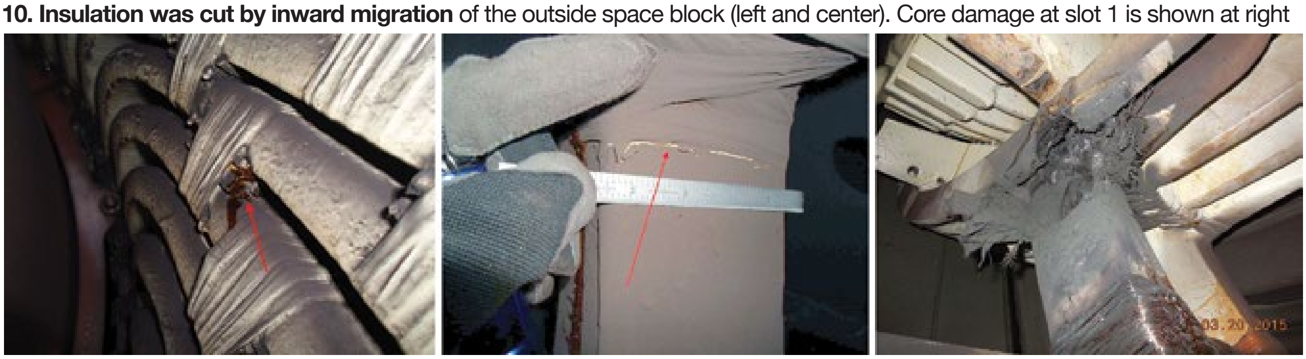
Overheating phase-to-phase failure

The subject 300-MVA, 18-kV generator was manufactured in 2000 and installed in a combined-cycle plant. On Feb 27, 2015, the plant was removed from service to upgrade the steam turbine/generator's DCS. The change involved converting from the steamer OEM's DCS to one installed by a different OEM on the gas turbines.

The plant returned to service March 16 at 10:10 a.m. Six hours later, the steam turbine tripped on relays 27, 86-1, and 87G. Both gas turbines tripped as well. The initial walk-down of the steamer revealed smoke coming out of the exciter-end generator bearing cavity; the generator frame was too hot to touch anywhere. Data analysis revealed a peak instantaneous fault current of 74 kA.

Generator cooling-water flow was controlled with a throttle valve; the throttle-valve's position was controlled by logic, with inputs from stator hot-gas RTDs. The hot-gas RTDs were accidentally configured as "J"-type thermocouples at the ADC signal pro-

10. Insulation was cut by inward migration of the outside space block (left and center). Core damage at slot 1 is shown at right



11. Overheat damage shown at left and in center led to the connection-ring failure at right

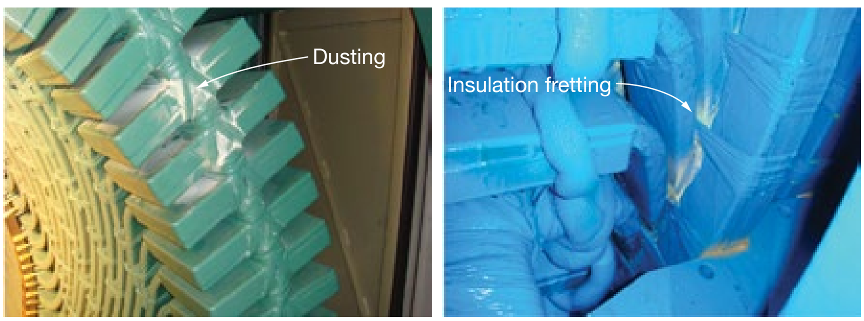
cessing card during the DCS upgrade, so the "measured" temperature never exceeded 80F, thus leaving the valve throttled "off." Back calculated, the generator gas temperature actually had reached an estimated 415F.

The DCS malfunction caused gross overheating of the generator. Damage was severe during the four-hour operating period (Fig 11, left and center), which led to the connection-ring failure shown at the right in the photo array.

Copper splices were applied to the connection ring and phase dropper, and were reinsulated locally. The stator and coolers were thoroughly cleaned and stator endwindings were treated with wicking resin. The core was requalified by both EL CID and loop/ring testing. The rotor exterior was cleaned.

The unit returned to service May 2. A stator rewind kit, purchased as a contingency, will be installed on a planned basis at the next turbine major outage—or sooner.

Craig Spencer, director of outage services for Calpine Corp's generator fleet, oversees maintenance for over 230 machines in 20 unique frame sizes from 13 different OEMs



12. Endwinding vibration is a major cause of dust generation

13. Failures resulting from endwinding vibration can cause considerable collateral damage

Endwinding vibration

Endwinding vibrational forces and duties have increased as generator ratings have increased and as more compact designs have evolved. Simultaneously, cost reductions for less robust designs have tended toward more vibration problems. Examples of dust generation from vibration are shown in Fig 12. Note that endwinding vibration has been found to have the highest total loss mitigation value on recent common generator failures. If not detected before failure, considerable collateral damage may occur (Fig 13).

Two common ways are used to

assess vibrational issues:

- Periodic visual inspection looking for evidence (dusting, fretting, greasing).
- Periodic impact (bump) testing to identify natural frequencies and ensure they are not causing resonance.

Because each of these alternatives requires an outage, there has been a trend toward installing endwinding vibration detectors (fiberoptic nonmetallic accelerometers) on units with suspected or known vibration issues. Sensors are installed in locations where high vibration is most likely. Displacement values are commonly read, but velocity/acceleration values may provide better analytical information. Displacement under 5 mils is usually considered safe, with 10 mils cause for concern and 20 mils considered dangerous.

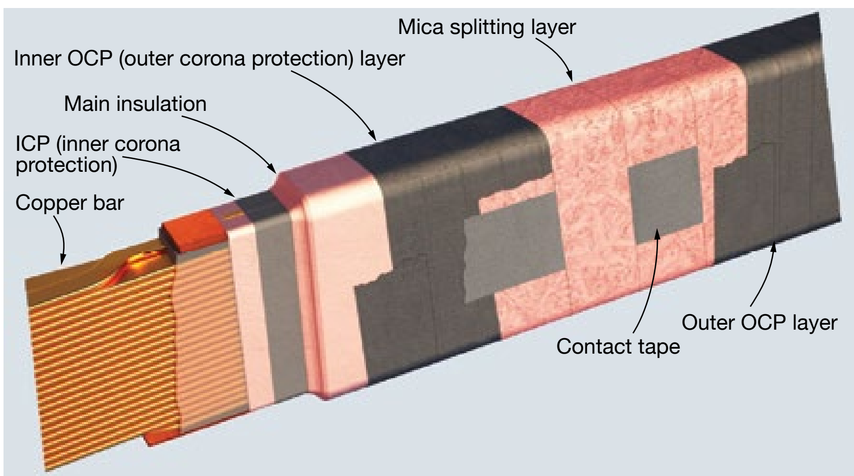
The bottom line: Endwinding vibration monitoring systems can be a valuable resource on suspect windings to provide early warning and allow optimum scheduling and planning of needed repairs.

Mladen Sasic has dedicated most of his career to instrumentation for generator condition monitoring—in particular, core lamination insulation testing and wedge-tightness assessment

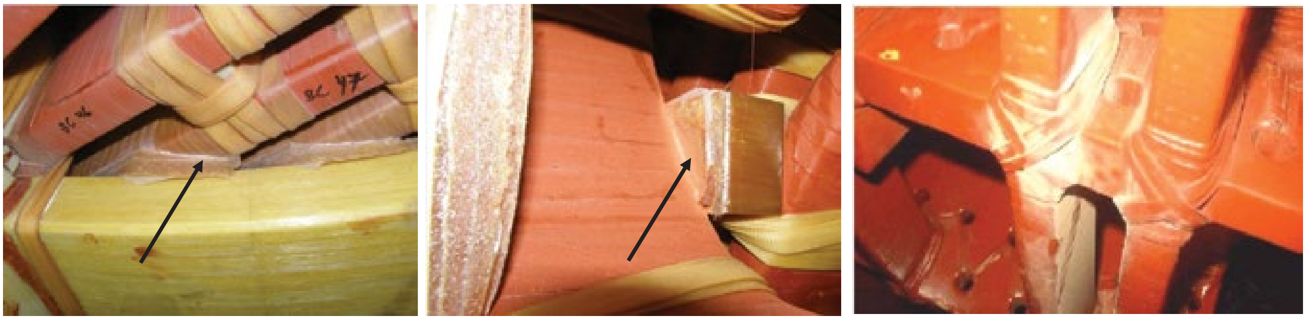
Stator global VPI technology

Siemens presented an overview of its generators using global vacuum pressure impregnation (GVPI)—including operating experience and repair options. The company introduced its GVPI system in 1988 and today has more than 1650 such stator windings in service with a total capability of 239,000 MVA. Thus far, these machines have combined for more than 25-million operating hours and 320,000 start/stop cycles—in round numbers. The units employ indirect-air, indirect-hydrogen, and water cooling. Voltage ratings extend to 22 kV, outputs to 870 MVA.

Design features of the GVPI insulation system for a stator bar are highlighted in Fig 14. The insulation ground-wall materials are applied over the copper in the following sequence: inner corona protection, ground-wall insulation, inner-outer corona protection, mica splitting layer interspersed with contact tape, and outer-outer



14. Global vacuum pressure impregnation (GVPI) system for stator windings has an enviable track record: No reported stator insulation-caused failures



15. Some operational issues experienced include dusting of debonded structural components

16. OCP (outer corona protection) erosion is shown on bars (left) and at core ends (right)

corona protection layer.

The speaker said that, to date, there has been no report of a stator-bar failure attributed to this insulation system. GVPI windings, he continued, do not require re-wedging, re-tightening of enwinding structure, or re-tightening of the laminated core—for the entire lifecycle of the generator, with a reliability factor of greater than 99.9%.

Damage to GVPI stator windings is very unlikely, and when it occurs, the cause typically is impact by a foreign object. Should such damage occur, the OEM has repair procedures to suit both the situation and customer preferences.

Some operational issues that have been experienced include dusting of debonded structural components, which may occur at any bonded interface in the end winding (Fig 15). Also, stator endwinding natural frequencies may experience a shift over time and if they approach the driving frequency, loosening will be accelerated. This condition can be addressed by adding tangential blocking between the top-layer bar ends near the series connections.

Localized erosion of outer corona protection has been found on several units at the ends of the core (Fig 16). Methods have been developed for the repair of such findings.

Scott Robinson has global responsibility for Siemens' generator service business—including R&D, management of technical issues, product development, customer satisfaction

Rotors (fields)

Field ground indications

Grounds in two different excitation systems were discussed by John Demcko, who has an exceptionally broad and deep background in power generation equipment: those with brushless excitation systems and those with collector rings and brushes. The two case studies presented illustrated the challenging complexity of excitation-system diagnostics and maintenance. When we speak of a field ground, the speaker said, what we really mean is an excitation system ground.

The first ground considered was on a brushless system. In spring 2006, a modern brushless field ground detection system, Accumetrics Inc's earth fault resistance monitor (EFREM), was installed on Combined Cycle Unit 4 at the company's West Phoenix Generating Station (Fig 17). It replaced an OEM system that never worked properly.

With the Accumetrics system, the field resistance to ground is monitored offline, as well as online, and is telemetered to the plant DCS. Six months after installation, the field ground alarm came in solid while the unit was offline. Since the alarm occurred during heavy rain, engineers decided to dry the system before drawing any conclusions. In 3.5 hours, resistance increased from 12 kohms to 20 Mohms. Better waterproofing and caulking of possible water ingress points thus far has been effective in mitigating the issue.

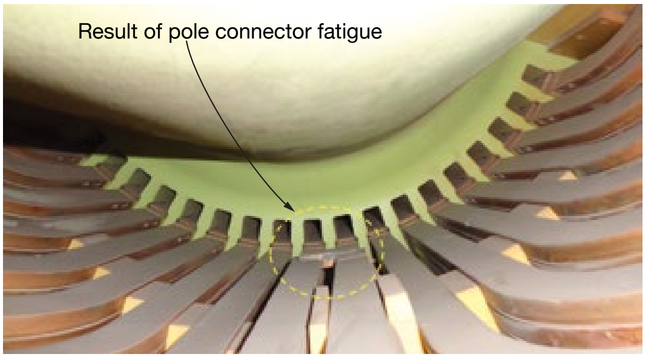
The second ground was on a collector/brush system. During a normal startup, generator voltage did not build up to nominal rated value. Investigation provided some startling information. First, the field itself had a ground. But there was a station-battery ground as well. The combination of the two grounds allowed part of the field excitation current to bypass a portion of the field turns.

While the field was being rewound, resolution of the station-battery ground was pursued. It was found at a taped connection joint left lying on the steel-deck floor (Fig 18). Over many years, the taped insulation had worn away, resulting in a hard ground.

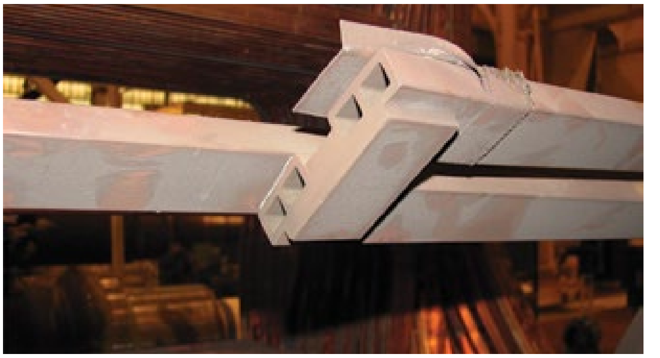
John Demcko is a senior consulting engineer in Arizona Public Service Co's Technical Projects Engineering Dept

17. EFREM system components are shown individually at left, assembled at right

18. Tape insulating a connection joint wore away over the years and caused a hard ground

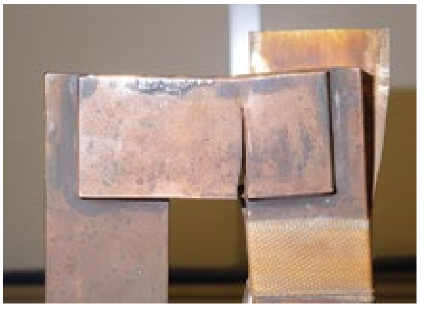


19. Result of field-winding pole connector fatigue is clearly in evidence

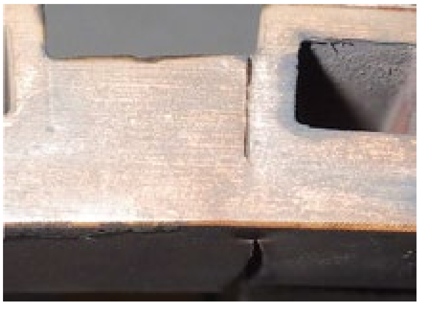


20. Detail of original connection is revealed during disassembly

21. Evolving crack in pole-to-pole connector



22. Severe tear in pole-to-pole connector



23. Incomplete braze in pole connector is easy to see

Experience with Alstom air-cooled generators, Part I

System-wide, Southern Company has seven Alstom air-cooled generators rated 313 MVA, 21 kV. There have been significant maintenance and operational issues on these units, including the following:

- Stator phase-connection conductor fatigue.
- Stator endwinding voltage grading deterioration.
- Stator spring-plate fatigue.
- Stator side-filler migration.
- Stator frame plate weld failure.
- Field retaining-ring insulation deformation.
- Field slot-liner cracking risk.
- Field-winding pole-connector fatigue.

Only the last was discussed in this presentation.

Initial awareness of the problem came in April 2012 coincidental with the follow-up inspection of a phase-bar blocking modification. Prior fleet-wide inspections offered no clear evidence of pole-connector fatigue. But review of previous inspection photos with a focus on the probable crack-initiation areas showed signs of possible initiation (upset metal).

Follow-up inspections over the last four years have shown all previous "possible initiation" sites to have definitive cracks with propagation in progress. Photos shared to illustrate the problem included those here labeled Figs 19-24.

24. New pole connector design is shown below old design

Inspections in April 2013, April 2014, and July 2014 on the unit with most advanced fatigue condition revealed continuing crack propagation on both pole (redundant) connectors. Repair was implemented in December 2014.

Engineers concluded there is a definitive correlation to start/stop cycles. Inspection data show the rate of crack propagation to have some consistency for a given pole connector but it clearly varies from one connector to another. It is expected that pole-connector replacement eventually will be required on all seven generators.

Jeff Phelps, principal engineer, supports Southern Company's generator fleet

Alstom generators, Part II

Initial awareness of the phase-connection issue discussed by the speaker came in August 2010 following a stator-winding in-service failure. Root cause: phase-bar resonance. The failed unit was repaired and returned to service.

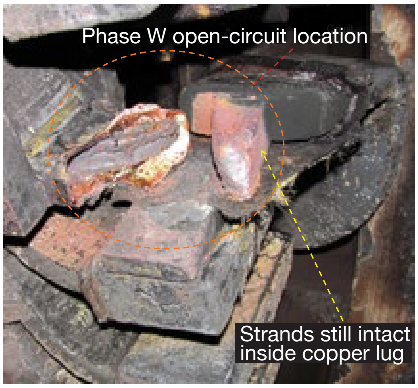
An aggressive plan implemented for the company's seven air-cooled generators of the type described focused on inspection and repair of "at risk" units (see report segment immediately above). It called for repairing damaged strands (where necessary) and improving the support blocking scheme at phase bars. The blocking-scheme mod has evolved and periodic maintenance is anticipated, including periodic natural-frequency testing. A monitoring program is in place to avoid a repeat failure event.

A winding in satisfactory condition is shown in Fig 25 (left). A close-up of the area is alongside. The failed joint is shown in Fig 26. The extensive burn damage resulted from the arc which continued to carry current for several seconds after ground relay trip as the field current decayed.

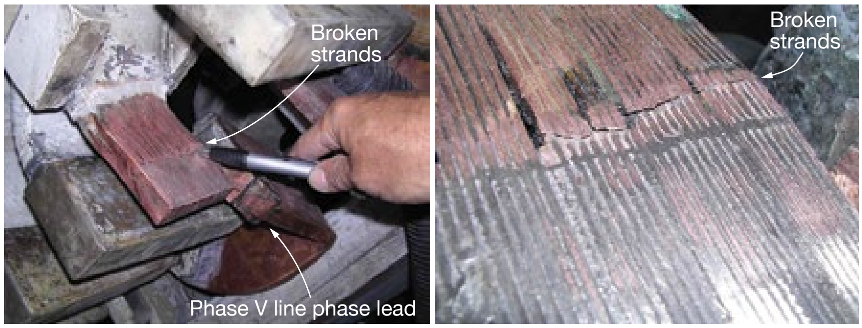
Fig 27 (left) revealed cracked strands (at the tip of the pen), which are shown close-up at the right. The photo in Fig 28 is of the repaired connection with additional blocking and tying.

The Alstom design places a resistance temperature detector (RTD) in each of the 12 phase-lead slots. Operational data show that the RTDs in slots with many cracked strands clearly exhibited a higher temperature rise than all remaining RTDs prior to cracked-strand repair. Data mined following the repairs show the temperature rise of each RTD returned

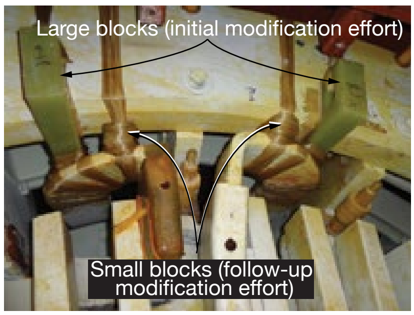
25. Original end winding showing phase-bar blocking design is at left; close-up at right. Supports use rope ties and conforming felt layer



26. Failed joint reveals extensive burn damage



27. Cracked strands at the top of the pen at left are shown in detail at right



28. Repaired joint features added support stiffness to increase phase-bar natural frequency

to values consistent with the overall average of all 12 stator RTDs. Thus careful attention to RTD readings offers an opportunity to remove a unit from service before winding failure.

Jeff Phelps, principal engineer, supports Southern Company's generator fleet

Excitation failure

Unit 4 at Handley Generating Station is an Allis Chalmers hydrogen- and water-cooled generator with brushless excitation. It went into service in 1976 and is used today primarily in peaking service. The main exciter is rated at 600 V/4500 amps. Conversion to DC is accomplished through a rotating 3-phase rectifier comprised of inboard and outboard diode wheels, each with eight fuses, eight heat sinks, and 16 diodes per phase.

Handley 4 was called upon to perform a required reactive capability test which dictates unit operation at maximum megawatt output and at maximum lagging MVArs for 15 minutes. The test was to be completed under a recently developed procedure for reactive capability testing. During ramp-up from no-load, the generator briefly exceeded the published maximum excitation limit. It was quickly brought back within the machine capability curve.

The MVAr output was above historical levels, but all generator parameters were acceptable and within manufacturer limits. Approximately 12 minutes into the test, the over-excitation limiter and instantaneous limiter alarms were received and the unit tripped from service.

Subsequent investigations identified significant damage to the diode wheels. All fuses on the inboard wheel were found open. Severe damage was noted on two of the diodes. Both of these fuses were associated with the same phase and had completely blown apart (Fig 29).

Parts from the failed fuses were ejected, damaging remaining components in the wheel as well as the wheel itself (Fig 30). Severe heating and arcing damage was noted on two heat sinks and their associated insulation.

Repairs required complete disassembly of both the inboard and outboard diode wheels. All fuses and diodes were replaced, damage to the inboard wheel was repaired and NDE tested, and heat-sink insulation and the two damaged heat sinks were replaced.

During the repair process, components of the undamaged outboard diode wheel were electrically tested. A large number of fuses were found open-circuited—including five out of eight fuses on one phase. Although each of these fuses is equipped with a fuse-failure pop-up indicator, none of the indicators activated. (Pop-up indicators only activate if the fuse fails electrically.) The owner's engineers concluded that fatigue failure of the fuse elements caused the open circuits. Periodic testing of fuses is necessary to ensure their integrity.

Further investigations concluded that only two of eight fuses were in service on one phase at the time of the failure. This caused overloading of the two circuits, and subsequent overheating of two heat sinks. The insulation under the heat sinks burned and allowed electrical tracking and a phase-to-phase fault in the inboard diode wheel. The surge in fault current caused the two remaining fuses to blow apart, and the unit tripped from service.

29. Diode wheels suffered significant damage. All fuses on the inboard wheel were open

30. Parts liberated from failed fuses damaged the wheel itself

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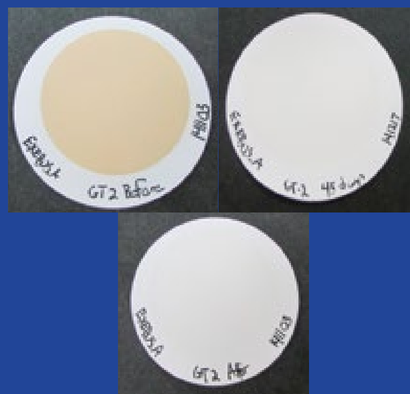

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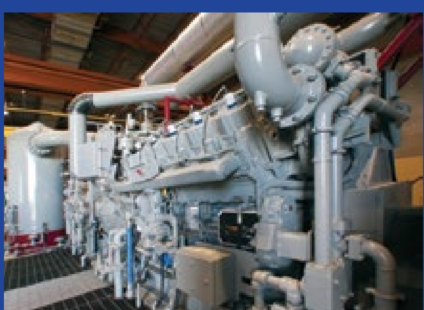

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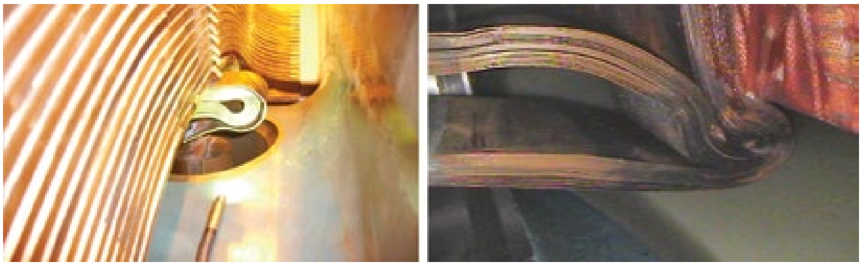


31. Broken J-straps: Complete J-strap separation from main terminal stud is at left; a deformed, collapsed J-strap is at right

33. Failed exciter lead connection at left was corrected with an upgraded connector (right)

Actions to prevent future incidents include daily inspections of the diode wheel, increased testing of diode-wheel components, revision to fleet reactive capability test procedures, and improved operator training.

Joe Riebau, senior manager of electrical engineering at Exelon Power, has more than three decades of experience in the testing and maintenance of powerplant electrical equipment

Emergency field rewind

Numerous maintenance problems with generators in the Duke system were described with slides narrated by the utility's Fred King and AGT-Services Inc's Jamie Clark. Issues included broken J-straps (Fig 31). On another unit, a flux-probe test revealed shorted turns in a large coil. Inspection revealed the root cause as movement of turn insulation (Fig 32).

32. Flux density test revealed shorted turns in a large coil. Root cause was movement of turn insulation

Failure of an exciter lead is shown in Fig 33 (left) with the upgraded connector to its right. Several cases of endwinding and connection-ring vibration have been experienced by Duke generators with indications as seen in Fig 34. Each of these was corrected by tie replacement and/or application of bonding resin (Fig 35).

Answers to several informal industry survey questions were provided by the presenters for everyone's benefit. The percentages of "yes" responses follow the questions below:

- Have you experienced J-strap failures? **50%**
- Do you require a pressure test on bore seals on hydrogen-cooled units? **89%**
- Have you found field slot-liner problems requiring field rewind? **53%**
- Have you operated a unit with one field ground? **47%**
- Do you require new copper for field rewinds? **5%**

34. Several cases of endwinding and connection-ring vibration were found during generator inspections. At left and right is connection-ring dusting on blocks/ties, in center is greasing on series loop blocks

35. Repairs to vibrating components included replacement of connection-ring ties

36. Generator rotor end plate before inspection

37. Red-dye confirmation of cracks is shown at left and right

- Do you require a high-speed balance after field rewind? **70%**
- Do you specify stator wedge materials for rewedge/rewind projects? **53%**

Fred King is a senior generator specialist with more than three decades of electrical experience at Duke; Jamie Clark is AGTServices' sales manager

Generator end-plate indications

The Altamira II combined-cycle plant was notified in October 2014 of some findings in the generator-rotor end plates that had occurred at other Mexican plants with similar air-cooled generators.

About two months later, inspections at Altamira II revealed several cracks on the rotor end plates for its two gas turbines and steam turbine (Figs 36 and 37).

The OEM strongly recommended not running the units in this condition because of the risk of catastrophic failure. Before restart, the OEM recommended replacing the rotor end plates at both ends of all three fields. Removal of the retaining rings would be required to do this, and based on the OEM's experience, destructive removal was likely. To avoid destructive removal of the retaining rings (spares availability was a major concern), the end plates were removed destructively, without touching the retaining ring.

Root cause of this fleet problem was stress corrosion cracking.

Recommended preventive action included replacement end plates made of an improved material, application of anti-corrosive paint on the end plates, and the elimination of tapped holes for the rotor baffle assembly around the inter-pole center (the lower set of holes, most easily seen in the center photo).

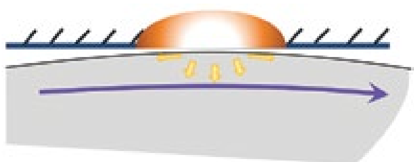
Eliezer Garza Ortiz, an electrical engineer with an MBA, is the director of Altamira II

Damaged steel

Neil Kilpatrick's presentation was an hour-long lecture/discussion tutorial covering the following topics:

- General machine construction.
- Damage mechanisms in steel, for non-metallurgists.
- Where different damage mechanisms sometimes are identified.
- Observable symptoms that might be present, with comments on symptom severity.

This tutorial focused on the generator rotor. Topics included, among others: damper current damage, electrical joint failure, fretting, deposition of decomposition products on visible rotor surfaces, overheating of retaining rings and other forgings, and stationary/rotating rub damage. Material presented on the last topic is summarized below to offer perspective on the depth of coverage and the value of participation in GUG meetings.



38. Rubbing between stationary and rotating parts causes frictional heating. Heat flows inward as illustrated

Stationary rotating rub failure sequence (refer to Fig 38):

1. Contact is established and maintained. Frictional heating occurs over the contact surface and heat flows into both contact elements.
2. A heat-source zone is established. The heat-input plane is the contact area at the interface.
3. Heat flows inward and along the surface.
4. The temperature rise depends on the amount of energy input and the time rate of input.
5. As temperature builds in the hot zone, the metal tries to expand, but the cold surrounding metal is much stronger and more stable and compressional yielding occurs. Increasing hot-zone peak temperature means more compressional yielding; as temperature increases, expansion increases, and strength drops.
6. This kind of rub can result in local metal temperatures in excess of 1300F, with metallurgical transformation to austenite.
7. Some hot metal will be "smeared" by adhesive interaction.
8. When rubbing stops, the hot zone effectively is quenched to the surrounding metal temperature. In typical magnetic rotor steel components, this means that a hardening transformation occurs. But, at the same time, a significant contraction of the former hot zone occurs, and the stress state of transformed metal zone will change to what can be a very high tensile stress.
9. The result is a zone of metal with high tensile stress, additive to normal operating stress, and with a ductility and toughness which tends to be very poor.
10. Intensity of damage tends to correlate with the local volume of damaged metal; high volume relates to more severe damage with increased cracking tendencies.
11. Crack initiation and propagation cannot be predicted, but, clearly, the probability of cracking must be significant.
12. This condition means that the part (rotor forging, blower hub, blower blade, etc) is now capable of erratic and unpredictable behavior.

Unless this is a superficial condition, repair/replacement likely will be required.

Metallurgical problems are widespread on generators and additional topics include these: braze-joint failure processes, torsional fatigue symptoms and analysis, general rotor overheating symptoms and analysis, coupling-bolt failure modes and analysis, and rub-induced bending analysis and repair.

Neil Kilpatrick recently opened his own shop—GenMet LLC—after accumulating more than 45 years of generator metallurgy experience at Westinghouse Electric Corp and Siemens Energy

Field rewinds, etc

This presentation was divided into three segments, with Keith Collins covering field rewinds and high-speed balancing, and Keith Campbell stator insulation. Collins opened the session with a general summary of cooling methods for field windings. But the focus of his presentation was on the merits of reusing copper versus rewinding with new copper (Fig 39).

The steps for a rewind with existing copper are the following:

- Visual inspection of the copper.
- Nondestructive removal and cleaning of copper fit for reuse.
- Visual inspection.
- Repairs, if any.
- Re-annealing and final inspection.

For a new-copper rewind, the steps discussed were these:

- Procure new copper and verify it meets specs, including shape.
- Remove the old winding—destructively if necessary.
- Install the new winding.

The pros and cons of using new copper versus old copper were discussed in detail, with excellent photography illustrating best practices, lessons learned, etc. Much can be learned by accessing the presentation on the user group's website.

Key takeaways based on MD&A's experience:

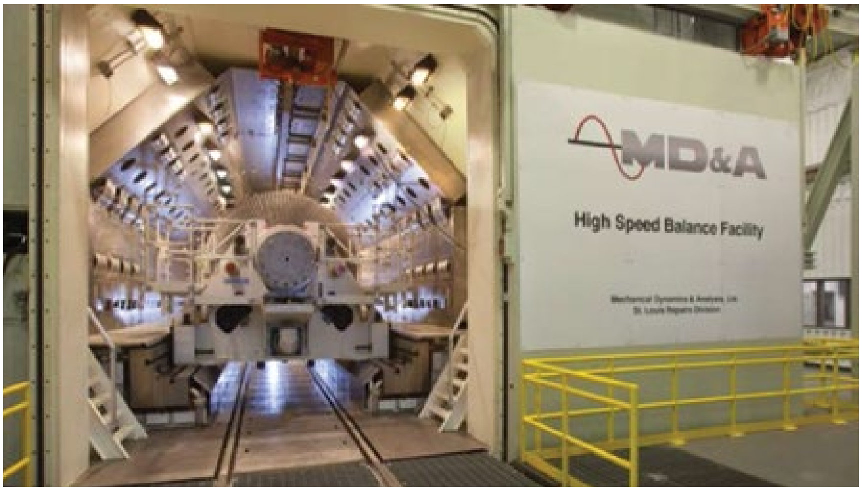
- New copper isn't required for a field rewind; nearly all damage to existing copper can be repaired by splicing and/or brazing.
- If damage is so bad that the use of new copper is suggested, there probably is a bigger problem at hand—such as forging damage.
- Reverse-engineer coils during rewinds to gather data for future use.
- If new copper is the path taken, be sure it is procured long before the scheduled outage.

Stator insulation. Campbell took over the speaking duties from Collins and listed these five factors as contributors to insulation degradation: time, thermal, mechanical, electrical, and the introduction of contaminants. Various aspects of stator-bar groundwall insulation degradation were considered and illustrated—including mechanical vibration (Fig 40) and electrical phenomena such as partial discharge and vibration sparking.

High-speed balance. Collins returned to the front of the room and began his second presentation with a backgrounder on the evolution of balance equipment. He recommended high-speed balancing of generator rotors following a rewind with new or existing copper, after the replacement of a major component, and after any machining. Remainder of the presentation offered details on MD&A's balance facility in St. Louis (Fig 41), which can handle rotors up to about 90 tons, 13 ft in diameter, and 49 ft long. Plus, is has full high-speed thermal test capability to accommodate electrical testing of the rotor at speed.

39. Field rewinds can be accomplished using existing or new copper

40. Mechanical vibration contributes to insulation degradation



41. MD&A's high-speed balance facility in St. Louis is one of only eight such bunkers nationwide

Information disseminated at the meeting showed only seven high-speed balance facilities in the country in addition to MD&A's, with most in the East—Schenectady, NY; Richmond, Va; Pooler, Ga; Columbus, Ohio; Charlotte, NC. The other locations: West Allis, Wisc, and Farmington, NM.

MD&A's Keith Collins is operations manager of the high-speed balance facility; Keith Campbell is a generator specialist

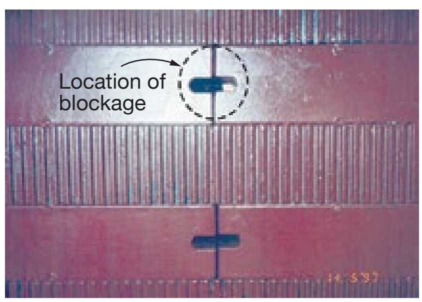
Generator rotor thermal sensitivity

Rotor thermal sensitivity normally can be attributed to one or a combination of the following factors: insufficient or unequal clearances, asymmetrical coil expansion, bound slot wedges, blocked ventilation passages, and shorted turns. Each of the above was discussed in this presentation.

Insufficient or unequal clearances can exist from one coil to another and/or from the coil ends to the steel end plate. This condition can cause forces to be applied that may result in a bending of the rotor forging and increased vibration.

Asymmetrical coil expansion can be caused by restriction of one or more coils and result in unequal coil expansion because of the lack of an adequate slip plane between coils and forgings. This may result in unequal expansion forces on the body forging causing it to bend and vibrate.

Bound slot wedges often result from deficient wedge design/incorrect installation, resulting in asymmetrical and



42. Blocked ventilation passages can contribute to rotor thermal sensitivity issues

restricted expansion which can place bending forces on the forging and cause vibration.

Blocked ventilation passages can occur throughout the ventilation circuits with one location mentioned in particular: radial discharge holes (Fig 42).

Shorted turns can have a variety of causes: conductor movement, incorrect blocking issues, conductor restriction leading to ratcheting or distortion, connector issues, foreign material. The location and magnitude of the shorted turns has a significant influence on the level of thermal sensitivity; specifically, the closer the coil with shorted turns is to the pole head the greater the influence of the short.

The presentation also reviewed NEC's solutions to the thermal sensitivity problems discussed.

W Howard Moudy is National Electric Coil's director of operations

Testing, general

Oil-intrusion events

Oil-intrusion events are a fact of life at Duke Energy, a large utility with hundreds of generators in service. To learn more about how others in the electric power industry deal with oil intrusion, GUG Chairman Smith and his Duke colleagues conducted an informal survey. More than three-quarters of those surveyed said they have oil-intrusion concerns.

Next question: "What level of oil intrusion do you consider a concern?" Responses varied:

- Less than 10 ml weekly concerned no one.
- Between 10 and 20 ml weekly concerned 26%.
- From 20 ml weekly to 10 ml daily was of concern to 37% of those surveyed.
- From 10 ml to 100 ml daily got 21% of the respondents concerned.
- The remaining 16% were not concerned until intrusion exceeded 100 ml daily.

Smith next summarized the following recent oil-intrusion events in the Duke fleet:

- Operator error was blamed for the pumping of more than 3000 gal of oil into the generator bushing box on a large water-/hydrogen-cooled machine.
- During startup, the oil detraining tank on a hydrogen-cooled unit was overfilling and the bypass valve had to be manipulated to control tank oil level. When the unit was being removed from service for repair, tank level increased and oil was pushed into the machine.
- A large hydrogen-cooled unit consistently required oil clean-up from the machine's belly but it had no liquid detector alarms. Although there's no known impact to date, stator re-wedging will be needed.
- Oil intrusion investigation on a large water-/hydrogen-cooled generator is ongoing. Intrusion was noted during the last rewind; the end-bell mating surfaces were not as flat as expected.

Cleaning was required in each of the four cases cited above. It ranged from minor to extensive and given the complicated internal complexities of the generator, cleaning may never be finished in some cases. Corrective actions, sometimes ineffective or incomplete, can include the following:

- Enlarge flex-seal grooves and add additional pumping locations.
- Re-pump flex seals.
- Machine end bells to achieve better mating surfaces.
- Replace TiteSeal™ compound with Flex Seal®.
- Install drain holes in bushings to drain oil from the cooling path of the bushings.
- Replace seal-ring springs.
- Correct piping deficiencies.

Kent Smith, a 35-yr utility veteran, is manager of generator engineering for Duke Energy

SFC flashover

Mystic Station has eight generating units, six of which are arranged in two separate 2 × 1 combined-cycle blocks. The gas turbines require use of a static frequency converter (SFC) for startup. A precise start-up procedure is followed, one using multiple buses ranging from the 5-kV SFC output circuit to the 16-kV-rated generator bus.

Startup consists of operating the SFC and excitation concurrently to bring the units up to 2400 rpm. The SFC is then switched off and disconnected, and combustion takes the units up to 3600 rpm. Finally, excitation is reapplied near 3600 rpm as the units become ready for synchronization to the grid.

During a troublesome start of one gas turbine, the SFC circuit failed to disconnect from the generator bus. This led to a direct connection between the SFC and generator after 2400 rpm. Then excitation was reapplied at 3600 rpm and voltage increased to 16 kV. The application of 16 kV on the 5-kV-rated SFC circuit led to failure of the SFC and caused multiple cable failures in trays linking the SFC to the generator bus.

A subsequent investigation determined the cause of the event as failure of the SFC disconnect switch to remain open after 2400 rpm. Insufficient noise filtering in the plant DCS and absence of feedback loop between field breaker and SFC disconnect switch position were deemed contributing factors.

Corrective actions implemented consisted of protection logic modification to add interlocks between SFC disconnect switches and field breaker, as well as between the SFC disconnect switches and generator neutral ground disconnect switch. Dead-band filters also were installed in the plant DCS to improve noise filtering, and field-breaker trip logic was modified to achieve faster tripping.

Temporary conduit running from the length of the generator bus to the second plant SFC was installed to reach plant operational availability within one week, but complete repair to original condition took significantly longer and required OEM involvement.

Kapil Inamdar is an engineer on the central engineering staff responsible for providing technical support to Exelon powerplants; Joe Riebau is senior manager of electrical engineering

EMI testing

Condition-based maintenance (CBM) is an important goal in the power generation business. The focus is on preventing in-service failures by maintaining equipment only when needed and identifying where maintenance is not necessary. CBM conserves resources, reduces production costs, and minimizes the possibility of damage during maintenance (such as that caused by a rotor drop).

Electromagnetic interference (EMI) is a powerful tool for condition-based maintenance and is useful in diagnostics of both electrical and mechanical problems in the generator system. It has been used for 80 years to locate defects in power lines that cause radio and television interference. Application to powerplant equipment began in 1980.

EMI signals are collected with a split-core radio-frequency current transformer (RFCT) and radiated energy is measured with a simple handheld instrument. These two techniques permit detailed condition and location identification. Maintenance recommendations can be given with the first test. Trending of numerous tests is not necessary to analyze data but may be helpful for long-term analysis.

There is no interference with plant operations while taking the EMI readings, which are passive and noninvasive. There is no applied signal and no risk whatsoever to equipment operation. The frequency spectrum is taken with an RFCT, typically applied to the generator neutral or a ground-

43. Scanning with hand-held EMI "sniffer," dry-type transformer at left and switchgear panel at right

44. A death was attributed to an explosion suffered during the unloading of hydrogen

45. Siding was blown off plant exterior by the detonation wave that occurred because of inadequate hydrogen purging procedures

ing cable, and the output signature can be analyzed on the screen of your personal computer.

The hand-held instrument measures radiated EMI and is simple to understand and use. In Fig 43 (left), a transformer is scanned for radiated EMI. Switchgear typically can be scanned in a few moments (right). This technique can detect and identify the cubicle where there is deteriorated insulation or loose connections.

Using the RFCT approach, each system defect results in a distinctive radio-frequency spectrum unique to the physical location and type of defect present within that electrical insulation system. More than five-dozen conditions have been identified with this test. Comparison of data collected at two generator loads can determine if loose windings are developing. Substantial basic training is required to interpret the RFCT output curve, and backup interpretation can be obtained from Doble Engineering when interpretation results are uncertain.

Doble's Paul Spracklen is a rotating-machinery systems expert

Hydrogen safety

Hydrogen is very explosive, colorless, and odorless, as well as difficult to contain. Yet it has been used widely as a coolant for generators since 1938 (today there are over 10,000 hydrogen-cooled generators in service). Hydrogen is used for several reasons:

- Windage/frictional losses are less than for air.
- The relative density of hydrogen is four times less than that of air and its heat-transfer characteristics are better.
- It is 14 times more efficient in removing heat than air.

Compounding the inherent dangers in handling hydrogen, the generator fleet is growing older, auxiliary hydrogen equipment is ageing, outage intervals are increasing, the workforce is getting younger and leaner, and training programs are not what they used to be. Thus the dangers of using hydrogen as a coolant may be increasing.

A recent newspaper headline stated: "Deadly explosion at ABS powerplant blamed on hydrogen gas." Damage caused by recent explosions is shown in Figs 44 and 45. There was a death while unloading hydrogen at the plant in the first photo. The explosion at the second plant occurred because of inadequate hydrogen purging procedures. While there were no deaths at that facility, damage was significant.

It is essential for plant personnel to know and understand the hazards associated with hydrogen and that all equipment for handling and storing this gas be certified and maintained in first-class condition (Figs 46 and 47). Finally, because purging is inherently complicated, and can be dangerous if performed improperly, all person-

46. Hydrogen tank farm is typical of that installed at many plants

47. Onsite hydrogen generators are an alternative to receiving hydrogen by truck, in bottles nel involved must be well trained, non-sparking tools (bronze) must be used, carbon dioxide must be readily available in sufficient quantity, appropriate safety signage must be in evidence in critical areas, and keyed lock-outs must be provided for "air" and "hydrogen."

E/One's Steve Kilmartin has more than 30 years of generator experience—including time at an OEM and a major engineering company

Generator testing, overhaul

EthosEnergy Group's (EEG) two-hour session was divided into these three topics:

- Generator deterioration causes and corrective actions.
- Overview of the company's generator maintenance capabilities.
- Illustration of EEG's capabilities by review of 16 case studies.

The first slide (Fig 48) illustrated the complexity of a powerplant and the "insignificance" of the generator. While comparatively small in size, the importance and complexity of the generator is hard to over-emphasize. In the figure, the generator is the tiny white object within the red ellipse.

The design life of generators is commonly considered to be about 30 years. Ageing considerations include fatigue life of the forgings, stop/start cycles completed, equivalent operating hours remaining, the machine's position on the "bathtub curve," rate of increase of component failures, and the point at which plant's economic feasibility becomes negative.

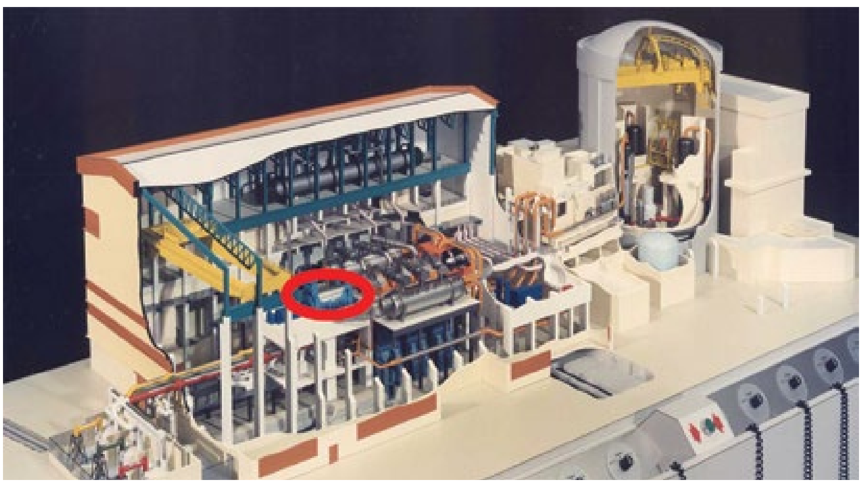
The four major stresses imposed on the generator were considered individually: electrical, mechanical, thermal, and environmental.

- Electrical stresses listed were core back-iron overheating caused by over-excitation operation, overheating of core ends caused by under-excitation operation, core manufacturing or repair defects, partial-discharge activity, and surface contamination and moisture.
- Mechanical stresses: core looseness, vibration and fretting, stator winding slot looseness and 60-Hz/120-Hz vibration, stator endwinding looseness and vibration, rotor component stresses caused by centrifugal forces, and abrasive material contamination.
- Thermal stresses: core insulation damage, poor ventilation, continuous operation at high temperature or overload, differential expansion between components, and thermal cycling.
- Environmental stresses: water absorption, oil contamination, acidic or alkaloid atmospheres, and carbon dust.

EthosEnergy Group has found that causes of in-service failures have been: 37% bearings, 33% stator windings, 11% unspecified, 6% shaft/coupling, 5% external devices, 5% rotor, and 3% brushes/slip-rings. By contrast, major problems found during inspection/test have been: 61% bearings, 10% unspecified, 8% stator windings, 8% shaft/coupling, 7% brushes/slip-rings, 4% external devices, and 2% rotor.

Test and inspection were discussed briefly. Tests commonly used on stators are: winding copper resistance, insulation resistance and polarization index, EL CID/loop test, partial discharge, insulation tan delta/power factor, and AC/DC hipot.

Tests commonly used on fields are winding copper resistance, insulation resistance and polarization index, repetitive surge oscillography (RSO), pole (and turn) drop, AC/DC HV hipot (on major repairs and rewinds).



48. Powerplant model shows the revenue machine (generator, encircled by red ellipse) virtually hidden by other equipment

Repairs (solutions) were discussed in detail. Topics covered included: stator core restacking, cleaning methods, repair of partial discharge indications, stator wedge testing and replacement, stress corrosion cracking of 18/5 retaining rings, exciter and collector issues, bearing and journal damage. Get the details by accessing the presentation via the Power Users website.

Remainder of the presentation was a detailed description of company capabilities for repairing generators, illustrated by a review of 16 case studies of work performed by EEG repair crews.

Darian Garcia is a project manager and Pawel Kwiatkowski is an applications engineer with EthosEnergy Group

GE presentations

As a major generator manufacturer and supporter of the Generator Users Group, GE had most of the third day of the 2016 user-group conference for discussion of its product line. There were many presentations, several summarized briefly below. The editors suggest following up by reviewing the various GE PowerPoints posted to the Power Users website.

- Overview. GE has three general lines of generators: air-cooled, 30-340 MW; hydrogen-cooled, 90-590 MW, and water-cooled, 530-1800 MW. For cost and quality reasons, the company has adopted a modular design philosophy using long-time proven features and components.
- Maintenance. The OEM's recommendations are detailed in GEK103566, recently updated. GE is migrating towards removal of the first-year inspection requirement, and the latest GEK document focuses more directly on updated recommendations with less-intrusive inspections.
- Generator uprate. This informative presentation discussed the important and not-well-understood generator kilowatt and kilovolt-ampere output issues, and the need for generator modification or replacement to safely support a plant uprate.
- Generator fundamentals. Discussion included interesting sketches that illustrated how and why a generator can convert rotating torque energy from the turbine into electrical power for the grid. Various physical configurations of air- and hydrogen-cooled generators were described with numerous photos. Some of the major generator components were described in detail—including the stator core,

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The GUG Steering Committee invites your input for the group's Third Annual Meeting. Here are some of the ways you can participate and make your attendance more productive:

- Suggest a topic for inclusion in the program.
- Make a short presentation on best practices, lessons learned, generator upgrade, outage profile, O&M history, etc. Can be 5, 10, or 15 minutes, or longer.
- Bring a thumb drive to the meeting with a couple of photos describing a problem at your plant and ask your fellow users for suggestions on a solution. Think of this clinic as free consulting by those who walk in your shoes.

The GUG Steering Committee

Chair: Kent Smith, *Duke Energy*
Vice Chair, Ryan Harrison, *ATCO Power (Canada)*
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Jagadeesh (JD) Srirama, *NV Energy*

Email Vice Chair Ryan Harrison (ryan.harrison@atco.com) with your thoughts/ideas today.

stator wedging system, field winding, hydrogen seals, and excitation systems.

- Excitation systems can be challenging components, as illustrated by a listing of 12 different excitation systems for GE and nine for Alstom, which was acquired recently by GE. Brushless and static excitation systems were discussed in detail, followed by coverage of generator protection systems.
- GE Power Services. Worldwide, the OEM has more than 10,000 generators in service and about 1600 GW of installed capacity (both round numbers). With the recent purchase of Alstom, GE is now an amalgamation of 16 companies that existed 40 years ago. It was characterized as a growing and dynamic business.
- Generator vibration and torsional dynamics. Every generator has some degree of thermal sensitivity and there are many possible causes; if the root cause is identified, corrective action can be taken. Motoring and negative-sequence events generally are well understood, and they occur occasionally. Depending on the severity of conditions, corrective actions may range from none to scrapping of the rotor.

Several additional important topics were addressed briefly: TIL 1292, "Generator Rotor Dovetail Inspection," and turbine/generator torsional dynamics, generator vibration monitoring, generator bearing-metal temperature, and grid series compensation and SSR.

- Global repair solutions. GE has power-generator repair facilities worldwide in 55 locations and staffed, in round numbers, by 4000 employees. Many of these sites are large, high-capability facilities. In the US, high-speed balance can be done only in Schenectady, NY, and Richmond, Va.
- Generator monitoring. In support of industry trends toward condition-based maintenance, GE has increased focus on monitoring instrumentation. Some of the following devices were discussed:
  - Upgraded stator leak monitoring system (said to eliminate the need for hydraulic integrity test ing during routine outages).
  - Robotics upgrade.
  - Partial-discharge sensors.
  - Shorted-turn flux probe.
  - Endwinding vibration detectors.
  - Collector health monitor.
  - Rotor shaft-voltage monitor.

Examples of instrumentation success stories also were presented. CCJ

Risk-based planning a high-profit message at annual meeting

By David Addison, Thermal Chemistry Ltd, and **Steven C Stultz,** Consulting Editor

The Australasian HRSG Users Group annual meeting (AHUG2016), held November 15-17 in Sydney, Australia, covered a full range of topics—including extended inspection intervals, performance improvement, plant-specific updates, cycle chemistry, and advanced materials.

Each annual conference, combined with its associated workshops, seems to develop an over-riding theme—one that threads its way through the presentations and on-floor discussions. For AHUG2016, the recurrent theme was risk-based inspections (RBI), as it was at the ACC Users Group meeting in Dallas last fall (see following article).

By better managing the inspection process, so the discussions went, owner/operators can perhaps extend outage schedules without harm to key equipment, reduce downtime, and increase revenues. But such an effort requires both precision and management.

Gatherings like AHUG2016 help generate and maintain these strategies by discussing specific ideas, methods, experiences, and questions. Similar user meetings are held in Europe, Russia, and Canada—and ideas are shared.

1. New Zealand's Te Rapa cogeneration facility shared its experience with extended inspection intervals for pressure parts

Extended inspection intervals demand risk-based approach

Mark Utley, Contact Energy (CE), New Zealand, and a member of the AHUG steering committee, led off Day One with a detailed look at risk-based inspection methods at three plants: Taranaki Combined Cycle, Te Rapa Cogeneration (Fig 1) and Otahuhu Combined Cycle B.

In New Zealand, boiler and pressure-vessel regulations are governed by the Health and Safety at Work Regulations, most recently updated Feb 15, 2016. A pressure equipment inspection program is based on the recommended in-service inspection intervals prescribed by Australian/New Zealand Standard 3788, "Pressure equipment—In-service inspection."

These intervals can be extended through an approved quality management system that meets the requirements of both AS/NZS 3788 and Appendix F of the "Approved Code of Practice for Pressure Equipment," published by the New Zealand Occupational Safety and Health Service (Dept of Labour). The base inspection period (starting point) is one year. Extending this can save both time and money.

The covered pressure equipment inspection programs are divided into three parts:

- Boilers and pressure vessels.
- Piping.
- Protection systems—such as safety valves.

A piping example: Risk-related features can include high-energy-piping (HEP) weld condition, flow accelerated corrosion (FAC), corrosion under insulation, and system chemistry.

To develop the RBI approach, personnel must identify all relevant features of the system, then collect and record clear and comprehensive baseline data. And sometimes, stated Utley, "when you start the inspection you begin to find completely unexpected problems—such as inaccurate construction data."

He then offered some sample priorities based on perceived risk:

- Areas of highest stress.
  - Piping at the HRSG end (more stressed than at the steam turbine end).
  - Terminal point and dissimilar metal welds.
- Areas not previously recorded.
  - Undocumented welds.
- Areas of non-ideal geometries.


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- Pipe-to-elbow welds.
- Areas repaired.
  - During fabrication.
  - During operation.
- Other concerns.
  - All weld types.
  - Chemistry regime (versus original design assumptions).

Throughout the RBI process, focus on these fundamental questions, the speaker said:

1. Do we understand what can go wrong?
2. Do we know what systems we have to prevent this from happening?
3. Do we have information to assure us that our systems are working effectively?

Turning to the three subject plants, Stage One risk-based assessments considered the following:

- Materials of construction.
  - Any materials not well-known to contractors (P91, heavy-wall stainless steel, etc).
- QA during construction.
  - Materials and consumables control, weld fit-up inspection, completeness of records, contractor reputation.
- NDT methods used.
  - Ability to detect defects—RT (radiographic testing) on heavy-wall components, etc.

The conclusion: Baseline inspection was needed in the high-energy Grade 91, 22, 11, and HT (heat-treated) stainless piping systems at two of the three plants.

Stage Two assessments focused on pressure equipment, and evaluated the following:

- Mechanical features that can develop into defects over time, and/or
- Process mechanisms that can change the pressure equipment condition and threaten its integrity.

This led to several subsets of inspection criteria for the same two sites. Precise details were given.

Next, an overall inspection and test plan (OITP) for a nominal 10-year period for pressure equipment (including boiler and piping) was developed, to be reviewed at least annually. The OITP must be all-inclusive and documented, with a clear audit trail. Application is then made to the New Zealand regulators.

For these three plants, regulatory reviews resulted thusly:

- Te Rapa. Moved from one-year to three-year internal inspection interval to match major outages.
- Taranaki. Currently moving toward a three-year interval.
- Otahuhu B. Shut down.

Ongoing compliance conditions also include:

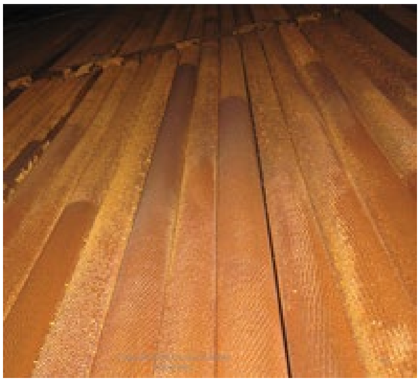
- ISO 9000 quality management system continuance.
- Annual audit by recognized inspection body.
- Extension applies only to pressure equipment scheduled in OITP.
- Any changes to equipment or process must be reported and reviewed.

To adjust to the new schedules, Contact Energy cycle-chemistry improvements are now taking place related to layup and storage procedures, improved instrumentation levels and equipment, and full compliance with IAPWS-recommended online chemistry monitoring of feedwater, evaporator, and steam circuits.

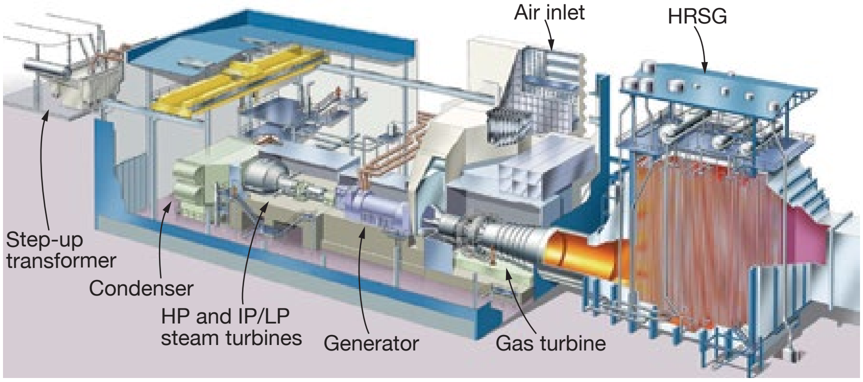
During questions and comments (some focused on local regulatory bodies and responsibilities), Utley offered a sharp and direct summary: "The owner/operator is ultimately responsible," he affirmed. "If you need to push plants harder, then an RBI process can give you confidence that you have the right information to do so."

Dry-ice tube cleaning

Joel Williams, Precision Iceblast Corp, provided a specific strategy for increasing efficiency and output, and decreasing costs: HRSG tube cleaning with



2. Iron oxide (corrosion) is a typical source of HRSG external tube fouling



3. Swanbank E power station is in extended storage, the value of its gas entitlements in global fuel markets greater than for domestic electricity production

dry-ice blasting. He first compared dry-ice particles with the more traditional use of abrasive media, which can damage the metal substrate. Dry-ice particles do not.

Carbon dioxide (CO_2) is now used effectively on the four primary types of buildup on HRSG tubes: ammonia salts, sulfate deposits, iron oxide deposits (corrosion), and insulation materials (Fig 2).

If such fouling is not removed, consequences often include increased gas-turbine (GT) backpressure, reduced thermal efficiency, and particulate emissions during startup.

Examples were reviewed, including common methods of determining when to clean:

- Visual inspection.
- Backpressure readings.
- Stack temperatures.

Revenue and cost impacts were listed and discussed.

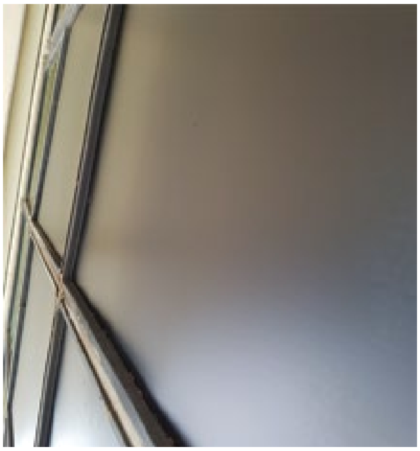
Williams then put on his sales hat. Precision Iceblast, he said, also offers deep-cleaning equipment specifically designed for HRSGs. Bundles with up to 24 rows of tubes, he reported, have been cleaned effectively and without tube damage.

Specific questions clarified CO_2 shelf life, remote site applications, and crew safety.

Swanbank long-term storage

Stanwell's 375-MW Swanbank E Power Station in Queensland (Fig 3) was removed from service in December 2014, primarily to benefit from the increasing world-market value of its gas entitlements (CCJ 4Q/2015, p 8). The unit's return to service (originally 2017) has now been extended to 2018, increasing various long-term storage requirements and risks.

Stanwell Corp's John Blake, a member of the AHUG steering committee, explained how the site continues to implement and expand comprehen-



4. HDPE sheets between the air-inlet pocket frames and filters seal off air flow through the gas turbine, keeping relative humidity below 10%

5. Diamantina Power Station, which produces 240 MW with two 2 × 1 power blocks, took steps to reduce dissolved oxygen in cycle water

sive cold-storage and preservation techniques for all systems. This was consistent with his 2015 presentation that explained how the small care-taker team does not simply *set and forget*. They remain alert and look for improvements.

Some of the 13 dehumidifiers have experienced component failures, so crossover ducts are now installed for both redundancy and to maintain air turnover during repairs. Also, initial attempts to make an air-inlet duct balloon seal completely were not successful. HDPE sheets offered improved seals. Specifically, 600 1.5-mm sheets were installed between the pocket frames and filters, holding relative humidity (RH) below 10% back to the GT exhaust (Fig 4).

The presentation and discussion generated many questions and comments on a range of topics, including these:

- Rainwater ingress through external casing (and corrosion under insulation).
- Roof leakage.
- Separation and measurement of the dehumidified-air (DHA) circuits.
- A growing interest (globally) in film-forming amines in place of DHA.
- GT bearing protection.
- Generators, breakers, and related equipment concerns.

Blake's summary statement fit the venue: "Long-term storage has a number of unknowns. It is good to come to these user group meetings to share our experiences and learn from others."

Penetration and casing seals

Because there are multiple expansion-joint locations in combined-cycle plants, there are also common problems, increasingly aggravated by two-shift and cycling operation. HRSG penetration- and casing-seal degradation was the next topic, offered by Dekomte's Jon Tarrant.

Topics included locations, applications, and OEM designs. Then came the identification of typical failures, followed by repairs, replacements, and retrofits. Example: For steam-line side-wall metal-bellows penetrations, Tarrant suggested, "Fabric retrofits offer advantages of lower cost, quick installation, and no requirements for NDT or heat treatment."

For OEM axial metallic bellows, which allow only minimal lateral movement, distortions and corrosion are common. Replacement costs are also high, so fabric retrofits can become a viable option. Retrofit details (bolsters, fabric, clamp bands) were presented.

Fabric retrofits are also suitable for packed-gland labyrinth seals, an upgrade to counter high maintenance, gas leakage, and typical water ingress. Design specifics were reviewed.

HRSG insulation topics included typical formats and maintenance procedures, and an update on pumpable insulation. Typically, work on liner plates (and insulation) requires unit shutdown. One option is pumpable insulation, injected from the outside of the HRSG (after ensuring liner plates are properly in place). Such material is a mix of short fibers dispersed in high-temperature binders which, upon drying, produces a strong insulation structure with low thermal conductivity (with good adhesion, high melting point, and low shrinkage).

The unit remains online while the product is pumped into place. Pumpable mastic is available in both regular and bio-soluble forms.

An interesting caution followed during discussions, supporting close inspection and possible component replacement. If bellows have failed near HRSG drains, the area could be an unsafe work environment with hot gas leakage. Hot gases can also damage electrical equipment.

Steam and water sampling

Following some open-floor discussions, John Powalisz, Sentry Equipment Corp, covered current steam and water sampling issues related to cycling operation, reduced plant staffing, and corrosion products (metals) transport leading to erosion and corrosion.

Sampling issues specific to combined cycle plants, he explained, are:

- Flow is too high during startups.
  - High temperature impact on equipment.
  - Inconsistent data (pH, for example).
  - Sample flow interruption by thermal valve trips.
- Flow is too low during low load, startups, or with plugging.
  - Erroneous data, no flow to analyzers.
  - Air ingress causing false numbers (carbon content).

The goal is to control the important parameters of velocity, pressure, and temperature for both online instrumentation and grab samples. Automated sampling racks, for example, should offer temperature control monitoring, pressure-reducing-valve (PRV) control, and the ability to set flow rates.

One interesting bottom line: "People are scarce; pressure and load changes are frequent," said Powalisz. Limited staff is available to operate the sample panel during transients. Therefore, it is good to automate (and/or outsource) as many functions as possible.

Iron-transport sampling continues as a significant issue. During comments and discussions, it was noted that iron transport indicates sub-

6. Internal oxides in the modified deaerator showed encouraging results

7. This major gas/LNG export facility has its own 500-MW combined-cycle plant

optimal cycle chemistry control and should be controlled at the source in the first instance through the correct application of cycle-chemistry guidelines—such as the IAPWS technical guidance documents (TGDs). More on these guidelines below.

Trying to address iron-transport issues at the sampling rack does not address their root cause, it was stated, and the risk of major component failures caused by FAC will still remain. An optimized cycle-chemistry program for the feedwater and evaporators of a CCGT plant will result in very low total-iron transport rates and very low total-iron levels in the sample lines.

Oxygen control

David Williams, APA Group, followed with a user case history on oxygen control for new HRSGs, describing the company's 240-MW Diamantina Power Station in Queensland (Fig 5), which opened at the end of 2014 with two power blocks.

After commissioning, cycle chemistry was within acceptable limits and controllable, except for feedwater dissolved oxygen (3 ppb versus the specified 5 to 20 ppb). Cycle chemistry control was achieved through condensate and feedwater dosing and blowdown. Unit chemistry was designed to operate as an AVT(O) system. (Proper oxygen in the feedwater economizers is critical to allow formation of protective layers, minimizing FAC.) After 12 months of operation, a 3-mm wall-thickness loss had occurred in the HP and LP economizers. Focused and comprehensive investigations began.

A critical discovery: The deaerator venting arrangement had not been installed as recommended by the manufacturer. Modifications were made first to one power block, and dissolved oxygen control in that block was possible (Fig 6).

Investigation after 12 months showed no evidence of FAC. Iron-transport studies showed a decrease in total iron levels (soluble and particulate), and magnetite levels through the condensate system were noticeably reduced. Inspection timing was then extended based on a risk-based approach.

Applying chemistry to RBI

One of the largest industrial projects in the world is a major gas/LNG export facility that includes a large combined-cycle plant (Fig 7). Petrofac's Hayden Henderson, a member of the AHUG steering committee, described this 500-MW power complex, part of the Ichthys LNG project at Bladin Point, Darwin (Northern Territory) led by Japan's INPEX Corp.

The complex features five GE Frame 6 machines with HRSGs, and three 100-MW steam turbines fed by a common steam header that connects to three isopentane utility boilers. Overall plant design features N+1 redundancy so that turbine trips do not affect LNG production. The plant supplies power only to the LNG complex and is not grid-connected.

The task discussed at AHUG2016: A collaborative effort to design a risk-based inspection program for all pressure vessels, piping, and utilities within the boundaries of the combined-cycle plant, and to extend inspection intervals from 12 to 36 months.

The goal:

- Highlight all relevant degradation-mechanism likelihoods and consequences in all piping and pressure equipment, and
- Create inspection plans, drawings, and written schemes of examination for all piping and pressure equipment.

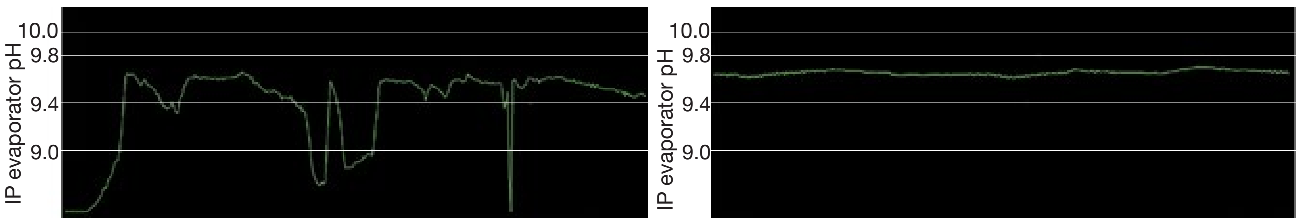
Regulations would allow the extension if the proper RBI program were used, the boiler had adequate water-treatment facilities, and the equipment had a demonstrated history of reliability.

Henderson's RBI presentation focused on station chemistry to define the inspection plan.

At project launch, data were limited, power demand and operating modes were not known, cycle-chemistry guidelines (from the EPC contractor) were not adequate, and co-owner (UK-based Petrofac Corp and INPEX) methodologies focused on oil and gas facilities, not combined cycles.

Chemistry guidelines were critical. IAPWS and EPRI guidelines were reviewed leading to fixed integrity operating windows (IOWs) for both feedwater and boiler chemistry. All decisions were made through workshops in a controlled collaborative process, targeting international best-practice cycle chemistry. NDT inspection would be completed at least twice within the first 36 months.

8. Tallawarra has had challenging chemistry and measurement issues



9, 10. IP evaporator (left) operated with unstable chemistry. Monitoring improvements led to stable chemistry (right)

The IOWs are now being developed into a cycle-chemistry guidance document. Provided the IOWs are met, the inspection plan is executed, and no defects are found, the boiler internal inspection frequencies can be extended to match hot-gas-path (HGP) inspections.

During discussions, AHUG Chairman Barry Dooley of Structural Integrity Associates Inc, offered an interesting Rule of Thumb: "In these types of plants, corrosion is either on or off; it's off if you get the chemistry right."

Cycle chemistry at Tallawarra Power

Ivan Currie, Energy Australia, then presented cycle-chemistry activities at the 435-MW Tallawarra Power Station (Fig 8) where he labeled the pursuits "a kaleidoscope." The facility was commissioned in 2009 for baseload operation, but is now transitioning to flexible operation. The plant operates with an oxidizing feedwater chemistry and trisodium phosphate in the evaporators. It is saltwater-cooled.

Unstable chemistry (especially evaporators) was making proper dosing difficult, and control alarms were frequent (Fig 9).

Causes included low sample flows, suboptimal pH analyzers, frequent load changes (impacting conductivity-based dosing), inappropriate alarm set points, and insufficient sample cooling under thermal-shock conditions.

Monitoring improvements included:

- Replaced the solenoid valve in the temperature protection system with a mechanical thermal shutoff valve (TSV).
- Upgraded pH analyzers.
- Improved the instrument maintenance schedule.
- Implemented pH-based trisodium phosphate dosing.
- Verified proper use of sample conditioning components.
- Modified alarm set points to align with new chemistry specification.
- Implemented trim cooling system for sample streams.

The monitoring improvements were conducive the following positive results (Fig 10):

- No nuisance alarms.
- Stable chemistry and dosing.
- Confidence in instrumentation.

Also, the plant implemented various instrument upgrades, modified blowdown procedures, and lowered drum level by about 4 in. Some issues remain such as tiger striping in the LP condenser, and discoloration adjacent to the HP feedwater line into the drum. Work continues.

11. Inspection identified cracking at the reheater header-to-manifold link

Reheater tube failure

Luke Mosele, site chemist, and Jason Spencer, operator/maintainer HRSG, NewGen Power, discussed tube failures at the 330-MW Kwinana plant in Western Australia. The 1 × 1 combined cycle has a dual-pressure HRSG with 80 MW of duct firing coupled to a 160-MW steam turbine.

The system includes a seawater-cooled condenser and demineralized water plant (ion exchange).

Investigations into excessive water usage began in February 2016, with tube failures the most probable cause. The plant could not be shut down at the time, and there were no external signs of leakage. Online checks showed a drop in reheater (RH) pressure.

12. This leak was found by filling the reheater with water via RH attemperator sprays

An earlier inspection had found cracks at several header-to-manifold links on the reheater (Fig 11).

However, a mid-February 2016 force-cooled shutdown inspection found that the leak was not originating from the lower or upper header-to-manifold links. The site then filled the reheater section with water via the RH attemperator sprays, to source the leak (Fig 12).

For commercial reasons the plant

13. Tube leak repair required access four rows back

was returned to service for three days. Then, it was shut down and scaffolding installed. A leaking tube was found four rows back. Several tubes (eight T23 and four T91) had to be removed (Fig 13).

There were challenges. Contractor experience was minimal. Initial heat-treatment methods were slow. Window welding (versus mirror) was used. The initial time estimate of four days grew into seven. Access was difficult and repair costs were high. Removed tubes were then fully analyzed.

Kwinana returned to cycling service for the next three months. But water usage increased again, and a new test found another leak in a similar location. Commercial operations had to continue until the October outage.

Major cracking was discovered in

14. Yarnima Power Station serves a remote island grid in Western Australia

four tubes, and staff decided to plug the tubes at the headers.

The plant returned to service in November 2016, with 68 thermocouples installed to monitor the operational modes (rapid load changes) which could be causing thermal fatigue. Specialized analyses continue.

Questions and discussion points included fatigue crack location ("odd"), other signs of cracking, modifications that might have an impact, materials, location maps relative to drains and attemperators, duct firing and ramp rates, thermocouple locations, and ability to see duct-burner flames through view ports.

Ongoing investigations include key players such as Quest Integrity Group, Thermal Chemistry Ltd, ALS Consulting LLC, HRST Inc, and Structural Integrity.

New power in the Pilbara

Yarnima Power Station (Fig 14) operates on an island grid in remote Western Australia. Challenges include frequent load variations (both daily and seasonal) and a requirement to maintain minimum spinning reserve. Also, original duct-burner design allowed firing only when the respective GT was above 90% capacity, and the plant rarely operates at this level. Following OEM reviews, new duct-firing options were tested, then reviewed and approved by regulators.

The 190-MW plant supports BHP Billiton Ltd's current and planned iron-ore operations.

The Yarnima complex, described by Mark Watkinson, principal chemist, TW Power Services, includes:

- Three SGT-800 industrial gas turbines from Siemens.
- Three HRSGs from RCR Energy.
- Two SST-400 industrial steam turbines from Siemens.
- Three black-start diesel/generators.

Newly sunk boreholes supply raw water to the site's treatment plant and storage tanks. Bore water has high alkalinity and hardness, high silica, and is intermittently contaminated with diesel oil (up to 1 mg/l as TPH, total petroleum hydrocarbons). Also, sources and water quality may change over time or suffer short periods of interruption. Wastewater is routed to two large tanks, then to acid-rock-drainage evaporator ponds.

Water treatment is complex, and no untreated source waters are suitable for cooling-water systems.

Treated permeate is used for cooling-tower makeup and for supply to the GT air-intake evaporative coolers. Cooling-water chemistry is operated at four to six cycles of concentration. Many water issues were identified in the presentation. A project to upgrade online instrumentation is in progress.

HRSG cycle chemistry is:

- AVT(O) for feedwater.
- Emergency dosing of tri-sodium phosphate (TSP) in the HP drum and evaporator.
- OEM oxygen scavenger never used; converted to ammonia dosing at deaerator outlet.

One of three HRSGs often is in layup/standby mode, but must be ready to return to service quickly when needed. Nitrogen capping is used for offline periods of up to four days. Beyond that the HRSG is drained and nitrogen blanketed at a positive pressure above 7 psig (no economizer protection).

Ongoing issues include:

- CO_2 pickup from storage tanks.
- Lack of monitoring for degassed conductivity and conductivity after cation exchange (CACE) on all units.
- Corrosion noted in economizers and boiler blowdown.

FAC has not been identified.

In keeping with the risk theme, Watkinson noted that "successful allocation of funds is based on risk profile and sound risk assessment."

Many questions and helpful ideas followed from the participants—including emergency phosphate dosing, possible pitting from poor layup, membrane biofouling, iron testing, fast-response condenser instrumentation, and flame monitoring.

HRSG designs and trends

Following open-floor discussions to begin Day Two, John Roberts of Jacobs, a global engineering consulting firm, provided a comprehensive overview of HRSG design improvements and trends, touching on the major global OEM suppliers.

Many trends are driven by the global emphasis on *green* options, creating variabilities in load that must be absorbed quickly by traditional power

(Fig 15). Fluctuating gas prices add to the uncertainty.

Fast starts and flexibility carry the weight; combined cycles are becoming "mid-merit" vehicles to meet demand. HRSG designers must therefore address:

- Faster ramp rates to match green-power unavailability.
- Ongoing demand for higher efficiency and lower emissions.
- Lower capital and lifetime maintenance costs.
- High reliability under all operating regimes.

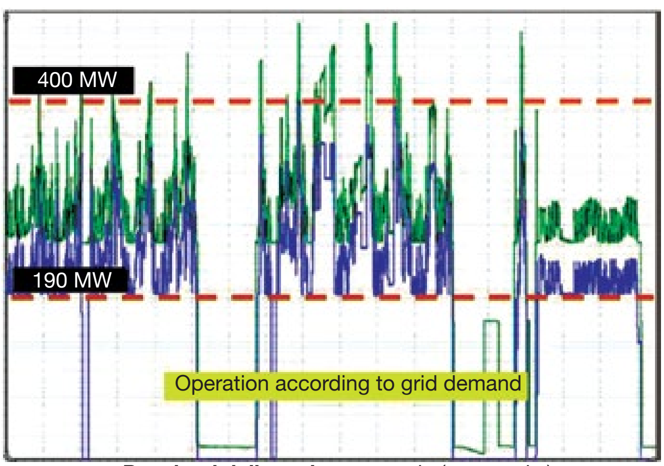
Primary design issues: "One of the earliest problems faced by HRSG designers," stated Roberts, "was large volumes of condensate." This requires good drains (Fig 16) and correct drain operation to prevent thermal transients.

He continued, "The steam drum is seen by many as the limiting factor to a fast start," because of problems caused by the differential temperatures (steam and cold feed). For this, OEM designers are offering two solutions: a patented DrumPlus™ design by NEM with secondary separators outside the drum (Fig 17), and vertical steam separators by Babcock & Wilcox (Fig 18). Single-row harp designs also were discussed.

Materials also remain a common issue. Criteria for progress include:

- Materials with greater allowable stress at high temperature and pressure.
- Properties of thermal conductivity and thermal expansion.
- Grain structure and heat treatment.
- Weldability and transitions.

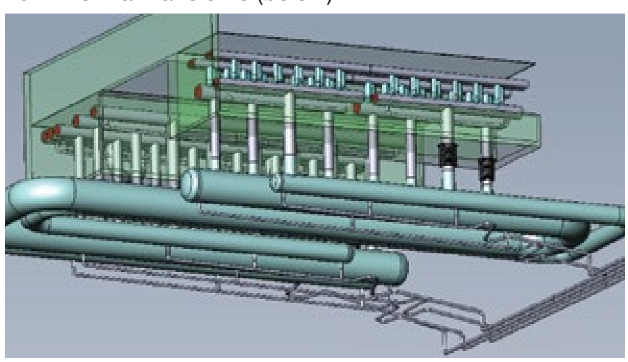
These items were reviewed and discussed.



Part-load daily regime example (two weeks)

15. Emphasis on "green" options create load variabilities that must be absorbed quickly by traditional generation (left)

16. Modern condensate drain system is a must to prevent thermal transients (below)



Almost unanimously, OEMs are recommending and offering online real-time monitoring programs for critical components (drums, high-temperature headers, etc). Specific commercially available examples were given.

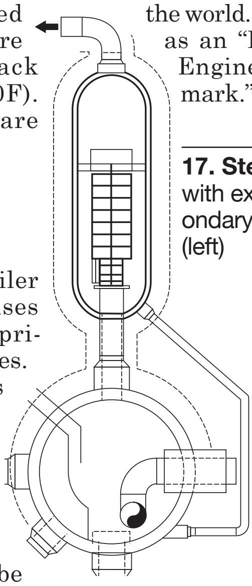
For superior efficiency, there is a possible move toward supercritical once-through (Benson-type) units, but design benefits and limitations must be carefully explored. Also in development mode is reduced backend temperature for more heat/energy extraction (stack temperature of perhaps 160F). Discharge corrosion issues are also under investigation.

Material damage tolerance and codes

Traditionally, the ASME Boiler and Pressure Vessel Code uses mechanical strength as its primary basis for construction rules. Other material considerations stem from recognized material specifications (ASTM, for example). Yet with more moves toward critical service (higher temperatures and pressures, and cycling), the current Code approach may be limited. Perhaps *damage tolerance* needs to be part of the Code.

Mike Drew, Australian Nuclear Science and Technology Organisation (Ansto), first addressed this topic by looking back to a 1983 main-steam piping failure at Philadelphia Electric Co's Eddystone Unit 1.

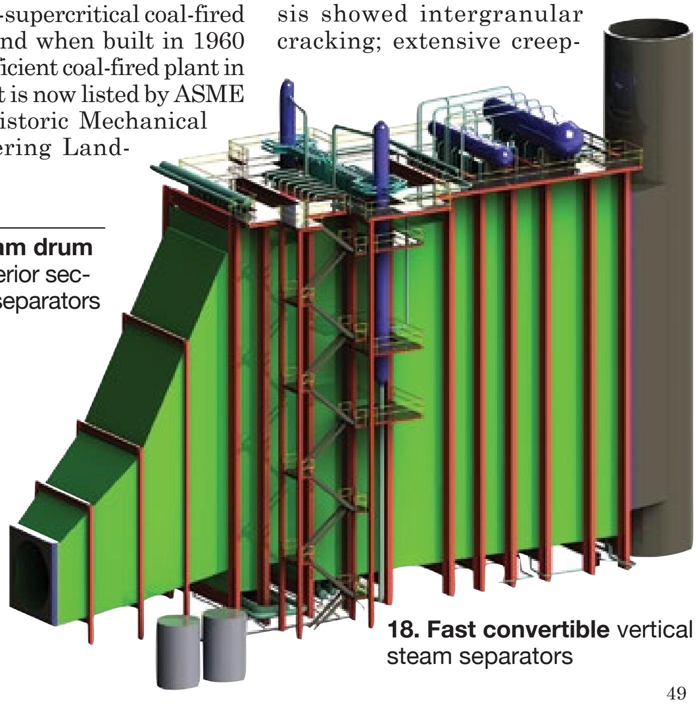
Eddystone (325 MW) was the world's first truly ultra-supercritical coal-fired utility boiler, and when built in 1960 was the most efficient coal-fired plant in the world. It is now listed by ASME as an "Historic Mechanical Engineering Landmark."



17. Steam drum with exterior secondary separators (left)

Original steam outlet parameters were 1210F and 5000 psig; temperature later was reduced and was held at 1135F until unit retirement in 2014.

A steam-pipe failure occurred after 130,000 hours of operation; and there were no indications that the leak might develop. Failure analysis showed intergranular cracking; extensive creep-



18. Fast convertible vertical steam separators induced cavitation was observed at grain boundaries in damage areas, with sigma damage (a loss of fracture toughness caused by exposure to high temperature) but no evidence of swelling. Piping material met the specification requirements (both mechanical properties and chemistry).

Cracking was directly related to residual stress induced by thermal shock events (condensate flow) during shutdowns. The material's ability to tolerate abnormal operating stresses was compromised.

For the replacement piping, primary emphasis was on chemical composition control to improve the material's damage tolerance—specifically:

- P91. EPRI recommends more restrictive compositional controls for P91 material. The example given was a P91 header failure in the UK at 60,000 hours, and high variability in ductility within the header. The EPRI specifications are now much tighter than the original for SA-335 P91. Examples were given showing differences in both strength and rupture ductility at different temperatures.
- TP304H and TP347H. The National Institute for Materials Science (NIMS) has evaluated creep-life variability factors for its Creep Data Sheet Project. Studies were conducted up to 200,000 hours. Drew presented data on the long-term effects of nitrogen and boron on material properties at high temperatures.

The bottom line: Damage tolerance should be incorporated into design. *Damage tolerant* means that a material can uniformly incorporate damage and will normally show signs of distress (during inspections) prior to failure. *Damage intolerant* means that there is localized accumulation of damage or strain, often at grain boundaries.

Drew offered the following recommendations:

1. Critical service should be defined for each construction code, with failure of a pressure part defined as one that would threaten personnel safety and/or result in extended downtime.
2. For critical service, a damage-tolerant material should be required, or if a damage-intolerant material is used, a penalty factor on allowable stress should be imposed.
3. For grades of materials in the power industry, codes should be updated to define a damage-tolerant class for a given alloy, perhaps labeled the *DT Class*. This can be added to ASTM requirements as supplementary.

Update on cycle chemistry

Chairman Dooley then presented an update on HRSG cycle chemistry and FAC. "The base issues are global," he said, "and many plants are experiencing repeat failures."

Repeat failure situations include:

- Corrosion product transport.
- HP evaporator deposits.
- Instrumentation (insufficient).
- Drum carryover.
- Shutdown protection (inadequate).
- Contaminant ingress.
- Failure to challenge the plant's chemistry status quo.

Dooley has analyzed data from 70 worldwide HRSG assessments and 114 fossil plant assessments. He knows this stuff.

Steam-turbine PTZ damage and failure

A case study covered a 675-MW 2 × 1 combined cycle equipped with a triple-pressure reheat HRSG. A failure in the phase transition zone (PTZ) occurred

19. LP turbine L-0 blade failure

at 95,000 hours. Cycle chemistry was an amine blend with reducing agent, and phosphate to all drums. There were multiple leaks in the titanium condenser tubes.

The LP turbine experienced an L-0 blade failure (Fig 19) and pitting was extensive (transition from pit to micro-crack to failure).

Seven root-cause chemistry situations were identified (five directly related to PTZ damage):

1. Total-iron corrosion products not measured.
2. No HP evaporator tubes removed to assess deposits.
3. Instrumentation at low level (53%) compared to recommendations in technical guidance documents issued by the International Association for the Properties of Water and Steam (IAPWS). Visit www.iapws.org.
4. Drum carryover not measured.
5. Shutdown protection (DHA) not applied.
6. Repetitive contaminant ingress.
7. Status quo on plant guidance and action levels.

Avoiding repeat situations is critical, explained Dooley:

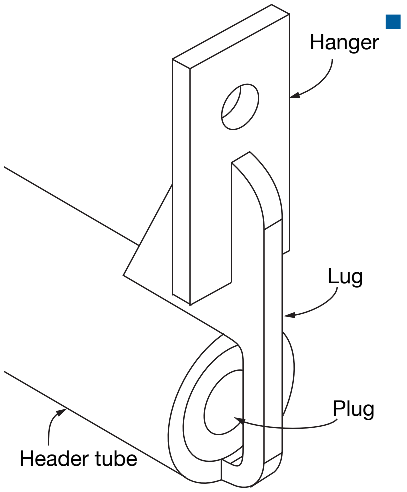
"Cycle-chemistry-influenced failure and damage always can be related back to multiples of repeat cycle-chemistry situations in fossil and combined-cycle plants."

Thermal assessments

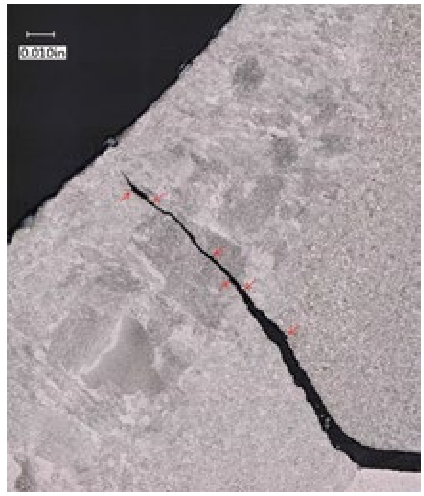
This was followed by an update on thermal assessments by Robert Anderson, principal, Competitive Power Resources, a Florida-based consultancy, and a member of the AHUG steering committee.

First step in a thermal assessment, he said, is to review HRSG design and component configurations. Primary dangers, well understood, are:

- Drain pipes too small.
- Blowdown tank above the HRSG's headers.
- Attemperator leakage or overspray.



20. This header was shortened and tubes removed



21. The crevice between tube and header became a concentration site

Drain pipes not having continuous downward flow.

- Drain operation not based on reliable condensate detection.

Plant DCS data can help identify condensate migration, RH and superheater (SH) overspray conditions, and HP pressure ramps set too high during startup. The data, however, must be reviewed carefully.

Operating choices are also important:

- Are drains opened during purges?
- Is there manual manipulation of outlet steam-temperature set points?
- Is a routine attemperator inspection program in place?
- Is a tube-failure root-cause program in use?

Participants then discussed drum thickness and ramp rates.

Economizer tube failure

Anita Zunker of PEI Pressure Equipment Integrity explained a recent HP economizer tube failure at the Stratford combined-cycle power station at Taranaki, New Zealand. Commissioned in 1999, the plant was in baseload service until moving to more flexible operation in 2013, with extended out-of-service periods. "Robust preservation procedures are in place," stated Zunker.

Current out-of-service programs include:

- Short term (few days only): wet storage.
- Longer term: nitrogen capped, drained hot, piping dehumidified.

The tube leak was detected at the end of March 2016. The pinhole leak occurred in HP economizer 7, top tube-to-header weld (sixth tube from east end). Material is carbon steel.

The repair method: Six tubes were demolished and the header was cut shorter (Fig 20).

A pressure test then found another leak (seventh tube from west end). That leak was plugged, and metallurgical analysis of the first leak showed oxide-filled cracks and corrosion on both tube and header surfaces (within crevice), along with minor pitting of the internal tube surface.

The cause was a corrosion fatigue crack, with the crevice between tube and header acting as a concentration site for corrodents, and as a stress riser (Fig 21).

Data from 2006 also were reviewed. The conclusion: original welding defects are an influence.

And the solution: Concentrate on what *can* be controlled. Maintain operating and preservation procedures to the highest standards to minimize ongoing risks. Be aware of the issues.

Online analysis of ultra-trace iron, copper

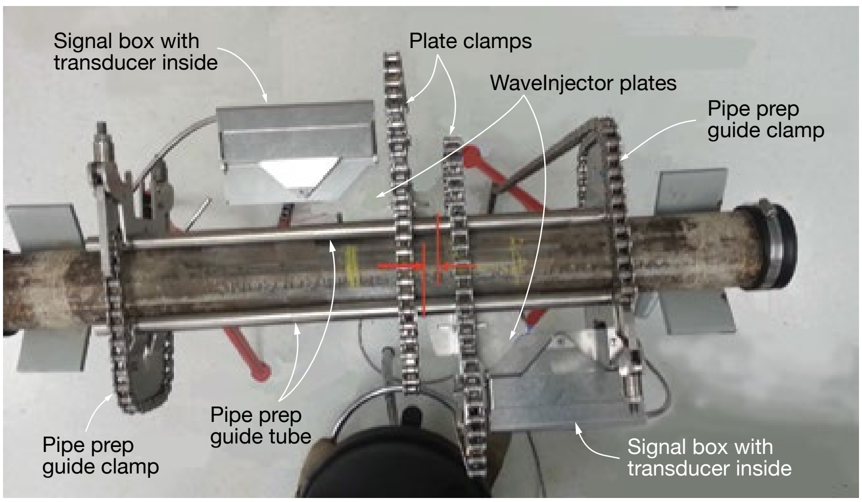
Tomi Maatta, ANZ-based MEP Instruments, addressed online analyzers for what he called "ultra-trace" iron and copper. The purpose: To understand the correlations between operating conditions, FAC, and metals transport.

This presentation of a promising new technology discussed separation of dissolved and particulate metals, voltammetrics, and repeatability of results.

Also discussed in detail were sampling points, analyzer layout, and detailed online test results. Corrosion examples also were shown.

Outage activities at Te Rapa

On Day One, Contact Energy discussed extending inspection periods at vari-



22. WaveInjector® ultrasonic detection can pinpoint water in drain lines

ous plants—including Te Rapa in New Zealand (refer back to Fig 1). Rachelle Meijer, Contact Energy, was at the podium on Day Two to discuss current outage activities at the plant.

A full external inspection had been conducted before the last outage. Hot spots were found around the diverter door and transition duct. A follow-up comprehensive internal inspection included hardness and dye penetrant testing of superheater tubes. Findings were:

- Duct liner plate buckling.
- Duct burner 2 (of 12) had sagged; DB 3 was beginning to sag.
- Duct-burner final elbows found highly corroded.

Soon after restart, water usage increased and IP steam production decreased. Shutdown followed. A leak was found between the economizer and evaporator headers. Tube samples were sent to Structural Integrity, identifying corrosion fatigue.

Contributing factors were:

- Thermal shocking during non-optimal trip test.
- Poor layup and storage in past.
- Poor design of header and tube attachments.

Moving forward, actions will include:

- Conduct further inspections at next outage.
- Install thermocouples and strain gauges.
- Install nitrogen generator for layup.
- Update procedures for trip testing.
- Improve mass balance data.

Various participant questions and constructive ideas followed.

Ultrasonic control of SH/RH drains

Anderson returned to the podium and presented on ultrasonic control of SH and RH drains.

Major amounts of condensate form in SH and RH tubes during pressurized startup, he said, and drain flow varies greatly with pressure. Small transients are noticeable in bulk steam, but at the tube level these transients (stresses) are very large. The solution is optimum drain operation.

One requirement is to detect water to minimize steam release during purge.

Thermocouples cannot do this; high-flow drain-pot arrangements can, but they are expensive and will not fit (physically) under many existing HRSGs.

Ultrasonic detection can determine water in drain pipes, using the transit-time technique, but must be adaptable to high temperatures. Such a design, the WaveInjector®, was reviewed in detail (Fig 22).

This is now installed on four different HRSGs for testing—various drain-pipe sizes, different materials, and various pipe configurations and control-valve types. Anderson said that "once installed, the WaveInjector is very reliable," but performance can be impacted by many variables. Testing continues.

Guidelines for cycle chemistry

David Addison, principal, Thermal Chemistry, and a member of the AHUG steering committee, followed with proper application of IAPWS guidelines for effective cycle chemistry. "Effective cycle chemistry minimizes deposition and corrosion within the whole water/steam circuit of a CCGT plant," Addison stated. "But it must be a continuous process."

With that introduction, he reviewed the common results of poor chemistry, including the following:

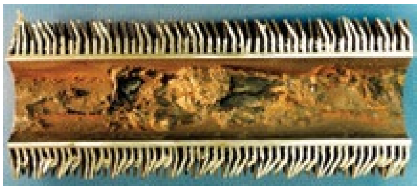
- Evaporator iron oxide deposits.
- Under-deposit corrosion and tube failures (Fig 23).
- Mechanical and vaporous carryover.
- Deposition in superheaters and reheaters.

For the steam turbine, this also means:

- Deposits (Fig 24).
- Pitting and cracking.

"However," Addison warned, "cycle chemistry often is overlooked, carried out incorrectly, or not carried out at all." Such issues often lead to both equipment failure and plant personnel safety concerns. They can present high-risk situations.

Addison also pointed to a problem not often considered: "A unit is designed in country A, manufactured in country B, built in country C, and uses specifications and guidelines from country D." Therefore, "the world now needs truly international guidance on cycle chemistry that can be the foundation for guidelines in each country, and for manufacturers and other organizations worldwide."



23. Under-deposit corrosion leads to tube failures

IAPWS is uniquely placed to offer such guidance, with active participation by knowledgeable representatives from nearly two-dozen nations and drawing on the resources of several international standards-setting organizations—EPRI, VGB, ASME, and others. The IAPWS TGD process is comprehensive, specific, and robust, with an extensive technical review component.

Addison then reviewed several examples, ending with two that were new for 2016:

- HRSG HP-evaporator sampling for internal-deposit identification and determining the need to chemically clean, and
- Application of film-forming amines in fossil, combined-cycle, and biomass powerplants.

He then outlined the following optimization path for cycle chemistry:

1. Understand your current feedwater and evaporator cycle-chemistry program.
2. Understand your HRSG design and materials.
3. Determine current details of sample points and analyzers, dosing systems, carryover testing, corrosion product sampling, and failure history.
4. Access IAPWS TGDs at www.iapws.org.
5. Select your feedwater program via volatile treatment TGD process.
6. Select your evaporator program via volatile treatment and solid alkali TGD selection process.
7. Apply customization according to the TGDs.
8. Review your analysis system against the instrumentation TGD.
9. Review carryover testing and steam chemistry according to TGDs.
10. Begin corrosion-product sampling and benchmark feedwater and evaporator total iron levels.
11. Undertake routine tube sampling and analysis.
12. Ensure proper layup and storage practices.
13. Ensure chemical dosing is automated and working.
14. During shutdowns, ensure specific cycle-chemistry inspections are completed and documented.
15. Review operating chemistry data at least annually.
16. Watch for new TGDs.

Latest IAPWS updates

Dooley followed Addison to explain both the TGD process and the various IAPWS technical groups—including the Power Cycle Chemistry Group—and offered an overview of current activities of the Australian National Association.

He also listed and outlined future possible TGDs:

- Ensuring the integrity and reliability of demineralized makeup water supply to the unit cycle (2017).
- Neutralizing amines (2017).
- Film-forming products for nuclear plants (2017).
- Air in-leakage (2017).
- Steam chemistry for geothermal plants (white paper 2017).
- Corrosion products in flexible (cycling) plants (white paper 2017) .

Steam/water analysis

Chris Wellard, Swan Australia, ended the day with a review of outdated versus modern sampling and analysis designs.

The fundamental instrumentation differences:

- Component-oriented design (dry rack/wet rack), or

24. Salt deposits in LP turbine attributed to a condenser tube leak (left)

25. Modules grouped by sample line are arranged for direct access to all components (right)

- Modular process-oriented design—online instruments featuring integrated sample preparation (degassed cation conductivity, cation conductivity).

With changes to plant operations (flexibility), new components, and changes to original water chemistry details and methods, traditional systems are no longer adapted to actual monitoring requirements. Even in some new plants, outdated dry/wet-type rack/panel arrangements can prevail, in part to reduce capital cost.

But there are consequences:

- High O&M costs.
- Upgrade or modification difficulty.
- Low reliability.
- Collateral damage to plant components.

The new modular Steam/Water Analysis System (SWAS) is driven by both process and function; modules can be grouped by sample line for:

- Improved O&M (less cost).
- Upgrades/modifications.
- Instrumentation giving perspectives on the process (Fig 25).

Discussions then centered on conductivity measurement and degassing devices. "Swan's position," stated Wellard, "is that the fully controlled thermal degasses system, with automatic boiling control, is the optimal method."

Examples of upgrades and replacement systems were then discussed.

Workshops

Three workshops were held on the third day:

1. Attemperator issues.
2. Preparation of a covered pipe system management plan.
3. Anatomy of HRSG thermal surveys.

Submitted questions

Technical questions submitted by participants before the event were discussed periodically during the meeting, both through the presentations and during open-discussion periods. Selected questions included:

HRSG O&M

- Risk-based inspection process.
- Spray water control (automatic and manual bypass).
- Low-load operation strategies.
- HP bypass on startup.
  - To save treated water.
  - To mitigate pressure-control-valve corrosion.
- Corrosion under insulation.

Cycle chemistry

- Long-term dry storage options.
- Corrosion-product sampling.
- Phosphate dosing-line issues. CCJ

Chemistry, corrosion, performance, O&M dominate annual user-group program

By Steven C Stultz, Consulting Editor

The eighth annual meeting of the Air Cooled Condenser (ACC) Users Group, held Oct 3-6, 2016 in Dallas, offered a tailored agenda based on previous participant feedback. The content recognized the seasoned combined-cycle professional, but also addressed those perhaps newer to the industry attending to absorb fundamentals along with up-to-date experiences and achievements.

Day One in Dallas began with three tutorials capturing the essence of the overall program:

- Chemistry and corrosion.
- Design and performance.
- Operation and maintenance.

Interestingly, many of the fundamentals attracted insightful comments and discussion threads by even the most seasoned veterans.

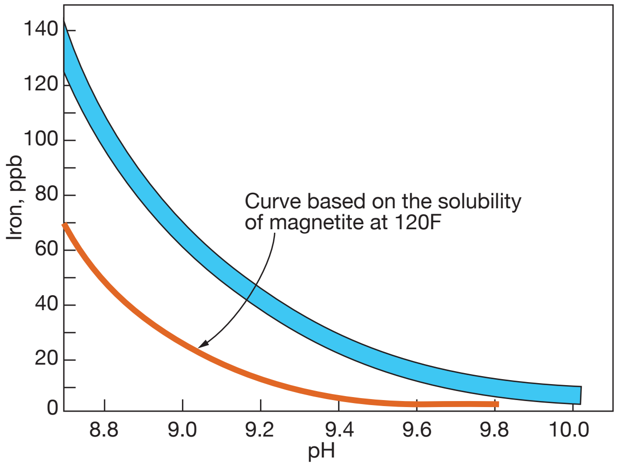
"We make every effort, each year, to adjust to the industry [and its people]," said ACC Steering Committee Chairman Dr Andrew Howell, senior systems chemist, Xcel Energy. "We know the industry is in transition, and we know that both the depth and breadth of ACC experience are expanding quickly. We will stay at the forefront and provide both education and discussion for both repeat and first-time participants."

One point stressed repeatedly was based on a good understanding of the fundamentals, but equally (if not more) importantly on in-depth awareness of ongoing and expanding operating experience. That point: Chemistry of the ACC controls chemistry of the generating unit.

Day One

Chemistry, corrosion

Dr Barry Dooley was first at the podium. Recognized internationally for his expertise and commitment to cycle chemistry, with a particular emphasis on flow-accelerated corrosion (FAC), the senior associate at Structural Integrity Associates Inc, presented a comprehensive review of steam-cycle chemistry and ACC internal corrosion. This launched the first tutorial.



1. Dooley/Aspden relationship, important to ACC operation, graphs the relationship between pH and total iron. Note that ammonia was used exclusively for pH control in this case; iron levels were measured at the condensate-pump discharge. Data for iron solubility are attributed to Piero Sturla of ENEL's Piacenza Laboratory (1973)

Meeting participants listened carefully as Dooley, a member of the ACC Users Group steering committee and executive secretary for the International Association for the Properties of Water and Steam (IAPWS), traced operating experience and research history through specific sites in South Africa, the US, and Australia.

South Africa is where researchers began to quantify chemistry impact on specific areas (tube entry, for example). This helped identify specific issues beyond just knowing that this was a two-phase environment. Cross-members were reviewed which increased understanding (liquid-droplet contingent).

As the amount of data collected increased, a plant in Queensland showed that "some OEMs do not communicate on cycle chemistry needs. Within short operation at this plant, high levels of damage began to appear. We learned specifically that pH levels impact iron throughout the cycle," Dooley said.

Dooley's experience gave full credence to meaningful summary statements, such as these:

- ACC chemistry and corrosion issues are the same worldwide, regardless of unit manufacture, size. and chemistry.
- Focused research began about 2007, but uncertainty was high and we knew it.
- We know now that compound turbulence is the main concern for ACC tube entry areas.

  For tube entry inspection, color is important and can be confusing, but clearly indicates the two-phase activity.
- Internal inspection is critical

STUG

STEAM TURBINE USERS GROUP

Fourth Annual Meeting

Sheraton Grand at Wild Horse Pass, Chandler (Phoenix), Ariz
August 28-31, 2017

Please mark your calendar and plan to attend
Registration opens in April at www.stusers.org

The STUG Steering Committee invites your input for the group's Fourth Annual Meeting. Here are some of the ways you can participate and make your attendance more productive:

- Suggest a topic for inclusion in the program.
- Make a short presentation on best practices, lessons learned, turbine upgrade, outage profile, O&M history, etc. Can be 5, 10, or 15 minutes, or longer.
- Bring a thumb drive to the meeting with a couple of photos describing a problem at your plant and ask your fellow users for suggestions on a solution. Think of this clinic as free consulting by those who walk in your shoes.

The STUG Steering Committee

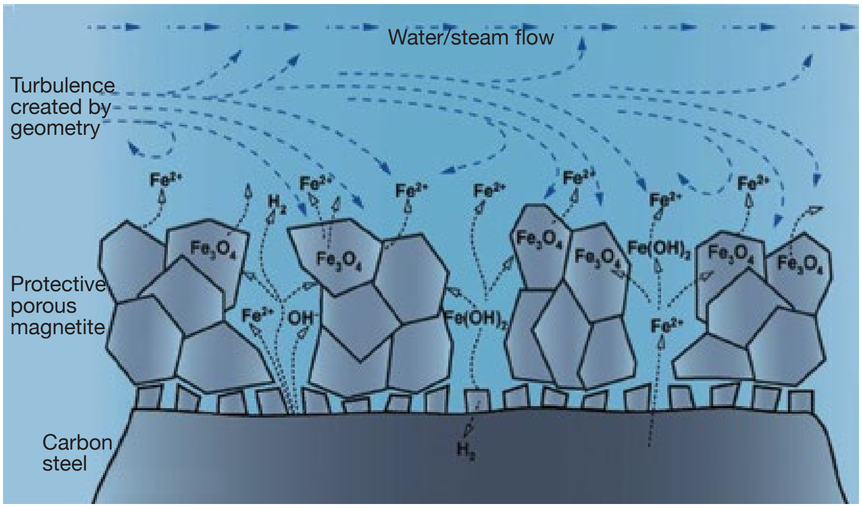
First row (l to r): Jay Hoffman, *Tenaska Inc;* Gary Crisp, *NV Energy*

Second row: Jess Bills, *SRP Desert Basin;* John McQuerry, *Calpine Corp;* Chair Eddie Argo, *Southern Company*

Third row: Jake English, *Duke Energy*

Top row: Lonny Simon, *OxyChem;* Vice Chair Bert Norfleet, *Dominion*

Email Vice Chair Bert Norfleet (bert.norfleet@dom.com) with your thoughts/ideas today.



2. Two-phase FAC (steam and water) is a consequence of a flow-accelerated increase in mass transfer of dissolving and reacting species at a high-flow or highly turbulent location

because tubes rarely are removed for laboratory inspection.

The ACC "controls" unit cycle chemistry, the speaker continued. A decade ago, international guidance was not available on this. Work since undertaken by IAPWS, in particular its publication of technical guidance documents, has provided plants much needed advice (sidebar, p 65).

Dooley next explained the development of the Dooley/Aspden relationship for pH control of the ACC. In summary, they found that total iron versus pH was consistent worldwide (Fig 1).

Further characterization became available with the Dooley Howell ACC Corrosion Index (DHACI), allowing standardized investigation and tracking for both tube inlets and lower ducts (details in CCJ 1Q/2015, p 110). More specifically, the index evaluates and describes concerns in both the upper and lower sections of the condenser. It is now is used globally to identify and monitor ACC condition, and allows for comparisons worldwide.

The essence of damage, according to Dooley, is the dissolution rate and impact on the directly related inner ferrous hydroxide (Fig 2). "But did we understand the environment, the mechanisms, and the proper prevention?" The answer: No, and still not yet. Studies continue as various solutions are applied.

As Dooley explained, "the key is understanding phase-transition-zone environments. The low-pressure turbine environment is thoroughly characterized, and this is the starting point for the ACC environment."

The solution, says Dooley, is dependent on removing the saturation of iron oxide Fe_3O_4 at the surface and precipitating it adjacently. The bottom line: Damage takes time (months or years) to repair. The best operating target is less than 5 ppb iron and pH great than 9.8.

He followed with an update (status) on film-forming products, and some initial trials to use these products to repair FAC damage. This is a long-term topic from last year's meeting, and will be ongoing. One specific technology was presented during the meeting and is reported below in the section on film-forming agents.

"We are still looking for answers," said Dooley. "The only source of complete knowledge is experience." Specific international guidelines were then discussed for ACCs and two-phase flow with reference to the IAPWS technical guidance documents.

Air flow management

Sander Venema, Howden Netherlands, followed Dooley with a presentation on air flow management. It reviewed fundamental definitions and fan laws: system resistance (pressure drop); fan performance definitions (aerodynamic power, air volume rate, fan pressure rise); and both total and static efficiency.

Fan performance details covered system and fan curves, operating points, stability, and stall points. For a refresher, access Venema's slides at www.acc-usersgroup.org (click the "Presentations" button). Application basics included fan diameter, type, number of blades, pitch angle, and operating speed. "The most easily adjusted parameters," said Venema, "are pitch angle and speed."

Pitch angle was covered in detail, comparing static pressure to flow and stall. One summary: increasing the blade angle will increase air volume flow, but will also increase fan shaft power, decrease pressure margin, and increase stall risk. "It will reduce fan efficiency, increase noise, and influence mechanical dynamics that should be discussed with the fan manufacturer," he noted.

Speed was then discussed through fan scaling laws (scaling of air volume flow rate) and the effect on shaft power. An interesting summary point: stalling issues cannot be solved by reducing fan speed.

Then came the practical versus the theoretical: Some common operating variables are fouling, air stream obstacles, and wind. The effect of wind received the most attention.

As would be covered further during the meeting, the primary effects of wind are the following:

- Additional pressure loss.
  - Increased resistance.
- Non-uniform inlet conditions.
  - Loss in fan performance.
  - Increased loading on fan blades.
- Recirculation (hot exhaust back into fan inlet).
  - Reduced thermal performance.

Illustrations showed the impact of various wind speeds. Non-uniformity was shown through air velocity measurements at various points within the ACC. Use of windscreens was then discussed, concluding that they have a positive effect on the expected life of the fan but noting that windscreen studies are ongoing. For a detailed discussion on ACC windscreens, see "Windscreens improve performance, reduce O&M cost of ACCs," CCJ 2Q/2016, p 60.

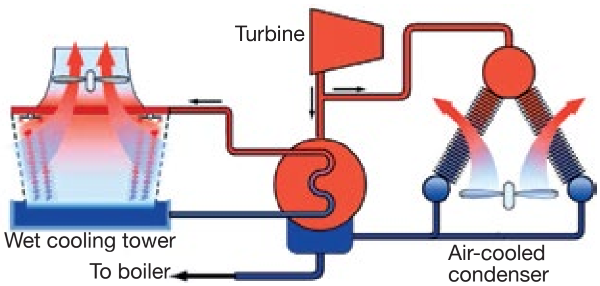
Participant questions and discussions followed, focusing on dynamic blade loading.

Performance enhancements

The morning sessions ended with a performance-improvement review by Chairman Howell.

"Basically," he said, "ACC performance is limited by ambient temperature and tube fouling, parasitic load demand, and potentially by non-optimal ACC design." The outcome of these limitations, the chemist continued, is increased cost of generating electricity, largely attributed to increased fuel use. "Highly significant," said Howell, "is high ambient temperature, which can reduce power generation by 10% to 15%."

ACC design factors therefore include ambient conditions (wind and temperature), anticipated load demand (both internal and external), the steam distribution system, tube design including number of rows, and



3. Hybrid cooling (wet and dry) is illustrated conceptually at the left, in service at right

the fans. Performance can be optimized by numerous design, operation, and upgrade options.

Standard operational improvements include external tube cleaning, air flow management (previous section), spray enhancement (fogging), and air in-leakage control. All topics were covered further at the meeting.

Some retrofits can be complex. In one example, Howell offered a good economic option for large plants in hot weather, especially those with high power replacement costs and adequate water supply. Although not generally used during cooler ambient temperatures, hybrid cooling (Fig 3) is achieved by adding a parallel wet cooling system to the ACC.

Howell then explained the system in detail, including the complete steam cycle and condensate/cooling system. The example given uses a two-cell wet system to supplement the ACC at a combined-cycle plant in Mexico.

A second retrofit example described adding a third street of cells to an existing ACC at a nominal 80-MW coal-fired facility in Wyoming. After this third street with five larger fans was added, at 97F ambient, the plant measured 7 MW of additional output. However, power production decreased in cold weather (less than 32F) due in part to more conservative unit operation.

Howell then addressed fan and motor upgrades, which would also be highlighted during the meeting. If there is no water source to even consider hybrid cooling, another option is to increase air flow through the fan system.

In this example, motors were increased from 100 to 200 hp which also meant replacing electrical switchgear, cabling, motors, gearboxes and fans, while completing detailed structural analyses for load-bearing and resonance issues. For this 100-MW plant, 15 new motors, gearboxes and fans were selected, leading to these results:

- Improved ACC performance under adverse ambient conditions.
- No additional water required.
- Increasing the number of blades to nine from four minimized vibration

and resonance issues.

- Air flow increased from 542 m^3/s to 730, static pressure from 71 Pa to 125.
- Parasitic load increased from 1.12 to 2.24 MW because of the larger fan drive system.

Significant performance results included:

- Removal of backpressure limitation (sustained improvement at 3.5 in. Hg abs).
- Increase in power output (could increase condenser load; steam flow through the turbine).
- Improvement in heat rate (lower condenser pressure/backpressure on the steamer—so-called "free power").

Howell then highlighted the presentation conclusions:

1. ACC performance is critical to low-cost unit operation.
2. Initial ACC design is critical to achieving suitable unit-specific baseline performance.
3. Careful and consistent operating practices can optimize unit performance.
4. Retrofit options can improve performance and reduce plant operating costs.

Ensuing discussions covered ACC permitting, design temperature selection, wind speed as a factor in thermal design, and a conclusion that retrofit projects tend to offer immediate results.

Gearbox maintenance

David Rettke, maintenance specialist, NV Energy, expanded his assigned topic of gearbox maintenance to include, and stress, condition-based maintenance (CBM). His talk was filled with examples of how CBM, if applied correctly, also allows fine tuning for long-term plans, improving long-term performance and value. Rettke highlighted, and exemplified, continuous active involvement in plant operations and maintenance.

At the Walter M Higgins Generating Station, Rettke is intimately involved in ACC maintenance. He champions the plant's programs for continuous performance improvement, root cause analysis (RCA), vibration monitoring, and CBM.

The effective CBM meeting, he noted, should have a 10-item agenda:

1. Maintenance history.
2. Operator interviews and surveys.
3. Safety issues.
4. Operational issues.
5. Maintenance issues.
6. Predictive tools data and results.
7. Root cause analysis results.
8. Possible continuous improvements.
9. Action items with dates.
10. Individual division of responsibilities.

Specific to ACCs, Rettke offered examples from Higgins. Some of the CBM discoveries were:

- Safer gear-reducer change-out using a fixture that bolts directly to the reducer.
- A way to remotely monitor gear reducer and motor vibration and oil pressure.
- A fixture to secure the hub with blades attached during gear-reducer change-outs.

Some direct benefits of CBM at Higgins include:

- All oil changes are determined by oil sampling, prior to filtering.
- Oil changes are based on sampling, not hours.
- Gear-reducer lube is filtered biannually.
- Blade angle and condition are checked annually and precisely recorded.
- Weekly walkdowns are performed for the entire ACC system by mechanical staff and include equipment and structure inspections.

Rettke stressed that these walkdowns (144 steps up and 144 steps down) – "have caught many significant issues over time." He followed with specific examples, including:

- Loose turnbuckles.

4. Fouling (fibers, dust, pollen, etc) of ACC bundles restricts air flow, limits heat transfer. Deposits shown have a fairly weak bond, but 50% closure of heat-transfer surface

5. Some types of fouling have a strong bond to the fin. Such deposits may require pretreatment with solvents or chemicals, and/or blasting with sodium bicarbonate, to achieve desired results with high-pressure cleaning

- Sealing media falling out of position between tube bundles and cell walls.
- Door hinges failing.
- Lights not working.
- Structure bolting missing or loose.
- Decking and grating not properly fastened.
- Various weld repair requirements.
- Repair needs for expansion joints from steam turbine to ACC.

He then declared, "An ACC is a live structure. It moves. Things come undone." This statement reinforced the value of consistent and comprehensive observation.

Rettke followed with a review of specific procedures and tools developed at Higgins, ending with a review of root cause analysis. He is both RCA administrator and RCA participant, and noted "Sometimes you need to do an RCA on the RCA." He then added: "Please remember that RCAs also have value when you do something right!"

Rettke clearly captured the post-lunch participants—a difficult assignment. Lengthy discussion followed on inspection and maintenance methods, experiences, and specific safety issues and techniques.

Tube-bundle cleaning

The term tube-bundle "fouling" had been used earlier in the day, and Huub Hubregtse, ACC Team Technology, offered specific examples and cleaning methods.

"Fouling," he explained, "consists of fibers, dust, pollen, and other materials on ACC bundles restricting air flow, reducing heat transfer, and increasing backpressure at the turbine exhaust." Such fouling normally has a fairly weak bond (Fig 4) and often can be removed by spraying high-pressure water.

Scaling is more difficult. A layer can be deposited on the fins by fumes, spraying water with high dissolved solids on the bundles, or gearbox oil leakage. This layer cannot be removed by water spray alone (Fig 5).

Some types of scale foulants have a strong bond from limestone deposits, oil contamination, or chemical fumes mixed with the cooling air. This must be dissolved in water or with chemicals.

After the use of chemicals, solvents and/or blasting with sodium bicarbonate, the residual deposit must be removed by high-pressure cleaning. If residue remains, it can become baked onto the finned tubes, forming a hard layer.

Cleaning is normally required when the internal static pressure rises to a certain level because of restrictions in


6. Cleaning equipment is lightweight for ease of handling, and automated


7. These tubes had been frozen and damaged by debris trapped behind support beams

the spaces between fins, normally detected by high condenser backpressure. Levels are site-specific.

For normal fouling, most cleaning equipment is lightweight and easy to handle, as with the washing system shown in Fig 6. Hubregtse concluded with examples of automatic cleaning systems, noting that most of the setup costs are in the rails. These systems, he said, are relatively simple and moderately priced. Automation, setup time, and cost discussions followed.

Willis Shook, Conco Systems, continued with three detailed case studies on water-wash tube cleaning, emphasizing that it is not unusual for an ACC project to encounter the unexpected.

The Yellowstone Power Plant ACC experienced severely leaking tubes. Ambient temperatures covered an extremely wide range, and local industries contributed to fouling.

The 65-MW facility is equipped with two pet-coke-fired fluidized-bed boilers, one steamer, and one ACC. The last has 10 modules consisting of eight condensing cells and two reflux cells. Each module contains one fan and six finned-tube bundles. Each bundle has 211 coated carbon steel oval tubes in a three-tube arrangement.

Fans are 26 ft in diameter, have 10 blades, and two-speed motor drivers that can be reversed in severe weather.

Some tubes had been frozen and damaged by debris trapped behind support beams, as shown in Fig 7.

Holes had also developed in the top of the tube connections to the steam header, and at the lower condensate header connections (reflux cells)—caused by corrosion from washing with poor quality water.

Yellowstone solutions included the following:
- Use of underground cable shrink wrap and aluminum duct tape to patch major leaks in tubes.
- Use of sleeve inserts and outer sleeves to fix tube-to-header connection leaks.
- Sandblasting and pressure washing of tubes to remove

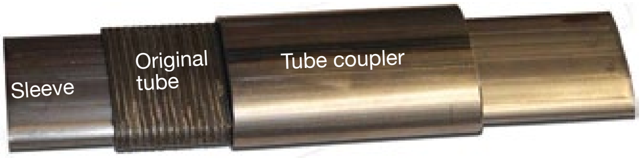
debris from finned areas.

- Use of epoxy paints to help preserve and close pin-hole leaks in steam header and condensate header connections.
- Wind fence.
- Upper wind wall.

Outer tubes were removed for access to inner-row tube leaks. Tube sleeve inserts and outer couplers (Fig 8) were installed. Condensate holes were repaired and coated with epoxy paint for added protection.

Another example plant burns coker gas from a nearby refinery. Steam is then sent back to the refinery. A harsh winter partially froze the coker gas line, creating a blockage backed by high pressure. When the blockage broke free, pressurized oil leaked through the loop-seal stack. Oil covered the outside surface of the ACC and the surrounding area.

Then another unexpected event. A truck carrying flyash overturned near the plant in winter, and the ash was sucked into the ACC fans. The undersides of the tubes were coated with oil and ash, with the oil acting like a glue.



8. Tube sleeve inserts and outer couplers are one way to eliminate leaks (above)

Attempts to clean using the installed high-pressure water system failed. An adjustable and higher pressure system was brought to the plant. Bundles were presoaked with biodegradable degreaser, then the unit was cleaned with the higher pressure ACC cleaning system.

Air in-leakage testing

Conoco Systems' Andy Leavitt, followed Shook, covering leak detection equipment and set-up, air in-leakage indicators, and testing challenges specific to ACCs. Standard in-leakage indicators are high backpressure, dissolved oxygen, and continuous hogger use.

His message of caution: The leak is not always in the ACC. It could be in the hogger or hogger exhaust, the gland-seal drain/trap, the crossover bellows, or base weld leaks in retrofit projects. "But even more frightening," he said, "is finding leaks in new units."

Discussions followed on the best media. "Helium is the best tracer gas," he concluded.

This presentation offered large variety of leak locations and detection examples. Day One ended with, in Leavitt's words: "ACCs present lots of possibilities."

Day Two

A key feature of ACC User Group annual meetings is interaction.

Barry Dooley led off Day Two by listing and reviewing the long list of questions he had been asked during the Day One breaks, the evening gathering, and breakfast. FAC mechanisms (and color indications) topped the list. Related questions centered on the speed of change (damage), determining iron levels, elevated ammonia levels in summer, optimum makeup, pH balance and maintenance, and clarity of compound turbulence indicators.

An understanding of pH impact seemed critical. Said Dooley, "Two-phase FAC is very sensitive. For example, a system pH of 9.6 can start the FAC process. A pH of 9.8 can stop and reverse it."

He then offered a brief presentation on aluminum cooling towers and jet condensers (indirect dry cooling). Operations and investigations (industry education) are following a path similar to ACCs (discussed in Day One). This time, however, "IAPWS is working on it up front and is, as one example, monitoring aluminum and iron levels." IAPWS is currently studying supercritical units with Heller Towers and jet condensers.

"We now know," Dooley continued, "that for these units we need a pH level of 8 or lower under oxidized conditions, so this is the opposite of ACCs. And we have to realize that the corrosion products (for monitoring) are soluble, not particulate."

Ongoing work will be discussed at future meetings of the group.

Film-forming agents

Paul Hattingh, Anodamine Inc, followed with the topic "Application of a film-forming agent and corrosion reduction in ACCs." Subtopic was non-toxic, OEM-compliant metal protection: A surface-active metal passivation technology for low-, medium-, and high-pressure boilers."

Visuals then clarified the process stages:

- Stage 1. Anodamine permeation through oxide to virgin base metal.
- Stage 2. Partial epitactic hydrophobicity; base metal protection.
- Stage 3. Complete oxide hydrophobicity. Protection achieved with continuous 1000 to 1500 ppb equilibrium residual. Dosage then can be reduced to maintain 800 to 1000 ppb.

Anodamine was contrasted with conventional film-forming amines (FFAs). Although research continues, some FFAs show various limitations—including trapping of inorganic contaminants and base-metal attack through under-deposit corrosion.

Specifics for Anodamine included reduced corrosion-products transport during cyclic operation, improved unit startups, and reduced operating costs. Case studies and economic examples were presented.

Discussion questions included relationships to FAC mechanisms (ongoing study), collaboration with IAPWS, and a statement of no known impact on system pH control.

Windscreen analysis

Reinforcing ongoing studies on the impact of winds, Cosimo Bianchini, Ergon Research, presented "Windscreen protection design based on CFD analysis."

As reported in CCJ 2Q/2016, p 60, wind impacts both the ACC and plant performance (power output) through degraded fan performance and recirculation of hot air into the downwind fan inlets. This presentation estimated a nominal 10% power reduction for every 10 m/s (22 mph) of wind.

Also, as reported previously in this periodical, the economic breakeven point remains uncertain for windscreen design and installation. Some gains are difficult to estimate, but performance improvements are being reported and analyzed.

Bianchini's presentation gave details on the 3D computational method; sub-models for fans, tube bundles, and screens; and expected outputs.

Case studies followed for comparison of various windscreen designs and configurations. Key elements are screen porosity and positioning. Also significant are any surrounding tanks, buildings, and geographic characteristics.

Conclusions drawn by Bianchini were that "3D CFD modeling of plant layout and components provides a reasonable and detailed estimate of the wind field around the ACC. It is now possible to verify several windscreen configurations to determine the most effective solution."

How IAPWS helps ACC owner/operators

Technical guidance documents (TGDs) have been developed by the International Association for the Properties of Water and Steam to provide advice on cycle chemistry to users responsible for fossil and combined-cycle plants. The documents, available at no cost on the organization's website at www.iapws.org, represent the accumulated experience of members of the IAPWS working group on power cycle chemistry from 24 countries.

- Monitoring and analyzing total iron in fossil and combined cycle plants (May 2014). Document details represent the consensus of 24 countries.
- Film-forming products (September 2016) received final review and approval from the two-dozen countries represented in IAPWS. Reviews included most of the chemical supply companies and most of the steam turbine, boiler, and HRSG manufacturers.
- Procedures for the measurement of carryover of boiler water and steam (September 2008) includes a technique for measuring carryover from drum boilers to assist in preventing steam turbine failure/damage.
- Instrumentation for monitoring and control of cycle chemistry for the steam/water circuits of fossil-fired and combined-cycle powerplants (September 2015) includes a table that can be used to determine the minimum level of instrumentation required for any fossil or combined-cycle/HRSG plant.
- Volatile treatments for the steam/water circuits of fossil and combined-cycle/HRSG powerplants (July 2015) includes the basis for AVT and OT for all plants, with customization for plants with ACC and using ammonia and amines. Recently added guidance is offered for fast start and frequently started HRSGs.
- Phosphate and NaOH treatments for the steam/water circuits of fossil and combined-cycle/HRSG powerplants (October 2015) covers the basis for selecting the optimum boiler/HRSG evaporator water treatment (phosphate and NaOH) for all drum plants, including customization for plants with ACC.
- Steam purity for turbine operations (September 2013) offers guidance for a wide range of turbines (fossil, nuclear, industrial, geothermal, etc) and failure mechanisms. It includes customizations for plants using amines.
- Corrosion product sampling and analysis (May 2014) covers the optimum procedures and techniques for monitoring iron and copper. A table of achievable iron levels for plants with ACCs is included.
- HRSG HP evaporator sampling for internal deposit identification (September 2016) includes the locations where to take samples from HRSGs, how to analyze the samples, and a new IAPWS map to assist in determining whether the HRSG HP evaporator requires chemical cleaning.
- Application of film-forming amines in fossil, combined-cycle, and biomass plants (September 2016) covers optimum application guidance for FFA/FFA products in all-ferrous plants. It includes customizations for shutdown/layup, multiple pressures, mixed-metallurgy feedwater systems, condensate polishing, and air cooling.

Direct-drive motors

At the 2014 ACC Users Group meeting in San Diego, Tom Weinandy, Baldor Electric/ABB, presented "Design considerations for a direct-drive motor retrofit on an ACC." He returned in 2016 with updates, discussing the prototype installations at Basin Electric Power Co-op's Dry Fork Station in Gillette, Wyo.

The basis of this multi-year work is an agreement between Baldor and Basin to supply two direct-drive ACC motors for an 18-month evaluation period (April installations 2015 and 2016).

Dry Fork is a nominal 400-MW coal-fired unit that came online in November 2011. The design includes a 45-cell ACC. Initial operations showed some significant issues:

- Motor bearing failures attributed to shaft-down orientation.
- System operations during peak season required 15% to 20% more air than could be provided with existing motors.
- Half of the gearboxes were leaking oil.
- Local wind gusts of up to 80 mph caused equipment concerns.

Dry Fork wanted a 250-hp (at 104 rpm) direct-drive design with a carrier bearing for added protection against side loading.

Weinandy began with a quick review of direct-drive technology, introduced to the cooling-tower market in 2008 with shaft-up configuration. Baldor launched its shaft-down, direct-drive ACC design in 2013, based in part on discussions at the 2012 ACC Users Group meeting in Gillette.

Considerations included more horsepower and torque, less noise, and a robust mechanical strategy to address wind issues. Weinandy provided full details, including the drive motor controls.

Retrofit installation challenges discussed included a drive-motor weight of 7679 lb but an existing trolley system rated below 5000 lb, and an increase in motor size.

Based on successful installation and operation of these prototypes to date, Weinandy stated that "it is their intention to replace the balance of the fan units with direct-drive technology." Timing is not yet determined.

OEM ACC specifications

Many questions about OEM specifications were raised and discussed at the 2015 meeting in Gettysburg, and Gary Pratt, engineering manager at Advisian/WorleyParsons, brought both pinpoint suggestions and good common sense rules to Dallas.

Pratt began with the basics: Prepare a specification that leads to an ACC that meets all codes, achieves optimal thermal performance, meets all permitting and environmental restrictions, epitomizes quality throughout, and is easy to maintain. And all at the right price—of course. He called it a balance of "infinite wants within a finite budget and schedule."

"Homework is absolutely critical," said Pratt, and we can't forget two sometimes overlooked but critical details:

1. Cycle chemistry must be part of the homework, how the ACC fits into the cycle as a whole, and. . .
2. You must consider ACC requirements for the current (and foreseen) generation of flexible and fast-start combined-cycle plants.

Pratt's credibility? He is a seasoned design engineer who communicates directly and frequently with plant owner/operators and site personnel.

Pratt quickly drew a distinction between ACCs and surface condensers. First, ACCs are more complex, with more technical scope. Second, there is less history with ACCs, and industry standards have not fully caught up with the operating experience. As an example, surface condenser standards from the Heat Exchanger Institute are in their eleventh edition. HEI standards for ACCs are in their first.

Therefore, when drawing up a specification, more responsibility is placed on both the engineer and the end user to properly specify and establish all relevant design criteria. At its highest level, the ACC specification must also cover requirements for the overall project.

Expanding, he listed the common sources of specification input:

- Design engineer knowledge and experience.
- Operating experience.
- Industry standards.
- User-group interaction and reports.
- Industry subject matter experts.
- Equipment manufacturers and suppliers.
- Construction and commissioning lessons learned.

He carefully reinforced the requirements of listing precise project communication and coordination methods, a rigid division of responsibilities, a fully loaded schedule, and logistics including inspection points, quality assurance, field testing, and guarantees.

He added specifics on terminal points, submittal schedules, drawing quality standards, approval cycles, and records retention.

On the product (OEM) side, Pratt also emphasized two general categories of requirements: Those that meet established codes and standards (building code, for example), and those more difficult to define: What the owner/operator is thinking about for best value, and the technology target that moves as user experience expands (perhaps during the contract period).

On the overall project side, Pratt pointed out several key elements—including full meteorological and topographical site data, and wind data for all seasons. Equipment location should be based on numerous factors—including wind, adjacent structures, space and height limits, and noise.

He ended with a list of current (and perhaps more difficult) topics, concerns, and ongoing developments, including:

- Motor selection: single speed, dual speed, and VFD.
- Windscreens.
- Fan and bridge vibration.
- Tube and fin materials (and cladded versus coated).
- Fans and gearboxes.

And for base awareness, he stressed two important items:

1. "Achieve clarity. If it's not written down you're not going to get it."
2. "Stay connected with the industry. Lessons learned prevent repetition of errors."

During comments and questions, Dooley suggested including IAPWS information with similar items (ASME Performance Test Codes). Interesting discussions followed on codes and other requirements that can vary by state.

Gear standard update

The Cooling Technology Institute outlined its proposed ACC gearbox standard, and requested input. CTI intends to complete a new standard that will offer reliability and minimal maintenance through:

- Robust product design specifically for ACCs.
- Proper sizing and selection.
- Proper installation.
- Best practices in operation and maintenance.

Initial meetings were held at the CTI Summer Workshop in July 2016. Attendees included three gear manufacturers, several ACC designers, EPC firms, fan manufacturers, but only one owner/operator.

Key issues addressed included gear ratings and service factors, wind effects on design, oil containment and filtration, and condition monitoring.

The update ended with an appeal for input from owner/operators. The committee chair is Craig Burriss of Amarillo Gear Co. Anticipated publication is in the first half of 2017.

9. Plumes from fog nozzles, installed to improve thermal performance, are visible for only a few feet before evaporation

Fogging enhances dry cooling

Huub Hubregtse returned to the podium and presented a case study on spray-enhanced cooling to help ACC performance during high ambient temperatures.

Some methods include wetting the heat-transfer surface (more common in Europe) but this can also cause corrosion of the tube bundles, damage to motors and gearboxes, algae on the structure and equipment, and limestone fouling when using hard water.

Fogging is often preferred. A fogging mist is released into the air flowing through the fans and tube bundles. The mist evaporates quickly, cooling the air. The only requirement is a relative humidity of around 50% to 60% (allowing evaporation to take place). The maximum quantity of water used is that needed to achieve 95% to 100% relative humidity.

Hubregtse presented a practical example using a four-cell ACC, ambient temperature of 86F, and relative humidity of 50%, referencing the Mollier diagram. Results included a boost of 2.21 MWh per day.

Also for this example, evaporation required water droplets of between 25 and 40 microns, calling for either an atomizing or a high-pressure spray nozzle system. The latter, with its large number of nozzles, is considered the most efficient.

He then reviewed, in detail, specifics on nozzles, sensors and controls, and water quality. Soft water must be used.

Hubregtse also stressed the impact on the gas turbine. "If the backpressure at the turbine exhaust reaches the trip point during high ambient temperatures, fogging can lower the vacuum enough to prevent this."

In the discussions, Hubregtse confirmed that evaporation takes place before entry through the tube bundles (Fig 9), so there is no fouling impact.

External inspection guide

In 2015, the ACC Users Group published the first draft of an internal ACC inspection guide (ACC.01), currently available at www.acc-usersgroup.org/reports. Dave Rettke brought 2016 participants up to date on the document.

His presentation discussed the guide's organization and depth. If this goes "too far down into the weeds," said Rettke, "to valves, for example, that is going too far. Valves vary by plant, and they have their own manuals. The best foundation is perhaps any external inspections discussed in OEM manuals."

10. Low-profile lifting devices are used to remove fan motor drivers and gearboxes

Areas of initial concentration are decking, steam ducting, and expansion joints. Other headings being considered are piping and hangers, tubesheets, tube washing systems, structural members, fans, and motors.

The goal of ACC.01 is to improve both safety and performance. Photos and a checklist will be included in the final document. A progress report will be presented at the 2017 meeting.

Windscreens at Caithness

The windscreens at Caithness have been reported in CCJ, most recently in the 2Q/2017 Outage Handbook issue.

Gary Mirsky, Galebreaker Industrial, reviewed the overall project and offered detailed literature references on this long-term program. "There was never a specific performance problem," he explained. "It was amperage, fans, vibrations, and motor-trip problems, all causing concerns." Motorized screens were installed, and the fans were changed from six blades to nine.

The conclusions to date, said Mirsky, are the following with the screens normally at 50% deployment:

1. Differences in back- versus front-cell air velocities are normalized.
2. Dynamic blade loading is reduced considerably.
3. Longer fan blade life is projected.
4. Measured static pressure differences are reduced.
5. Average static pressure is reduced indicating air flow increases.

The update gave an interesting perspective on what is both an expanding and analysis-driven technology.

Dry cooling research

A research summary presentation by Addison Stark, program director, Advanced Research Project Agency—Energy (ARPA-E), explained the goals of this US government initiative to help improve efficiency, reduce energy imports, and reduce energy-related emissions. Efficiency related to decreasing water availability was the topic in Dallas.

Three overriding facts were presented to support the theme of "Energy as a water problem":

1. 41% of freshwater drawn in the US is for thermoelectric power plant cooling.
2. 3% of cooling-tower water load is evaporated and dissipated.
3. Energy and agriculture are competing for the same fresh water resource.

Referencing studies that included EPRI and DOE, Stark gave these statistics for the US powerplant infrastructure (2008):

- Water cooling, 99% (cooling tower 42%, once through 43%, cooling pond 14%).
- Dry cooling, 1%. Direct air-cooled condenser dominates. Indirect dry cooling and hybrid cooling are minimal.

Stark also stated that "more stringent EPA regulations on water intake and thermal discharge will render once-through cooling obsolete" in the future.

He then addressed air versus water cooling and introduced the Advanced Research in Dry Cooling (ARID) program launched in 2015, with 14 projects, including air-cooled heat exchangers. Project teams design kilowatt-scale testing prototypes to ensure the technologies can scale up to the megawatt-cooling capacities of real systems without significant performance loss.

Discussion points included a reminder from ACC owner/operators that good theoretical developments can cause real problems and require some degree of caution.

11. Placement of ground-level screens was based on results of CFD modeling

12. Fogging system installed at Midlothian to demonstrate performance improvement increased steam-turbine output by 5.8 MW at 100F and 30% relative humidity

Midlothian Power

Terry Hiefner, engineering supervisor, Midlothian Energy Facility, Engie NA, followed with an overview of the plant the attendees would tour the next morning, and its activities. Midlothian, located just south of Dallas/Ft Worth, consists of six single-shaft, F-class combined cycles, the first of which began commercial operation in 2001. Total rated output: 1495 MW.

Hiefner concentrated on the ACCs—including maintenance activities, instrumentation, windscreens, a multi-year and multi-unit fogging project, and near-term plans for direct drives and fan conversions.

He began with the motor/gearbox/bearing assembly details, describing maintenance activities as:

- Component rigging improvements.
  - Trolley-beam south wall extensions.
  - Motor and gearbox low profile lifting devices (Fig 10).
  - Grating rigging access for fan inlet screen.
- Equipment failure history.
- Preventive maintenance summary.

Reviewing maintenance, he noted issues with the motors and gearboxes, caused largely by water ingress.

Staying with maintenance (and preventive maintenance) Hiefner highlighted schedule details. One significant item was a walkdown each (and every) shift.

Instrumentation specifics include retrofit gearbox oil-pressure transmitters tied to plant DCS (for improved monitoring), and fan cell temperature RTDs to trend fogging performance and monitor any fan stalls attributed to wind velocity or direction.

Windscreens have improved unit performance (output) and are removable for maintenance access and outage laydown. Ground-level screens (Fig 11) were placed based on CFD modeling.

Midlothian's multi-year fogging project began in 2012 when a 12-stage system, rated 600 gpm of demineralized water at 1500 psig, was installed on Unit 6 as a proof of concept (Fig 12).

The 12 levels, located below the ACC, contain nearly 18,000 nozzles in sum (1200 per fan). Variable results average a unit increase of 5.8 MW at 100F and 30% RH (ambient).

Systems were installed on Units 3 and 5 in 2013, with similar performance results.

Midlothian next investigated the placement of nozzles immediately below and above the fans, and in 2014 converted Unit 5 to a mixed system, relocating half of the nozzles immediately below the fans and a separate lower-pressure arrangement (500 psig) above the fans.

Expectations were a 6-MW boost in output, 3 MW from fogging below the fan, 3 MW from fogging above the fan. Actual results with nozzles below and above the fan in operation: 4.5 MW below and 1.5 MW above. The hybrid system improved unit performance at 100F and provided "significant cooling" of 20 deg F.

In 2015, the below-fan nozzle design was implemented on all remaining units. The overall fogging program now includes 90 ACC fans, 180 pumps, and 67,500 nozzles (750 per fan).

The next significant ACC program at Midlothian will be a direct-drive/Hudson fan conversion by Industrial Cooling Solutions (ICS). Attend the 2017 meeting for a progress report.

Meeting participants visited the plant the next morning. As recapped by Andrew Howell, "Plant Manager Mike Knisley and his team went all-out to describe and show their ACCs, including operation of the spray-misting system, for our observation." CCJ

Protect equipment against corrosion with neutralizing amines, filming products

By **Mike Caravaggio** and **Steve Shulder,** Electric Power Research Institute

Amines—both neutralizing and filming, as well as proprietary filming products—have the potential to reduce corrosion in heat-recovery steam generators (HRSGs), condensers, and steam turbines in combined-cycle plants, and provide offline protection.

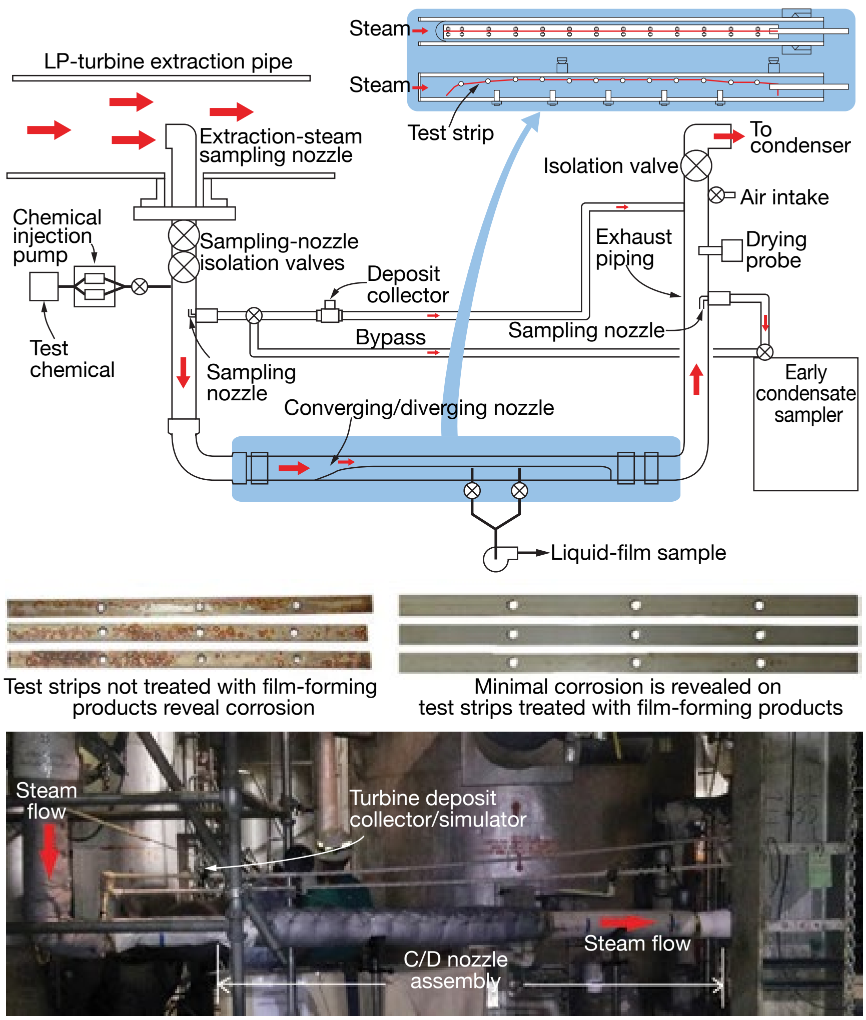
However, until recently, little independent information has been available on these chemicals for powerplant applications. To understand how amines and filming products work and to effectively apply them, the power industry needs independent research and proven treatment guidelines for proper application.

Neutralizing, organic-based amines have advantages over ammonia treatment for corrosion control in two-phase environments because of their better dissociation and distribution properties, resulting in a higher at-temperature liquid-phase pH. These advantages have been demonstrated in the nuclear industry for improving corrosion control in reheat moisture separators.

Similar improvements have been noted, in some cases, in corrosion control of water- and air-cooled condensers in fossil applications. Nonetheless, while neutralizing amines may have benefits in these environments, they can also have a negative impact if the product breaks down too quickly.

Filming (or film-forming) amines and products also have advantages in corrosion control over traditional treatments. Through the formation of hydrophobic films on internal steam/water surfaces, they can disrupt corrosion cells. However, questions remain regarding their powerplant applications.

For example, while filming has been demonstrated in field applications on boiler waterwalls and in superheat and reheat tubing, it has not been demonstrated for steam turbines, although a side-stream low-pressure (LP) phase transition zone test loop (Fig 1) has indicated significant protection when subjected to contaminant addition.



1. Test loop simulates LP-turbine expansion using a converging/diverging (C/D) nozzle (top). Results indicate filming amines and products can offer significant corrosion protection against contaminants as shown by the two sets of test strips (middle) . Photo of the test setup is at the bottom

Also, although filming amines and products have been shown to form hydrophobic films that are anticipated to inhibit corrosion, the level of this corrosion inhibition has not been quantified for known offline and online tube corrosion mechanisms in conventional boilers and HRSGs.

Moreover, the minimum concentration of filming amines or products and the application duration for various filming agents to achieve a protective film under various powerplant conditions are

not well established. Variables such as makeup rate, unit configuration, unit cleanliness, and feedwater component metallurgy have all been demonstrated to have a significant effect.

Conventional powerplant chemistry monitoring techniques are incapable of evaluating whether film formation has occurred, significantly complicating continuous control and optimization of filming-amine- or filming-product-based treatments. Additionally, variations in filming-amine and filming-product formulations mean no single analytical technique is available for evaluating the presence of the chemicals in water and steam samples.

In the future, the requirements for corrosion protection in power cycles are expected to increase as plants cope with the demands of increasing cycling operation, low-load operation, and extended layup protection. Exclusive use of ammonia might be inadequate to meet these future challenges. Judicious investigation is needed of alternative treatments—such as amines and filming products.

In recent years, the Electric Power Research Institute (EPRI) has tried to fill the gaps in information on amines and filming products in powerplant applications by conducting an ongoing series of research studies. They are aimed at building a body of knowledge on a broad range of aspects of these chemicals and compiling that information into comprehensive treatment guidelines.

This article provides some background information and highlights of that research.

Amines and filming products

Amines are a large class of organic compounds. Those that may be applied for chemistry- and corrosion-control purposes come under two broad categories: neutralizing and filming. In addition, some filming products are available that are not necessarily based on amines.

Neutralizing amines (such as dimethylamine and ethanolamine) behave in much the same way as ammonia, reducing the solubility of iron oxides by increasing the pH of the condensate, feedwater, or evaporator/drum water. Neutralizing amines have been commonly used as alkalizing agents for feedwater treatment since the 1950s. Their role in the steam/water cycle is understood from the standpoint of their physical and chemical properties (dissociation, distribution, and decomposition). Dissociation and distribution are equilibrium related; decomposition is permanent.

The properties of some neutralizing amines have the potential to improve the pH conditions in HRSG LP and HP evaporators and economizers, the phase transition zone (PTZ) of the LP steam turbine, the condensing steam in wet- and air-cooled condensers, and the pH conditions at any other two-phase flow locations.

The potential to improve pH in these environments arises from lower volatility to improve distribution of the amine to the liquid phase in low-pressure applications and higher basicity caused by higher dissociation of the amine, resulting in higher pH at operating temperatures compared to ammonia.

A potential limitation of neutralizing amines is that they may break down into organic acids at high temperature in fossil-unit steam and actually give rise to a lower pH than with ammonia alone.

Filming amines and products provide corrosion protection by forming a physicochemical barrier between the metallic surfaces and the working fluid (water) to prevent corrosion from occurring. Filming amines and products can also provide a film on the steam-touched surfaces and offer protection against oxygen pitting when units are offline and exposed to humidified air or water formed via condensation.

The term "filming amines" denotes not just one chemical but a family of chemicals that is relatively broad and diverse. A filming amine can have a primary, a secondary, or a tertiary amine structure or a combination of these functionalities attached to any number of hydrocarbons greater than 10.

In many cases, the vendors of modern filming-amine formulations do not provide a detailed definition of the specific chemical structures for this class of materials. Filming amines generally are formulated with one or more neutralizing amines to maintain their stability. Such combination amines normally increase pH in addition to establishing a protective film. Some filming products currently on the market may not be based on an amine chemistry. "Filming products" typically do not include a neutralizing amine in the product and just consist of a proprietary filming chemical so they do not influence pH.

Filming amines and products can be used in continuous feeding mode to reduce iron corrosion, or short-term for preservation of idle equipment during layup. Continuous feed and layup protection are the primary applications in fossil plants.

Filming amines and products have to be applied with sufficient time and concentration to provide a protective film on all metal surfaces. The larger the unit or surface area the longer it will take to provide protection. Because this is an equilibrium reaction, a sufficient "active" residual must be maintained throughout the steam/water cycle.

Unfortunately, there are currently no independent methods to measure the active residual of commercially available products. Overfeeding of filming amines should be avoided to minimize the potential for fouling online instrumentation and the formation of "gunk balls" (gelatinous spheroids). Careful attention also should be paid during the initial application for the possible release of anions trapped within deposits, often referred to as "cycle clearance."

State of knowledge on filming amines

In 2015, EPRI's "State of Knowledge on Film-Forming Amines" (Product ID: 3002003678) compiled current EPRI and publicly available information on film-forming amines in conventional fossil and combined-cycle plant steam- and water-cycle applications. This report does the following:

- Establishes the state of knowledge with respect to filming amines for steam- and water-cycle treatments in powerplants.
- Contains information on filming products in addition to amines. Focus is on filming amines because more independent research has been done on them.
- Provides detailed information on the chemistry of filming amines, (1) their mechanism of action, (2) volatility in steam and water cycles (distribution), (3) thermal stability in steam and water cycles (decomposition), (4) dissociation and impact on pH and conductivity, (5) requirements for chemical addition, (6) beneficial corrosion prevention/reduction effects throughout the cycle (by component/damage mechanism), and (7) negative effects throughout the cycle (impact on cation conductivity, ion-exchange resin, and instrumentation).
- Recommends where research and application knowledge are needed to facilitate the adoption of filming amines as a power-cycle treatment.

Monitoring of amines, filming products

Ongoing EPRI field studies are investigating the monitoring and control requirements to achieve corrosion control when applying commercially available neutralizing amines, filming amines, and filming products on

a continuous basis in conventional fossil and combined-cycle plant steam/water cycles.

The studies aim to determine what monitoring is required to achieve optimal corrosion results in plants applying amines or filming products. For plants using neutralizing or filming amines or filming products, pH control based on measurements at 25C (77F) may be insufficient to determine the optimal corrosion-control conditions. The studies are attempting to assess this situation and outline a path toward corrosion optimization for plants applying these chemicals either in isolation or in combination.

For neutralizing amines, field studies on corrosion optimization are being conducted at several combined cycles. Work includes sample collection from available monitoring locations in the steam/water cycle. Analysis of grab samples includes cations (sodium, ammonia, and neutralizing amines), anions (chloride, sulfate, acetate, and formate), total organic carbon, and suspended iron.

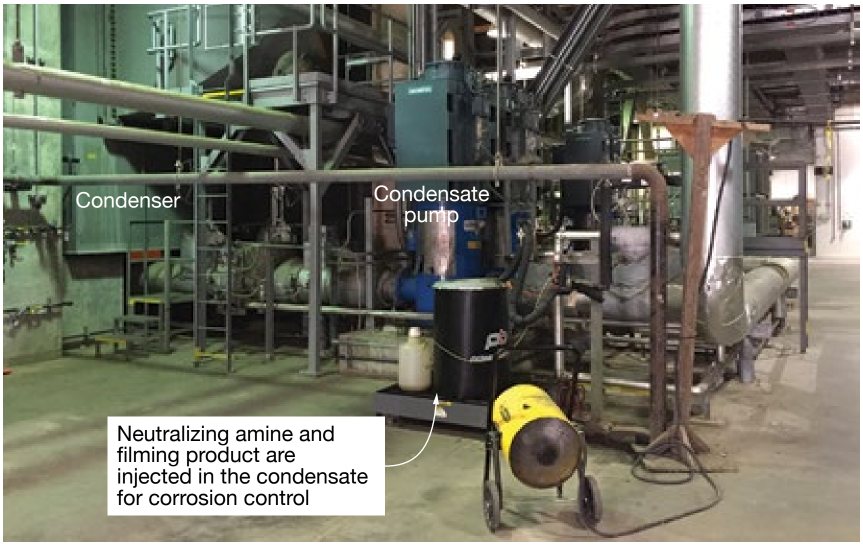
The participating powerplants are applying treatments that include neutralizing amines. The application of these treatments is being optimized through field-work analyses. Optimized corrosion product transport results for iron have been less than 1 ppb in the condensate/feedwater and evaporator circuits.

Results to date indicate that, for neutralizing-amine treatments, the conventional corrosion-control parameter of pH measured at 25C does not correlate well with iron corrosion product transport. Analysis of the calculated at-temperature pH using EPRI's MULTEQ (MULTiple EQuilibrium) program shows better correlation and is being used in corrosion-control optimization activities for the neutralizing amines. EPRI also has identified a control process using conventional online chemistry monitoring.

The study and its latest findings are described in the report "Neutralizing Amine Application for Continuous Service in Fossil Plants and Heat Recovery Steam Generators" (3002006356).

An ongoing project complementing this work has designed and installed a pH monitoring system that splits a fully condensed sample into a two-phase mixture for controlling a neutralizing amine treatment.

The project is evaluating whether the split-sample pH can be used to determine if the combined impact of a neutralizing amine treatment and its breakdown products are improving or having a detrimental impact on the at-temperature two-phase pH under operating conditions and how this relates to iron corrosion-product release rates.



2. PSEG's Bethlehem Energy Center began applying an ammonia and neutralizing amine blend in 2012. A filming amine was added to the mixture in 2015

For filming amines and products, EPRI research is seeking to develop electrochemical techniques used for evaluating corrosion inhibition on a continuous online basis. In the future, it is anticipated that a prototype field probe will be available for installation at a powerplant applying a filming amine or product treatment, and that a field trial will allow for evaluation of the probe as an online continuous monitor of film integrity that can be used for treatment optimization.

Ultimately, this work will allow for independent monitoring of film formation of different filming amines/products and provide a tool for owner/operators to begin optimizing these treatments.

Corrosion control in the PTZ

For turbines, offline periods can result in pitting corrosion, which might lead to corrosion-fatigue and stress-corrosion-cracking failures during operation. With increased power generation from renewable sources and more stringent environmental legislation, both conventional and combined-cycle plants are running in a more flexible mode, with more frequent cyclic/low-load operation, seasonal operation, and shutdowns.

The chemistry of the steam prior to a unit shutdown can have a significant impact on the formation of pits and the pitting rate. Adding a filming amine or product could be effective in mitigating or preventing these damage mechanisms.

An ongoing EPRI project aims to determine whether filming amines and products can be used to significantly reduce the risk of corrosion and damage in the steam turbine-phase transition zone (PTZ) of LP turbines during and after a steam-chemistry excursion with elevated levels of chloride and sulfate.

The resulting data are being used to quantify the risk or benefit compared to conventional steam chemistry from a previous study where neutralizing amines were used and ammonia was added for feedwater pH control.

To date, the project has established the ability of the four commercially available filming amines/products to substantially reduce corrosion when subjected to non-optimal steam chemistry conditions and elevated anionic constituent levels compared to the use of ammonia for pH control. Additional testing is being performed to determine if filming products may reduce corrosion on previously pitted specimens. Current testing with the commercially available filming amines/products also has indicated a substantial reduction in corrosion.

The project and its findings are described in the report "Control of Corrosion in the Steam Turbine Phase Transition Zone (PTZ) Using Filming Amines" (3002006103).

Quantifying corrosion improvement

The power industry has had difficulty quantifying the corrosion improvement of filming amines and products by materials of construction, because of the confluence of uncontrollable variables present in field applications. As a result, plant operators need tools to assist in quantifying—across the range of commonly used materials—the corrosion inhibition of different filming amines and products under powerplant conditions, and in quantifying

the impact of water chemistry on the ability of filming amines and products to inhibit corrosion.

For powerplant feedwater, an EPRI study plans to quantify the effectiveness of filming amines and products in reducing the general corrosion rate of carbon steel and admiralty brass. First phase of the study was a proof-of-concept trial in a laboratory setting to evaluate the feasibility of using an in-situ electrochemical corrosion probe to measure corrosion rates in simulated feedwater. The research will examine the effect at various temperatures typically experienced in the feedwater systems for a variety of test solutions that would be expected in plants applying a filming amine or product treatment.

Test coupons of carbon steel and various copper alloys will be immersed in flowing solutions with a fixed residual concentration of the filming amine or product and fixed chemistry parameters (hydrazine, oxygen, and pH levels, for example) at elevated temperatures. Corrosion rates will be determined under these defined conditions. Success in the laboratory may lead to implementation of a corrosion probe for these systems at power stations.

The research and its findings are described in "Effect of Filming Amines in Steel and Copper Alloy Corrosion" (3002006101).

For powerplant boilers, EPRI studies will take a dual approach to assess the corrosion protection provided by filming amines and products in field applications. The first approach has been to develop laboratory tests for evaluating corrosion protection afforded by films on boiler (waterwall and superheater/reheater) tubing under simulated offline conditions and online conditions. These tests are being used to evaluate tube samples collected from plants applying filming amines and products for the level of corrosion protection achieved.

An additional laboratory test is being constructed to evaluate the effect of filming amines and products on corrosion fatigue. The second approach: Continue to collect case-study information with regard to the rate of corrosion-fatigue and stress-corrosion-cracking failures in fossil plants susceptible to those problems—both before and after the application of filming amines or products.

Case study

Limited documented cases exist about the effectiveness of filming amines for corrosion control. A recent EPRI report, "Filming and Neutralizing Amine Application for Continuous Service in Fossil Plants and Heat Recovery Steam Generators" (3002007937), provides a case study documenting the experience of a 3 × 1 combined-cycle plant that implemented use of filming and neutralizing amines for improved corrosion control in its steam and water cycles.

The plant featured in this case study is PSEG's Bethlehem Energy Center, in Bethlehem, NY. It is equipped with three 160-MW gas turbines and a 300-MW steam turbine. All three HRSGs are triple pressure with feed-forward LP drums.

Initially the plant operated on an all-volatile treatment with ammonia in the condensate/feedwater as well as in the three evaporator sections of the HRSGs. However, the plant was incapable of optimizing chemistry control with ammonia alone. In 2012, it began applying an ammonia and neutralizing amine blend (Fig 2). In 2015, Bethlehem continued to refine the chemistry treatment with the addition of filming amine.

The case study documents both chemistry and iron corrosion-product analysis results. It analyzes these data versus the known iron corrosion mechanisms in a combined-cycle steam and water cycle. These numbers are both less than those for the ammonia/neutralizing amine blend and the ammonia/neutralizing amine/filming amine blend.

Additional ongoing research

To further the understanding of filming amines/products, EPRI is conducting research to determine the influence of the products on deep-bed condensate polishers and online instrumentation used to monitor cycle chemistry. A recently released report, "Filming Product/Amine Impact on Condensate Deep-Bed Resin Polishers" (3002008140) reviews the influence of these products on polisher resins.

Laboratory testing is being conducted to assess the ability of filming amines/products to minimize single- and two-phase flow-accelerated corrosion and to mitigate corrosion damage in ACCs. Testing also is being conducted to evaluate the ability of ion chromatography to provide an independent method to measure the active residual of these products in the steam/ water cycle. CCJ

Mike Caravaggio, EPRI's senior program manager for major component reliability, can be reached at 704-595-2589 and mcaravaggio@epri.com; Steve Shulder, program manager for boiler and turbine steam and cycle chemistry, at 704-595-2953 and sshulder@epri.com.

Beware hidden superheater, reheater overheating

By Natalie Marini, HRST Inc

HRSG superheaters and reheaters are vulnerable to overheat damage that is not detectable from data typically monitored in the control room. Damage can occur even if the steam temperatures entering and leaving the attemperators and exiting the HRSG are within limits.

Stealth changes in HRSG operation, maintenance, and performance can drive overheat damage. Examples encountered by HRST engineers include the following:

1. Duct burners firing harder and longer than ever before.
2. Gas turbine (GT) upgrades that increase exhaust temperature, elevating tube metal temperature.
3. Original designs with very small margins between the predicted operating temperatures and the maximum design limits, significantly reducing remaining life.
4. Duct-burner-system mechanical degradation causing localized downstream high-temperature zones.
5. Removal of troublesome gas baffles, resulting in hot bypass gas that increases downstream heat transfer.

Example 1. Duct burners are firing harder because of low natural-gas prices and changes in market demand. When the burners run longer and harder, problems previously believed minor can turn into much larger ones. With frequent firing, overheating damage occurs much more rapidly. Long flames, inconsistency in flames from one side of the duct to the other, and poor distribution of exhaust flow are all common issues that can have damaging effects.

Example 2. The highest superheater and reheater tube metal temperatures in the first tube panel commonly occur during low load, unfired operation. In past analyses of the effects of GT upgrades on HRSGs, HRST engineers have found that the tube metal temperature during operation was already within a degree or two of its design limit at low-load operation—before the upgrade (Fig 1). Gas turbine upgrades change the exhaust gas flow and temperature entering the HRSG. A small increase in temperature may not seem like a big deal, but a 20-deg-F change in tube metal temperature can reduce remaining life by 50%!

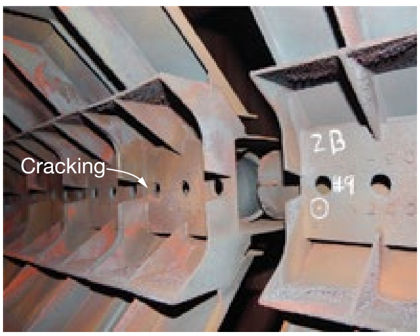
Example 3. In some situations, the OEM's original tube-metal-temperature design limit does not represent the maximum temperature a bundle should be allowed to operate at for prolonged periods. When tubes operate at temperatures approaching the upper limits allowed by the ASME Boiler & Pressure Vessel Code for that material (for example, using SA213-T91 tubes at temperatures approaching 1200F), internal oxide formation can significantly shorten tube life. When

HRST Performance Pro - Active Case Maximum Metal Temperatures

Customer name:	Calc Date: 12/29/2016 9:55 AM
Description: CT Upgrade	By: NMarini
Customer Ref:	HRST Ref:

Module Name	Default	Base Load Unfired	Low Load Unfired	After Upgrade Base Load Unfired	After Upgrade Low Load 1	After Upgrade Low Load 2
HPSH1	1,084	1,082	1,096	1,084	1,112	1,096
RH1	1,081	1,079	1,089	1,084	1,131	1,089
RH2	1,037	1,034	1,031	1,037	1,023	1,031
HPSH2	1,010	1,005	963	1,001	928	963
HPSH3	930	927	916	926	903	916
RH3	924	919	900	918	887	900
HPSH4	828	824	818	823	810	818
HPEV1a	357	359	334	359	331	336
HPEV1b	319	323	299	324	297	300
HPEV1c	300	306	282	336	281	283
HPEV2	289	293	273	294	272	273
IPSH	535	543	506	645	506	506
HPEC1	532	536	506	637	506	507
LPSH	512	516	487	618	488	488
HPEC2	502	503	484	604	485	484
IPEV	262	265	254	266	254	254
HPEC3	394	405	388	437	391	389
IPEC	390	400	378	401	381	379
HPEC4	371	380	368	392	372	369
LPEV	234	238	231	238	231	231
LPEC	273	297	272	297	269	272

1. Performance Pro™ modeling software predicts what tube metal temperatures will be after a gas-turbine upgrade. Red tint identifies metal temperatures above recommended design limits



2. Deterioration of duct-burner baffles and runners can cause excessive downstream temperatures

3. Troublesome gas baffles should be repaired or replaced, not removed. Latter can lead to downstream overheat failures

COMBINED CYCLE USERS GROUP

Seventh Annual Meeting

Sheraton Grand at Wild Horse Pass, Chandler (Phoenix), Ariz

August 28-31, 2017

Please mark your calendar and plan to attend

Registration opens in April at www.ccusers.org

The CCUG Steering Committee invites your input for the group's Seventh Annual Meeting. Here are some of the ways you can participate and make your attendance more productive:

- Suggest a topic for inclusion in the program.
- Make a short presentation on best practices, lessons learned, HRSGs, control systems, plant outage management, diagnostics and prognostics, knowledge management, training, safety, employee retention, fuel systems, emissions control, heat rejection systems, etc. Can be 5, 10, or 15 minutes, or longer.
- Bring a thumb drive to the meeting with a couple of photos describing a problem at your plant and ask your fellow users for suggestions on a solution. Think of this clinic as free consulting by those who walk in your shoes.

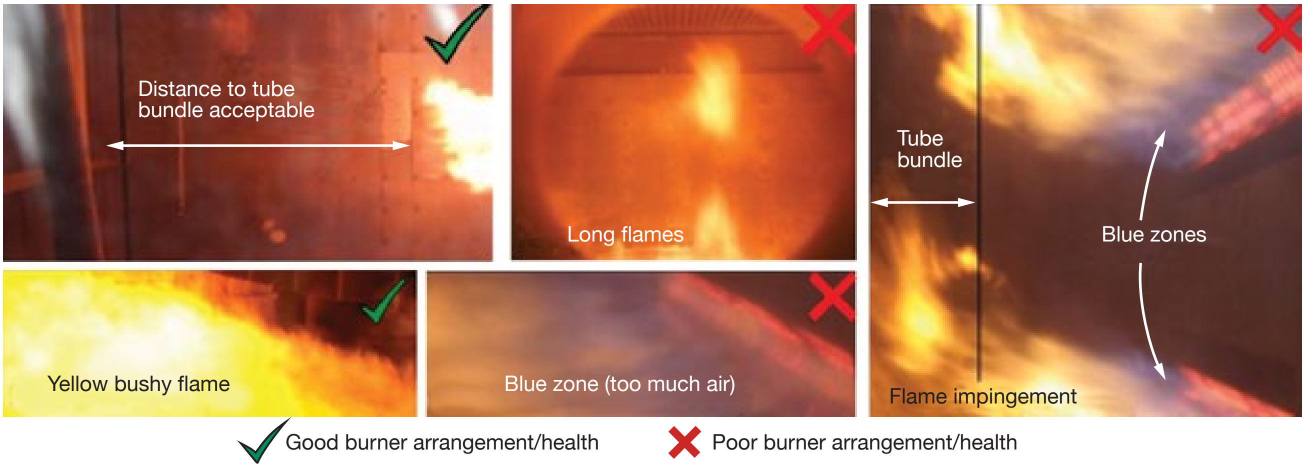
The CCUG Steering Committee

Top row (l to r): Dr Robert Mayfield, *Tenaska Inc;* John Baker, *Riverside Public Utilities;* 2016 Chair Steve Royall, *PG&E*

Bottom row: Jimmy Daghlian, *NV Energy;* 2016 Vice Chair Phyllis Gassert, *Talen Energy*

Camera shy: Brian Fretwell, *Calpine Corp*

Email Vice Chair Phyllis Gassert (phyllis.gassert@talenenergy.com) with your thoughts/ideas today.



4. Online inspection through viewports can determine flame length, color, and shape

internal oxide forms, tube metal temperatures increase, further reducing the expected tube life.

Example 4. In many HRSGs with duct burners, the baffles support the runners. As duct burners age, the baffles and runners may deteriorate and sag (Fig 2). Circumferential cracks can form in the runner, initiating at the fuel nozzles, and occasionally the runner may even split in two. The result is a flamethrower effect where the pipe has failed. In those cases where the pipe crack only goes around a portion of the runner's circumference, a gap can open at the crack, resulting in a large flame facing downstream. This can cause localized overheating of the downstream tubes.

As prevention, annual duct-burner maintenance may be necessary to preserve the strength of the burner baffles and elements. If the duct burner is in a poor condition with buckled baffles and crack indications seen around the fuel pipe nozzles, reinforcements can be installed to strengthen the failing system and prolong life.

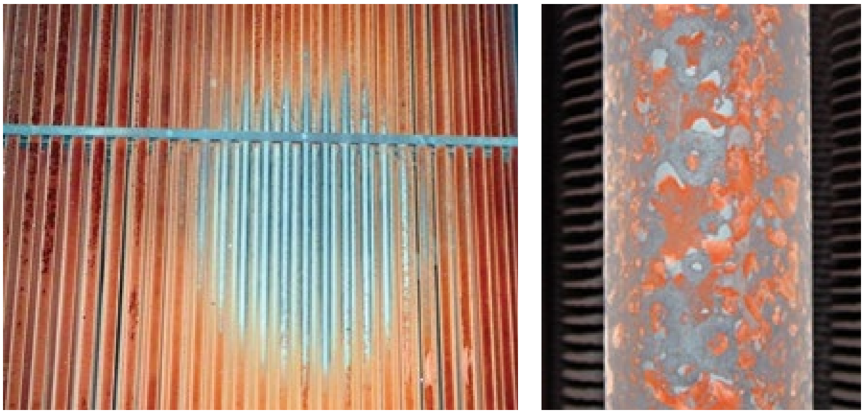
Example 5. Coil-to-coil baffles in the tube bundles upstream and downstream are also important components of a healthy HRSG. Large gaps between upstream tube bundles affect the exhaust-gas flow distribution at the duct burner, and can cause burner flame problems. Large gaps between the tube bundles downstream of the burner allow hot gas from the firing duct to reach downstream tubes not designed to handle the elevated temperatures.

Fig 3 shows a past inspection where a site experienced an overheat failure in a rear tube adjacent to the center gap downstream of the duct burner. The owner/operator had removed the failing gas baffles a few years prior to the failure.

Detailed inspections are vital to identifying causes of potential overheat and avoiding problems. During online inspections, looking into burner view ports can be very telling (Fig 4). A good flame length is one that typically extends no more than one-half to two-thirds the length of the firing duct. Flames should terminate several feet upstream of the tubes. A bright yellow, bushy flame is ideal. Long skinny flames licking the tube bundle drive up local tube temperatures, often above design limits.

When performing offline inspections, examine duct-burner baffles and runners for signs of ageing to plan preventive maintenance. Failed stitch welds, sagging elements, crack indications along fuel-pipe runners, and buckling baffles all should be addressed.

Standing from the floor looking up in the burner duct, discoloration of the tube bundle that aligns with burner-element elevations often indicates localized overheating (Fig 5). Flaking or exfoliated tube material also is an indicator. Flaking tube material can be seen in these localized zones as well as in the upper and lower crawl spaces at the header connections (Fig 6). If scale is forming on the outside of the tubes, it is most likely forming on the inside as well, particularly with grade T91, T22, and T23 materials.



5. Overheat zone is clearly visible on panel at left; impact of overheat on tube internal surface is at right

Internal oxide growth decreases the internal heat transfer and causes the tube metal temperature to increase, while simultaneously reducing tube wall thickness. The increased metal temperature reduces the creep strength of the material and the thinner tube wall increases the stress. The combined effects shorten tube life significantly.

Exfoliation of internal scale also can damage downstream equipment—including the steam turbine. If superheater or reheater overheating indications are found, a borescope inspection can check the tube internal condition. The HP and/or IP sections of the steam turbine also can be inspected to look for solid particle erosion caused by oxide exfoliation.

Superheater and reheater tubes are cooled by steam flow. If steam flow is upward in the bundles just downstream of the burner, then the highest tube metal temperatures are most likely to occur near the roof. This can be exacerbated by long flames at the top of the firing duct attributed to poor distribution of exhaust flow.

If damage indications near the top

6. Oxide exfoliation of tube external surface is clearly visible at left, internal surface (via borescope exam) at right. Exfoliation is an indicator of overheating

7. Scaffold at left is prepared for duct-burner baffle-reinforcement at right

are seen from the floor, then close-up inspection of the upper elevations may be warranted. Emerging drone inspection technology may be useful at this location, to avoid the steep cost of scaffolding.

Signs of overheat found? How to prevent further damage and determine the remaining life of the material? If any signs of overheat are in evidence, there are a few options available to assess tube-panel condition and determine the reduction in creep strength and remaining life of the material. A remaining-life assessment is recommended.

Inspection of the area of concern may include tube OD measurements, borescope ID inspection, and evaluation of fin condition. Tube-metal thermocouples can be added to the areas suspect to flame impingement to measure the effective tube temperature. From this, creep damage can be calculated and used to estimate the life of the equipment. Keep in mind that accurate measurements using thermocouples can be a tricky feat and proper planning and engineering are required.

Fins can be removed in the affected zones and in-situ internal oxide thickness testing can be performed. This is a UT technique and can be an effective method for evaluating the extent of tube damage.

Tube samples taken in the area of flame impingement can be assessed for creep damage.

The HRSG should be evaluated based on the new operating envelope any time a GT upgrade is planned. This can identify possible overheating beforehand, as well as other potential problems. A computerized thermal model of the HRSG can be used to set a range of acceptable firing limits and other operating parameters post-upgrade.

The duct burner should be inspected and maintained regularly by identifying and reinforcing sagging baffles, particularly with designs in which the baffles support the burner elements (Fig 7). Cover any large bypass gaps in the tube bundles with baffles.

In summary, combining longer firing hours with an aging HRSG fleet, a mix of GT upgrades, deteriorating duct burners, and tube-bundle gas-baffle failures, and you get the trending uptick in superheater- and reheater-tube overheating. Minimize long-term damage, possibly prevent it, by using thermal models to evaluate the effects of upgrades, plan maintenance in advance, and arrange for routine inspection of duct burners. Where signs of overheating are identified, have confidence that there are ways to mitigate the damage and extend remaining life. CCJ

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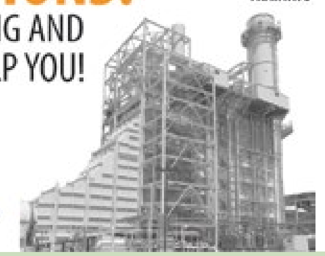

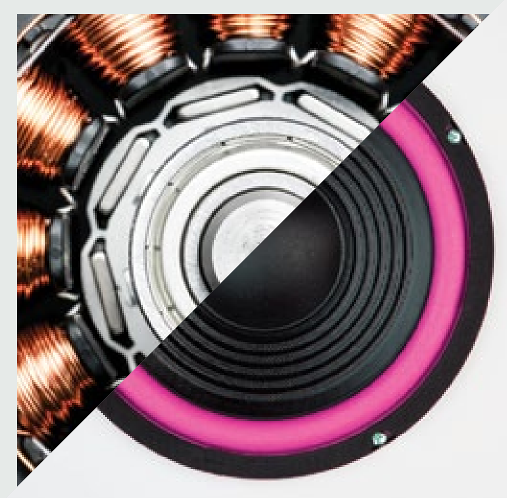


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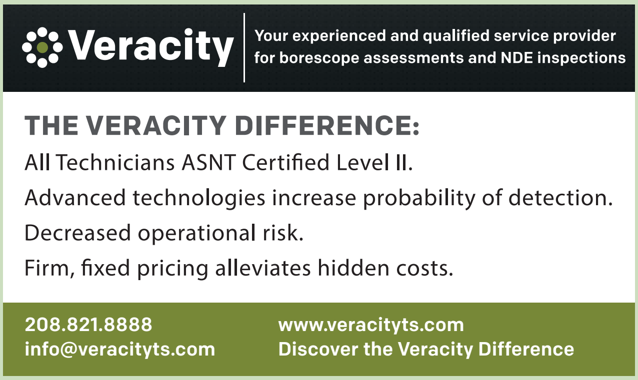
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Ten years ago, or so, in most areas of the country it didn't much matter how long it took to start up a steam turbine. The majority of those units were in baseload service, or nearly so, with fewer than about a dozen starts annually. Transitioning to the new world of competitive generation and must-take renewables, and their demands for daily start/stop, fast ramp, and other operating capabilities for which most steamers were not designed, has not been easy.

Attend meetings of the Steam Turbine Users Group (www.stusers.org) and you'll see first-hand what your industry colleagues are doing to remain competitive. Control-system upgrades that include both automated starting and shutdown, and heating blankets ("Steam-turbine warming blankets enable faster starts," 3Q/2015, p 92, photo below), have eliminated cold starts at many plants and reduced start times by as much as 50% in some cases, more in others ("Downtime duration dictates different 'agility' decisions," 1Q/2016, p 60).

Attendance at meetings of the user group supporting your plant's steam-turbine (ST) and balance-of-plant (BOP) control systems also is recommended: Refinements are ongoing and it's important to know what's worth the investment in time and money and what might not be.

At the last meeting of the Ovation Users Group (www.ovationusers.com) the editors sat down with engineers from conference host Emerson Automation Solutions to understand better how they help turbine owner/operators build more flexibility into their operations and improve plant performance to competitively and profitably satisfy changing load demand and cycling requirements.

The company's extensive BOP experience, they said, shows that for power blocks experiencing heavy cycling, it's critical to look at the complete operational cycle from shutdown back through startup to drive maximum performance. Understanding the latest controls methodologies for applying targeted automation and advanced control strategies can help sites achieve quantifiable and sustainable combined-cycle efficiency improvements.

The first step in this process requires the site to understand the plant's current operating performance, relative to the fleet, to determine if and where there are opportunities for improvement. Developing and leveraging a "matrixed database" of the combined-cycle sites in the US to establish the baseline performance against which all sites with equivalent equipment can be measured provides important insight into the world of the frequent startup and shutdown process. This can be done in several ways.

One method involves collecting relevant historical operating data from the DCS or other historian and then manually calculating key performance metrics—if historian data are available and dead bands are sufficient—such as the fuel burned, start time expended, or emissions generated to complete a specific segment of an operation or process.

This information helps answer questions like these, faced daily by owner/operators:

- What is the optimum shutdown load path I can use to plan tomorrow's unit release or are there steps I can take to ensure my restart tomorrow will be *hot* based on my projected release time?
- How much fuel or time does it take to develop floor pressure in the drum and how much NO_x was emitted during that time?
- What are those same values measured from gas-turbine (GT) start to synchronization?

Given ongoing O&M pressures and the limited resources of most power generators, a better option might be to have the control-system vendor write logic directly into the DCS that automatically calculates and reports on critical startup efficiency parameters.

The raw data are there, it's just a matter of extracting them in a meaningful way. Trying to replicate these data at the corporate historian level often results in some loss of integrity because of data compression and archiving techniques. This effort requires a highly structured process and close collaboration between the DCS vendor and the site.

DCS-integrated

A10 steam turbine has heating blanket to enable fast starting dynamic performance metrics serve to benchmark current power-block performance and support evaluation of opportunities for improvements. Additionally, they are later used to track and document actual improvements as the optimization project progresses.

Data collected then are used to develop accurate models of the complete operational cycle, from the beginning of shutdown back through startup. The development of these process models provides the most accurate picture of the dynamic process capabilities and allows for the mathematical solution of optimal loading paths.

Through this process, the Emerson engineers said, they have found that effectively managing the process energy state on shutdown can have a significant impact on the fuel necessary to restart the process. Achieving this demands coordination among all major control areas such as heat-recovery steam generator (HRSG), BOP, ST, and GTs.

Once the optimized startup and shutdown processes are validated (and statistically significant variables identified) using the developed models, the next step is to focus on minimizing variability through increased task automation to reduce dependency on personnel to perform "routine operations."

This typically includes modifying start times and loads, automating load control, coordinating loading of GTs and ST, and subsequently reducing thermal stress (through predictive temperature control) in the HRSGs and steam turbine/generator. Using advanced control and automation strategies (model-based and predictive technologies) that holistically control the site's mass energy balance will minimize energy losses and maintain the process within engineering constraints.

There is no silver bullet for improving combined-cycle plant performance, and while each site is the expert on its process, the Emerson team encourages power generators to consider the multi-discipline approach available from industry experts knowledgeable about optimization.

Successful vendors adhere to a highly structured process to identify opportunities for improvement, the participants said, and then select targeted automation and advanced control applications. Implementing the optimal combination of these tools can provide significant benefits—including improved startup time, reduced emissions, improved unit stability, and increased ramp rate—all while justifying the project financially based on reduced fuel consumption and fewer trips. CCJ

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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.

RMS Energy

Performs all aspects of isolated phase bus duct maintenance, inspections, removal, installations, retrofitting and testing. Services also include cutting, aluminum and substation welding, transformer termination compartment removal, and provision of replacement parts.

Rotating Equipment Repair Inc

Specializing in high pressure multi-stage boiler feed pumps, RER provides its customers high quality engineering services, repairs, and parts for centrifugal pumps through the utilization of highly skilled professionals, cutting-edge technology, and proven work methodologies.

Sargent & Lundy

Provides complete engineering and design, project services, and energy business consulting for power projects and system-wide planning. The firm has been dedicated exclusively to serving electric power and energy-intensive clients for more than 120 years.

Siemens Energy

A leading global supplier for the generation, transmission, and distribution of power and for the extraction, conversion, and transport of oil and gas. Leadership in the increasingly complex energy business makes it a first-choice supplier for global customers. Known for innovation, excellence and responsibility, company has the answers to the sustainability, flexibility, reliability, and cost challenges facing customers today.

SSS Clutch Company

Clutches enable operators to disconnect generators from simple-cycle turbines for synchronous-condenser service. Clutches also find application in CHP plants and in single-shaft combined-cycle facilities where operating flexibility is beneficial.

Strategic Power Systems

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

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.

SVI Dynamics

Engineers and supplies gas-path solutions for power and process applications including inlet/exhaust system upgrades, silencer repairs and retrofits, gas plant hot-gas-path inspections, and fleet-wide gas-path maintenance.

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.

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.

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.

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 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.

World of Controls

Worldwide, low-cost provider of DCS circuit boards offering an array of ancillary services which include testing/repair of circuit boards, parts, DCS troubleshooting, Dos support, HMI upgrades/backup and field-based mechanical and controls training.

Young & Franklin

Premier fuel control supplier for combustion turbines for both long-term hydraulic solutions and, more recently, innovative all-electric controls solutions. Product scope supports natural gas, liquid, syngas, and alternative fuels as well as providing air controls to provide proper fuel to air mixtures.

Zokman Products

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

Amman East

Amman East Power Plant

AES Jordan PSC

370-MW, dual-fuel, 2 × 1 combined cycle located in Al Manakher, Jordan

Plant manager: Meftaur Rahman

Moving platform improves safety during unloading of oil

Challenge. Amman East, a 370-MW combined cycle powered by two dual-fuel Ansaldo Energia AE94 gas turbines and located near the Jordanian capital, relies heavily on oil today. The "political situation" in Egypt interrupted the plant's gas supply in 2011.

About 30 to 36 tanker trucks are received daily at Amman East's six-vehicle unloading bay. A necessary step in the unloading process is the need for a contractor to climb up on each truck to open its top hatch, thereby creating a fall hazard from a significant height. A full body harness with static lifeline was the original method of assuring personnel safety. However, the concrete bases anchoring the cumbersome static lifelines were damaged frequently by truck movement.

Solution. Initially, plant personnel thought to redesign the lifelines and modify their concrete bases consistent with the latest safety standards. But then they came up with the idea of a mobile platform to make the entire system more efficient, reliable, and safer.

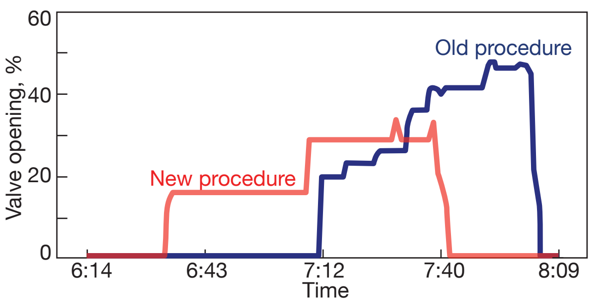
A preliminary study supported this thinking.

Bids for a turnkey project solicited from several contractors were higher than the plant could afford, so design was brought in-house. The first of the three platforms required (one can serve two trucks simultaneously) was fabricated by a contractor and installed to test functionality and safety before ordering the other two (Fig 1). Success confirmed, the remaining two platforms were fabricated and installed.

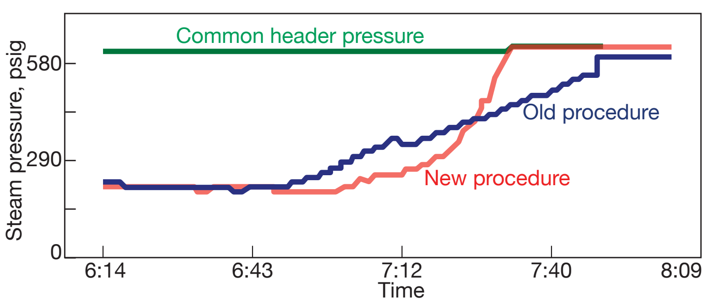
Results. The platforms have met expectations, with the following benefits:

- Maintenance and operating costs have been reduced. Fall harnesses are no longer required, eliminating the costs associated with buying and caring for them, and for the repair of lifeline foundations.
- Unloading is faster because the hatches on two trucks can be accessed at one time.
- Safety is enhanced because the

1. New platform, designed by plant staff, serves two oil tankers simultaneously



2. Reduction in steam venting during startup saved a significant amount of water



3. Steam-pressure ramped to header pressure faster using the new startup procedure

platform eliminates the need to use truck ladders, which can be slippery and difficult to climb.
- Plant involvement in platform design and installation allowed the project to be made operational for about one-third the cost of contracting that work.

Project participants:
Mohammad Al-Qudah
Muin Goma

Optimizing water consumption pays big dividends

Jordan has one of the lowest levels of water resource availability, per capita, in the world. Water will become even more scarce over the next two decades given the nation's population is expected to double. Plus, climate change potentially makes precipitation more uncertain and variable in this region. The bottom line: Management of water resources is a critical issue facing the national government. Owner AES is in lock-step with the country's goal of reducing water consumption with its "Put safety and environment first" program.

Challenge. An AES team studied the plant's water use and identified the following five areas with an opportunity for reducing consumption:
- Fire protection system. It relies on four pumps—two jockey pumps, one motor-driven pump, and one diesel-powered pump. An engineering review revealed two issues:
  1. Leakage of underground piping.
  2. Frequent starting/stopping of the jockey pumps used to maintain water pressure in sprinkler pipes, likely indicating leakage from that portion of the system. Investigators found that the pumps, which used to start every three hours or so, were now starting every 10 seconds.
- Blowdown cooling. Plant was designed to use raw water for quenching HRSG blowdown 24/7 before discharge to an onsite pond.
- Maintenance of service rooms in the administration building.
- Plant startup. The unavailability of gas forced the plant to stop/start operation from continuous. The former requires more water than the latter.
- Irrigation. A significant amount of water was being used to irrigate plants and gardens.

Solutions:
- Fire protection system. The water supply network was divided into zones and monitoring of pump operation was initiated. Plus, significant seat leakage was in evidence on one valve and that was corrected. Result: The jockey pumps are cycling on every three hours or so once again.

  Finally, NFPA standards were reviewed, and Amman East's insurance provider was consulted, before modifying the fire system relief valves to discharge to the raw-water storage tank rather than to drains.
- Evaporation-pond water is now recycled for blowdown cooling instead of using raw water.
- Service rooms and restrooms were inspected and corrective actions taken to conserve water.
- Plant startup procedures were modified to minimize water use. One result of the optimization exercise was a reduction in steam venting (Fig 2). Another action: Increase the gas-turbine ramp rate, thereby reducing the time to reach merge-point steam pressure, saving water in the process (Fig 3).
- Irrigation. A treatment system was installed to allow use of evap-pond water for irrigation. Water quality, verified by a third-party testing firm, complies with Jordan's agricultural water specifications.

Results, in gallons of water saved per day, were the following:
- Use of evap-pond water for cooling, 4000.
- Use of evap-pond water for irrigation, 8000.
- Eliminating leakage in the fire protection system, 9250.
- Modification of fire protection system relief valves, 1300.
- New startup procedure, 2650.
- Installing water-saving devices in the administration building, 400.

Total reduction in water consumption: 25,600 gal/day.

Annual financial benefit: $25,000.

Project participants:
Anas Diab, performance manager
Khaled Oasem, plant chemist

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 in 1Q were Waterside Power and Lawrence and Worthington Generating Stations.

The second quarter issue featured Best Practices from Athens, Effingham County, T A Smith, Armstrong Energy, MEAG Wansley Unit 9, Green Country, Paris, and Brooklyn Navy Yard Cogen.

In 3Q/2016, the following plants were featured: Fremont Energy Center, Granite Ridge Energy, Lea Power Partners, Millennium Power Plant, and New Harquahala Valley Generating Station.

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Ammonia consumption reduced without compromising NO_x emissions

AES Levant Power Plant

AES Levant Holdings BV
Jordan

250-MW, tri-fuel, peaking facility consisting of 16 diesel engines located in Al Manakher, Jordan

Plant manager: Meftaur Rahman

Challenge. Jordan's AES Levant IPP, located near the Amman East Power Plant profiled above, is configured with 16 diesel engines capable of operating on heavy fuel oil, distillate oil, and natural gas. Each of the recips has a dedicated stack and is equipped with a selective catalytic reduction system (SCR) for keeping NO_x emissions within regulatory limits.

With gas unavailable in the region, the 250-MW plant has run on heavy oil since commissioning in July 2014. One challenge associated with burning heavy oil: SCRs require significantly more ammonia for NO_x control than they do when burning distillate or natural gas. The handling, unloading, and storage of ammonia were of concern to personnel because of its high volatility and noxious nature.

The plant, designed for peaking service and a capacity factor of 40%, was called on to run at 75% CF because of the gas supply issue—doubling the already large quantity of ammonia required to sustain operations. Compounding the challenge, ammonia was not available in-country; neighboring Israel was the only nation in the region able to assure reliable supply. The supplier there then raised the price of ammonia from \$450 to \$470/ton. Import of very large quantities of ammonia by sea was not an option because the capacity of the plant's storage tank was only 32,000 ft^3.

Solution. Engineering review confirmed that excessive ammonia injection promotes soot formation when burning heavy oil, given its constituents—including sulfur. This can have detrimental effects on SCR performance. Also, excess ammonia (high slip), deposited on flyash particles as ammonium salts, was in evidence in particulates that separated from the flue-gas stream and fell to ground near the stacks.

A testing program conducted by Levant staff that compared NO_x emissions against ammonia injection values revealed ammonia use could be reduced by one-third and still satisfy environmental permit requirements.

This first stage of the plant's ammonia-reduction plan complete, Phase 2 of the test program was initiated. One component of this ongoing effort concerns the relationship between NO_x emissions and ambient temperature: The lower the ambient temperature the less NO_x produced. Given the use of aqueous ammonia as the SCR reagent, thinking is evaporative cooling might have a beneficial effect enabling a further reduction in the amount of ammonia injected.

Additionally, more detailed analysis and calculations have determined the Phase 1 results may have been conservative and that a further reduction, albeit small, in the amount of ammonia injected may be possible.

Another part of the solution was to encourage one or more Jordanian companies to produce ammonia for plant use.

Results. The financial, safety, and environmental/health/housekeeping benefits of the first phase of the ammonia-reduction initiative were significant, including the following:

- A saving of \$1-million annually in reagent cost.
- Ammonia deliveries reduced by 100 trucks per year.
- A significant reduction in particulate emissions.

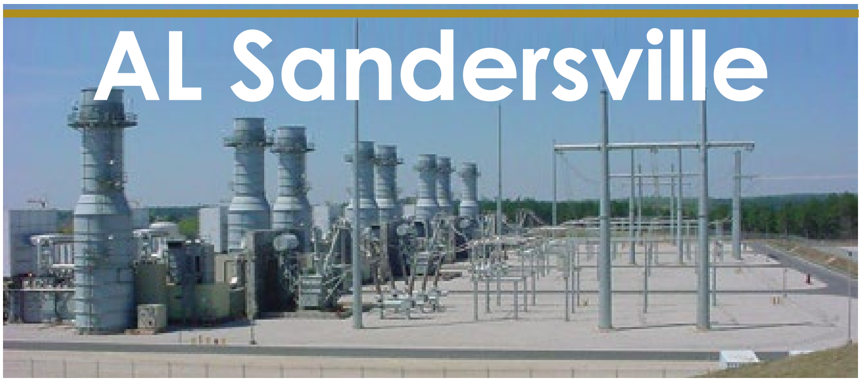
Plus, success in sourcing ammonia from within Jordan at a contract rate of \$400/ton, promises an additional cost benefit to the plant and the opportunity for the country to build a new industry and create jobs.

Results of the second phase of the ammonia-reduction initiative have not yet been quantified.

Project participants:

Mohammad Hammad, performance leader
Husni Qaseem, electrical and controls leader

AL Sandersville



Cable support retrofit solution saves time, money

Challenge. AL Sandersville, a simple-cycle peaking plant with eight 7EA gas turbines, relies on 13.8-kV cables in elevated trays for delivering generator output to 500-kV step-up transformers.

During a preventive-maintenance inspection, technicians found the cable spacers, 24 sets per unit, to be made of wood and in various stages of deterioration. The poor condition of the support blocks allowed cables to sag where they enter a transformer junction box and rest on sharp metal edges (Fig 1).

The decision was made to replace all wooden spacers with HDPE plastic spacers; the challenge was to do it safely without damaging the heavy cables and with the least impact to unit availability. Cable trays are located in space-constrained areas, making the use of a crane difficult. Bids received from contractors estimated the project to take a month and cost $67,000 for labor alone.

Solution. The technicians designed and built a cable lifting rig that mounted directly on the bus tray to lift the cables safely without damage (Fig 2). They also self-performed the work during the scheduled spring and fall outages.

Results. All cable spacers were replaced without damage and should last for many more years than the original wooden spacers (Fig 3). The work was completed without any forced or unplanned outage time and avoided the labor costs of a contractor.

Project participants: O&M Manager Randy Morton and lead technicians Derek Boatright, Ralph Chandler, Joe Vaughn, Robert Riddle, and Larry Shearouse.

AL Sandersville Power Plant

Owned by Southeast PowerGen LLC

Operated by Cogentrix

640-MW, gas-fired, eight-unit, simple-cycle peaking facility located in Sandersville, Ga

Plant manager: Mike Spranger

1. Support blocks deteriorated allowing cables to sag

2. Cable lifting rig was designed and fabricated by plant personnel

3. Long-lived spacers of high-density polyethylene were installed without incident

Ferndale

CRO interface upgrade improves plant operability

Ferndale Generating Station

Owned by Puget Sound Energy

Operated by NAES Corp

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

Plant manager: Tim Miller

Challenge. When Ferndale Generating Station was commissioned in 1994, the operator interface in the control room consisted of four Bailey OIS 20 proprietary consoles with 19-in. 640 × 480-resolution CRT displays and an alarm printer tied to the DCS.

There were also several standalone interfaces in the plant for systems controlled separately from the DCS by programmable logic controllers (PLCs). In light of proven performance capabilities and benefits of third-party operator interface systems, Ferndale elected to go with Wonderware in 2003.

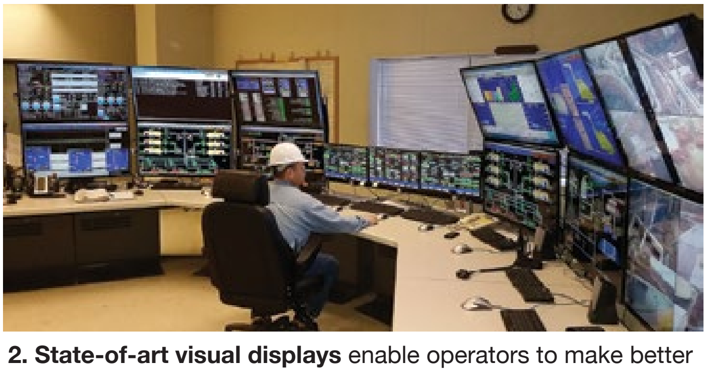
Our in-house plant staff configured and implemented the new DCS interface for several reasons: substantial cost savings, develop staff technical abilities, and allow for better site customization. Utilizing the original control-room console desks, four Wonderware InTouch operator stations were installed with 21-in. 1024 × 768-resolution CRT displays. We eventually upgraded our plant PLCs and networked them, enabling Wonderware to provide monitoring and control for these systems from the control room as well.

As the power market has evolved in the Pacific Northwest, so too has the nature of plant operations—that is, from baseload with relatively few starts and stops to a more dynamic profile with greater start/stop frequency. The growth of renewable resources in the power supply system increased the need for dynamic balancing, which prompted our owner to implement automatic generation control (AGC) at Ferndale in early 2015. It became apparent that the plant's control-system utilization and complexity had outgrown the ability of four displays to adequately keep up with operating demands.

Solution. We again called on our staff to come up with an innovative and cost-effective operator interface solution that would allow more effective information exchange— specifically, additional interactive displays.

Since the four Wonderware com-

1. Custom structure made of conventional components supports two tiers of monitors



2. State-of-art visual displays enable operators to make better decisions faster puters could be configured to support two monitors each, the plant opted to expand the displays from four smaller screens to eight 40-in. flat-panel LED monitors. Adding four more 40-in. monitors—for displays of alarms, weather, and security cameras—plus three 24-in. monitors for each of the turbine controls yielded a total of 15 high-definition monitors.

We then had to figure out how to fit them onto the existing control console desks and arrange them in a horseshoe configuration for ease of viewing. Given the limited area on the console desks, our staff came up with a two-tiered design.

To support the two tiers of monitors, they devised a custom support structure using standard steel pipe connected with the kind of aluminum fittings typically used for hand rail systems (Fig 1).

After preparing the pipe for fitting, they had it powder-coated for aesthetics. Since the staff completed the project during their regular work hours, we only had to cover the cost of materials for the upgrade, which totaled about $7500 with the following breakdown:

- Monitors (warehouse store), $6,130.48.
- Duplex video cards and cables, $399.79.
- Railing fittings, $629.18.
- Pipe, $258.00.
- Powder coating, $162.75.

Results. With the additional monitors, which are substantially larger and of much higher resolution, our operators have more information right in front of them on an ongoing basis. This enables them to make better decisions faster—especially in situations where they may need to act pre-emptively. The ability to react quickly to a deviation ensures more controlled, reliable startups (Fig 2).

As an added benefit, the optical quality, size, and ergonomic arrangement of these new displays reduce eye strain, which makes a substantial difference to an operator on a 12-hr shift.

By relying on plant staff to design and execute the new arrangement, and making use of the consoles on hand and other readily available materials, we completed the project for approximately $7500. Had we handed over the upgrade to a vendor on a turnkey basis and requested new purpose-built consoles, the costs could easily have approached $100,000.

Project participants:
Michael Hunt, maintenance mechanic
Jim Nevins, lead technician

MPC Generating

Hydrogen system supply redundancy

Challenge. MPC Generating is a simple-cycle peaking plant with a crew of five technicians and normally is staffed Monday through Friday from 0700 to 1730. The facility has two W501F gas turbines; one of the generators is hydrogen-cooled.

Hydrogen normally is supplied to the generator from a bank of 12 bottles. A pressure gauge is located at the hydrogen supply bank and an operator records the pressure during daily rounds. The hydrogen supply bank is changed when the pressure falls to approximately 300 psig which is typically a couple of days' supply.

One weekend, a sizable swing in ambient temperature caused a significant increase in hydrogen consumption; the resulting low-pressure condition in the generator tripped the unit.

This event also triggered the hydrogen generator to auto vent, making the unit unavailable for several hours while the generator was purged with carbon dioxide and recharged with hydrogen.

Solution. Staff designed and installed an independent emergency hydrogen supply line with a separate and dedicated redundant hydrogen supply bank. The emergency hydrogen supply is clearly labeled so that it will not be mistakenly used as the normal supply bank.

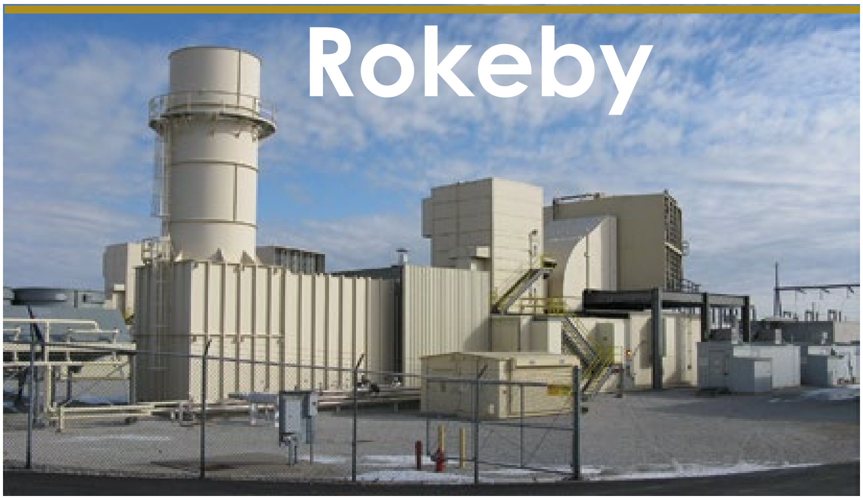
The redundant supply line is parallel to the normal supply line and has a separate pressure regulator that is set 10 psi less than the normal hydrogen supply line pressure of 70 psig. If hydrogen supply pressure drops to 60 psig, the emergency bank will provide hydrogen to the generator.

Results. Since the addition of the redundant hydrogen supply the plant has not experienced any forced outages caused by low hydrogen pressure

Project participants:
James Goins Jr, O&M manager
Chris Harris, lead technician
Scott Hobbs, lead technician
Charles Gibson, lead technician
Nick Sanz, technician II
Gavin Spann, technician II
Bly Crane, plant administrator

MPC Generating LLC
Owned by Southeast PowerGen LLC
Operated by Cogentrix
380-MW, gas-fired, two-unit, simple-cycle facility located in Monroe, Ga
Plant manager: Mike Spranger

Rokeby



Rain garden/ sanitary lagoon upgrade

Challenge. The original sanitary lagoon at Rokeby Generating Station was designed and constructed during an early phase of plant expansion. After lagoon installation, an additional unit and support facilities were added to the site, resulting in the lagoon not having adequate capacity.

This triggered periodic material removal by an outside contractor. Annual contractor costs for pumping the lagoon was approximately $48,000 and was increasing as additional non-sanitary discharge points were added to the system. Furthermore, regulations covering lagoon design had been updated since the original Rokeby lagoon was installed and it no longer met county permitting requirements.

Solution. After gathering data on plant wastewater and rain-event flows into the sanitary system, plant personnel determined the sanitary and site drain flows should be separated. Data also indicated the sanitary lagoon could be significantly smaller once the flows were separated.

Since the site was developed over multiple phases, drawings of the underground piping were not as accurate as required; therefore, the first project action was to update piping drawings. This demanded excavation (hydrovac) activities to verify piping configuration. Once the existing drawings were updated, the piping system was redesigned to separate sanitary- and storm-water flows.

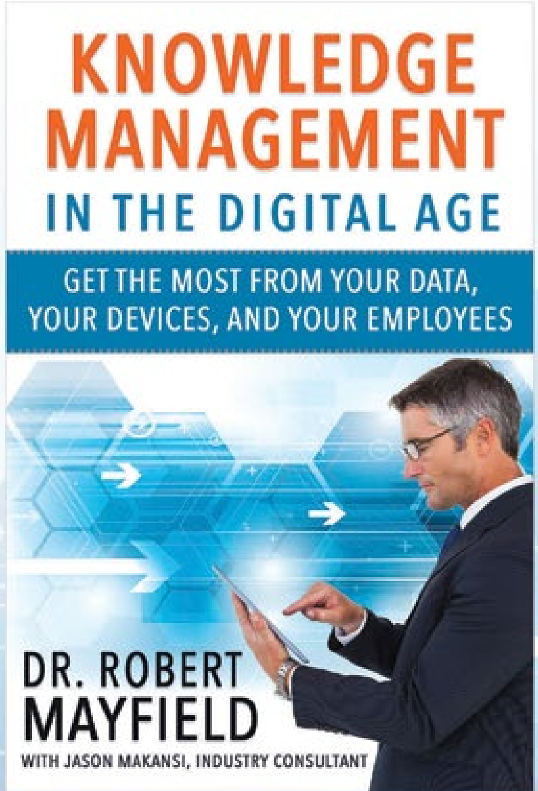
After system flows were determined, a design was developed using a standard sanitary lagoon for the waste flow and a bio-retention "rain garden" for storm-water and oily water separator discharges. The rain-garden percolation test was successfully completed and results were sent to a rain-garden design firm.

The project required modification of the site NPDES permit. The new permit removed the sanitary-lagoon outfall, required metering of a pump-pit sump discharge, and reconfiguration of the oily water inlet piping. Instead of installing a flowmeter at the lagoon inlet, the permitting authority allowed LES to record the site's sewage injector operation to estimate flow to the sanitary lagoon.

Results. All existing sanitary, oily water separator, and storm-water flows can be handled by the new sanitary lagoon and bio-retention system, saving $48,000 in annual operating costs. A side benefit of the project was updated underground utility drawings and reconfiguration of the oily water separator system.

Project participant: Chris Hodges

Rokeby Generating Station
Lincoln Electric System
245-MW, dual-fuel, simple-cycle peaking facility located in Lincoln, Neb
Plant manager: Bruce Barnhouse


KNOWLEDGE
MANAGEMENT
IN THE DIGITAL AGE
GET THE MOST FROM YOUR DATA, YOUR DEVICES, AND YOUR EMPLOYEES
DR. ROBERT
MAYFIELD
WITH JASON MAKANSI, INDUSTRY CONSULTANT

Some new faces, same great program

The technical agenda for the 7F Users Group's 2017 conference, May 15-19, at the La Cantera Resort & Spa in San Antonio, Tex, is gas-turbine-focused and robust, and offering diversity of subject matter to address the many O&M challenges facing plant management today.

Recall that the program for last year's 25th anniversary meeting was changed to drill deeper into engine topics, moving in-depth sessions on heat-recovery steam generators, steam turbines, and generators to the Power Users program in late summer where that equipment could be covered in greater detail.

Unfamiliar with Power Users? It is the umbrella organization for managing and coordinating the technical programs for the 7F, Combined Cycle, Generator, and Steam Turbine Users Groups. For more information, see ad, p 77, and/or visit www.powerusers.org.

The 7F Users Group steering committee is not quite the same today as it was at last year's meeting when this picture was taken. In the front row (l to r) are Sam Graham, Tenaska Inc; Pete Margliotti, Engie NA; Bob LaRoche, SRP; Ed Maggio, Tampa Electric Co; Richard Clark (resigned); David Such, Xcel Energy Inc. Second row: Clift Pompee, Duke Energy Corp; Jeff Gillis, Exxon Mobil Chemical; Luis Barrera, Calpine Corp; Peter So, Calpine Corp; Paul Whitlock (resigned). Top row: Bryan Graham, Entergy Corp; Gene Szpynda, NYPA; Justin McDonald, Southern Company; Ed Fuselier, Kindle Energy LLC; Art Hamilton (retired). New members: Christa Warren, Dominion; Matthew Dineen, Duke Energy Corp

2017 agenda

Monday (May 15) starts off easy enough: The annual golf tournament is conducted from 8 a.m. to 1 p.m. in parallel with tours of PW Power Systems Inc's nearby facility specializing in 7FA component inspection/repair/manufacturing. Busses leave the hotel lobby at 9, 10, and 11; the tours each take about an hour and a quarter.

Remainder of Monday (2 p.m. to 6) is set aside for technical sessions presented by PW Power Systems. Features and benefits of the third-party supplier's commercial offerings—some of which you may not have associated with PWPS™ previously—dominate the content descriptions for those sessions posted at www.7Fusers.org.

In the editor's view, a nugget in the supplier's program of value to virtually all plant O&M personnel, and especially those at plants self-performing maintenance, is the "7F Scrap Clinic." Given today's razor-thin margins in the generation business, you likely do not want to scrap repairable components.

Tuesday and Wednesday are the "meat and potatoes" of the meeting, offering perhaps a dozen or more presentations by owner/operators and open discussions on a variety of topics that impact plant performance, safety, etc. You can expect about 250 users to attend these closed sessions, from 8 a.m. to 3:30, p.m., ready to share their experiences—both good and bad.

Sessions running from about one to two hours each focus on the compressor, combustion, and turbine sections of the engine, safety, performance and controls, auxiliaries, and 7F Top Issues and best practices.

The 7F Best Practices Awards program is a collaborative effort between the user group and CCJ (p 104). Presentations of the 2017 awards will

Bob Holm, who resigned from the steering committee when he retired from OxyChem just prior to last year's meeting, is honored by 7F colleagues for his many years of dedicated service to the user group. Holm was overwhelmed by both by the outpouring of congratulatory messages and the monster gift—an engraved R0 compressor blade commemorating his contributions to the industry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be made at the conclusion of the Top Issues discussion Wednesday afternoon. Finalists this year are the following plants:

- Barney Davis Energy Center.
- Calhoun Power.
- Effingham County Power LLC.
- Faribault Energy Park.
- Green Country Energy LLC.
- Nueces Bay Energy Center.
- Nuevo Pemex Cogeneration.
- Plant Rowan.
- Rathdrum Power LLC.
- Thomas A Smith Energy Facility.
- Vandolah Power.
- Woodbridge Energy Center.

Special vendor presentations are incorporated into the program from 3:45 to 5 both days, just ahead of a three-hour vendor fair beginning at 5:30. There are two 45-minute supplier sessions, each with three companies presenting in parallel. It's virtually impossible not to find at least one topic of interest. Here's a rundown:

Tuesday, Session 1:

- Repair of platform cracks on 7FA.03 first-stage buckets, *Dr Warren Miglietti, ProEnergy*
- 7FA diffuser-duct insulation and liner system upgrade to improve reliability and performance, *Lester Stanley and Scott Olson, HRST Inc, and Jeff Wilkinson, Alliant Energy*
- Benefit of stacking inlet cooling technologies for power augmentation, *Chris Mieckowsi, Stellar Energy*

Tuesday, Session 2:

- Emergent generator repairs required because of increased cyclic duty, *Jamie Clark, AGT Services*
- 7F product offerings for enhanced operational flexibility, *Dr Peter Stuttaford and RuthAnn Rawlings, PSM*
- Impact of GT upgrades and increased cycling requirements on catalyst systems, *Andrew Toback, Environex Inc*

Wednesday, Session 1:

- Machinery protection and monitoring, *Jim Fenton, Alta Solutions Inc*
- Mitigating the impact of weather conditions on GT operations, *Adam Jeffries, AAF International*
- 7F turning-gear design, operation, and maintenance, *Tim Connor, Koenig Engineering Inc*

Wednesday, Session 2:

- Advanced ultrasonic inspection methodologies for aft compressor-wheel cracking, *Kevin McKinley, Veracity Technology Solutions*
- The changing landscape for combined-cycle operation, *David Cicconi, Emerson*
- Condition-based maintenance of the generator, bus, and transformers, *James Timperley, Doble Engineering Co*

The OEM owns Thursday and Friday. Program arrangement this year mirrors that of 2016 with appropriate subject-matter breakout sessions. This avoids the mesmerizing effect of a seemingly endless parade of speakers that one can experience with a single-platform format, the old standard. The new format allows users to drop out of a session without disrupting other attendees and return invigorated, not having had to listen to a presentation of little or no interest.

Thursday begins with a two-hour general session, half of what it was last year, and transitions to five 45-minute breakout sessions with 15-minute breaks between. Each breakout period features presentations on four topics arranged in parallel. A 45-minute feedback session closes out the classroom activities with both users and the OEM participating. The busy day ends with a three-hour product fair from 6 p.m. to 9.

The Thursday breakouts promise a blend of information of value to users with less than three years in the industry as well as those with a decade or more of experience. Topics include the following:

- Compressor, including lessons learned from flat-bottom inspections.
- Combustion, including an update on DLN 2.6+ fleet experience and NO_x spikes.
- Turbine, including experience with AGP and repairs of cracked third-stage buckets.
- Exhaust-frame enhancements.
- Rotor-life-management best practices and latest life-extension results.
- Accessories and controls, including best practices and troubleshooting recommendations.
- Electrical systems, including maintenance best practices and impacts of cyclic operation.
- Digital solutions, including analytics for improving reliability.
- Repair operations: New service shop network for keeping owner/operators involved throughout the repair process.
- 7F.05 and beyond, including fleet experience, best practices, information-sharing with Dot-05 users, and technologies in development.

Important to note is that several of the 45-minute presentation/discussions are offered twice, so you have a couple of opportunities to attend sessions of greatest interest.

7F Grad School is the theme for Friday's program. The grad-school idea was introduced by GE last year and was well-received. Subject matter is broader than offered in the Thursday program and allows attendees the opportunity to develop a deeper understanding of "why things are the way they are." It's also a way to decompress from the onslaught of technical material received the first four days of the conference and gain valuable perspective.

Program arrangement is the same as for the Thursday program except that there are only three breakout sessions on Friday before the meeting concludes shortly before noon. Here are the topics:

- Market dynamics for engineers and the impacts they have on operations. Factored into the presentation/discussion are the effects of renewables, fuels and their prices, energy storage, expiring PPAs, etc.
- Controls 101. Demystifying modern control systems for the mechanically inclined.
- Repairs 101: Session will answer such questions as, "Why are you proposing to do that to my parts? Can I weld single-crystal buckets? How firm are the recommended intervals?" and any that you want answered.
- Aeromechanics 101 includes an overview of airfoil design, blending considerations, the hazards of running with cracked airfoils, etc.
- "Make my plant better" is a strategic discussion session involving plant-level considerations, uprate opportunities, and oft-overlooked mods capable of maximizing site performance.
- O&M zeroes in on outage planning and execution best practices, inventory management, minimizing variable costs, etc.

Faces

User groups are particularly valuable to O&M personnel "stranded" in plants who need avenues of communication to reach colleagues capable of providing meaningful advice. Don't call top management; they hired you to give them the answers.

It is unlikely that any problem you face has not been experienced by at least one other user. The challenge is finding that person. If you're new to the

Best Practices Awards recipients recognized at the 25th anniversary meeting

Armstrong Energy's Pete Margliotti accepts plaque from CCJ Editor Bob Schwieger for an upgrade to the plant's fire protection system to ensure greater coverage, faster response. Details: 2Q/2016, p 91

MEAG Wansley Unit 9 was recognized for safety initiatives regarding the storage of chains and hoists and the labeling/color coding of tools and ladders. At left is Vince Clemmons; at right, Matt Engelbert. Details: 2Q/2016, p 93

Green Country Energy recovered from a black-plant trip with better processes and procedures to ensure superior preparedness in the future. At left is Jeff Aldridge; at right, Justin Sperrazza. Details: 2Q/2016, p 98

generation business, the first step might be to ask your questions in an online forum serving your engine model. The 7F Users Group operates what is widely considered one of the industry's most effective forums; if you're not using it, you are missing a real opportunity. Join today at www.powerusers.org.

Think of communications as a three-legged stool. The online forum (pixels) is one leg. Publications (print) are another. Reading about the experiences of others can help avoid problems in the first place. Face to face is the final leg, enabled by attending a meeting focused on your model of gas turbine. You need all three legs to stand on your own and grow.

Building a personal network of subject-matter experts is particularly important today given retirements of knowledgeable personnel and the trend to smaller and smaller staffs in a time when increasing demands are being heaped on you by an ever-widening range of federal/state/regional/local regulations. The all-volunteer steering committee is well aware of your challenges because its members, active 7F owner/operators all as required by the organization's bylaws, face the same ones.

To illustrate: Several of the most experienced committee members recently opted to retire from their day jobs; others have transitioned to the so-called "dark side." In the last couple of years, Jim Sellers of Entegra Power, Paul White of Dominion, Bob Holm of OxyChem, and Art Hamilton of Emera Energy retired. Hamilton is the most recent addition to that club. Those leaving their plants for better opportunities, and resigning from the committee as required, included the affable Richard Clark, now with GE, and Paul Whitlock, now with Mitsubishi Hitachi Power Systems Americas' M&D Center.

Holm was recognized in 2016 for his many years of very active participation as a discussion leader during the annual conferences and as a regular and valuable contributor to the forum. He was always ready to help all whom he could. Impromptu remarks by committee members during presentation of a special career award (p 100) characterized the unsuspecting Holm as an example for others to emulate and as a great role model.

Handed the microphone, Holm urged all attendees to participate in 7F User Group activities and share their experiences—successes and failures—both in person and on the forum. He also stressed the need for those just starting out to find a mentor.

The loss of so many leaders in a short period of time might have some wondering about the committee's capabilities going forward. Don't. With a quarter of a century of experience running what is believed to be the largest user group in the world serving a specific frame, the committee always has a ready reserve of capable recruits. In the last year, for example, it added Christa Parren of Dominion and Matt Dineen of Duke Energy.

Today the 15-person steering committee has good balance between senior and junior members. Six members have eight years or more of committee experience (Pete So of Calpine Corp is the most senior with 18); nine have four years of service or fewer. The members represent companies with 249 7F engines, or about 30% of the global fleet.

User presentations

If you want a crash course in 7F issues and solutions the 7F Users Group conference and vendor fair is where to learn from informed colleagues. Haven't attended previously? Don't know what to expect? Have to convince management on the value of participation? One way to get these answers is to peruse the presentations made by owner/operators last year and available to users, like you, on the "shelves" of the 7F Library at www.powerusers.org.

Perhaps you're not confident and think you might not "fit in" among the experts. Not true. Last year, about half of the attendees were first-timers, by show of hands.

To help encourage your visit to the 7F Library, here are thumbnails of two user presentations made last year:

Flat-bottom-slot compressor wheel repair. Unfamiliar with the indications found in the flat-bottom slots of compressor wheels 12-17 in some units so equipped? Obtain a copy of the OEM's Technical Information Letter (TIL) 1972-R1 and come up to speed. Cracking in the slots is attributed to thermal cycling: compressive stresses are imposed on the wheels during startup, tensile stresses during shutdown.

Check points suggested by the OEM are 1700 and 2200 actual fired starts. The first is when the experts say indications would have propagated sufficiently to be measured, the second is when you might expect to find indications large enough to potentially cause an event.

Given that an accurate audience poll using the user group's electronic voting system indicated 79% of attendees had units with flat-bottom slots (the remainder, round-bottom), there was high interest in this user's experience. Here are the highlights:

- An hours-based major was conducted when the machine had fewer than 1200 starts, and the owner decided to mag-particle check the R17 slots at that time. Indications, found on 25 of the 60 slots, were 0.25 in. or less, which were "acceptable" according to the OEM. A measurement of 0.375 in. would have been of concern.
- The R17 slots were rechecked a few months later when the engine was opened to deal with a third-stage bucket failure. There was no change in the indications.
- In another three months (round number), a forward stub shaft issue dictated a rotor swap; recheck of R17 slots again revealed no changes in the indications.
- The original rotor was rebuilt by GE and a new stub shaft installed. A Package 5 upgrade (new R0 through R8) was done at that time and the flat-slot-bottom indications were blended. The refurbished rotor was installed in another machine. No problems were identified by visual inspection of that unit after 10,000 hours of service and nearly 150 starts.

Conclusions drawn by this user suggested it's likely unnecessary to replace wheels if you find indications that do not exceed the OEM's guidelines; blending can extend life, although the manufacturer would not guess as to what the extended timeline might be.

Another user in attendance offered his knowledge on four units having indications from R11 to R17. He said crack propagation can be estimated based on start data and that growth can be minimized by avoiding forced cooling. Yet another user said he had four units (two 7231s and two 7241s) with from 60,000 to 90,000 hours of service and found cracks from R13 aft, but not on all the units. Indications were blended and the units continue to operate.

Someone else said additional motivation for eliminating forced cooling was to avoid HRSG tube-to-header cracking. An OEM engineer cautioned against making changes to startup and shutdown procedures before evaluating their impacts on fuel cost and air-permit requirements.

FlameSheet a commercial success. A utilities maintenance manager at a major chemical producer called PSM's FlameSheet™ a "remarkable technical success" in his presentation.

Prior to installing FlameSheet, he said, the plant could operate both of its 7FAs to maximize output, but that exposed the company to the consequences of low demand and low power prices. When operating one engine, the plant could satisfy the owner's requirement but was unable to ramp quickly enough to capture high market pricing.

FlameSheet, the speaker continued, extended GT turndown, enabling the cogen plant to increase market participation with its full capability while minimizing exposure to unfavorable market conditions.

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.

Among the other topics covered by users in formal presentations and availabile in the 7F Library include the following:

- Compressor pitting and corrosion requiring replacement of blades through Row 8 and a change in washing procedures and filters to mitigate the problem, which is still under investigation.
- S14 tip liberation attributed to high-cycle fatigue, but the root-cause analysis was unable to identify the cause of HCF.
- Fleet-wide compressor (flared and unflared) experience based on findings from nearly 90 borescope inspections and a dozen and a half unplanned events.
- Experience with non-OEM controls on 7FAs. CCJ

Faribault

Manmade ponds reclaim storm water, build community relations

Faribault Energy Park

Owned by Minnesota Municipal Power Agency

Operated by NAES Corp

265-MW, dual-fuel, 1 × 1 combined cycle located in Faribault, Minn

Plant manager: Bob Burchfield

Challenge. In 2007, the Minnesota Municipal Power Agency pursued a unique approach to water conservation by constructing clay-lined ponds at its Faribault Energy Park. The network of ponds reduces the burden on the local aquifer, collects and reclaims storm-water runoff for plant use, and provides a place where the community can fish, picnic, and walk trails. Following the owner's innovative conservation efforts, the plant O&M team implemented several simple methods for further reducing water consumption.

Solution. The facility was designed with hydrological features that keep storm water onsite and prevent discharge to the city treatment works and nearby surface waters—specifically:

- A network of small ponds to capture storm water and snow melt.
- Routing of road and plant drains to a storm-water collection pond.
- Topographical layout to maximize capture of rain and snow-melt runoff.

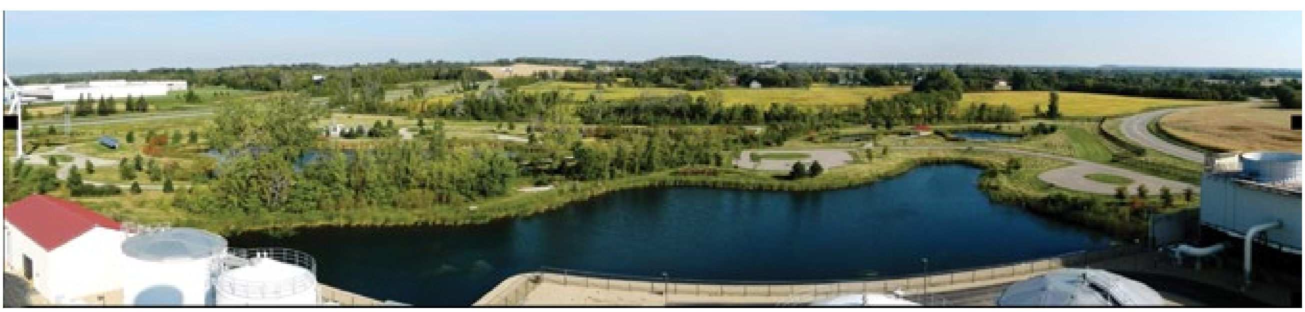
Makeup water for the cooling tower and steam plant is drawn from the large pond (named the Freshwater Pond) shown in Fig 1. Three other ponds, separated by overflow weirs, connect the storm-water retention pond to the Freshwater Pond (Fig 2). All ponds collect rain water and snow melt.

Plant and road drains are routed to the storm-water pond for use as plant makeup. The oily water separator shown in the diagram is equipped with a series of baffles to trap any oil that might be carried along with plant drains, forcing water to exit below the surface line where the lower-density oil would accumulate. If oil residue were ever to reach the storm-water pond, its below-grade discharge pumps would prevent oil migration further downstream.

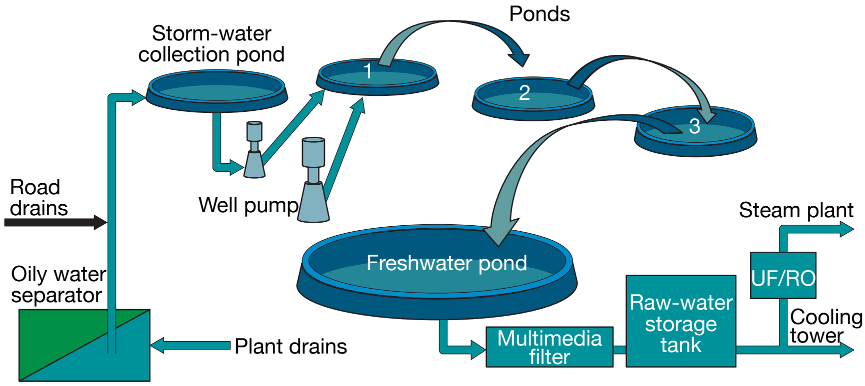
Level-control pumps discharge the contents of the storm-water collection pond into Pond 1, which then gravity-drains to each downstream pond via overflow weirs, eventually collecting in the Freshwater Pond for plant makeup. When the Freshwater Pond level drops to a predetermined set point, a well pump supplies water to Pond 1, which in turn discharges to each downstream pond until the level is restored in the Freshwater Pond.

The O&M team devised a simple but effective monitoring program to further conserve water. Operators routinely monitor the makeup flow to the condenser. If flow increases, it indicates that steam or water is leaking from the plant. Fig 3 shows a graphical display of condenser makeup flow including the totalized gallons for any given previous hour.

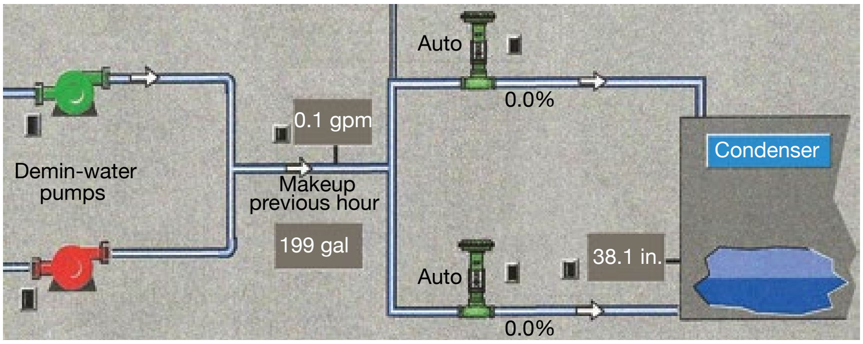
In a cycling plant, data can be misinterpreted if documented too soon



1. Freshwater Pond in Faribault's wetlands park and pond system as it looks from the top of the HRSG



2. Network of ponds collects rain and snow-melt runoff for plant makeup



3. Monitoring of condenser makeup flow warns plant personnel of leaks

after a startup, because the condenser level may rise above the control set point for several hours following a start. The data are meaningful only after the actual condenser level matches the control set point for a few hours at steady-state conditions.

During routine planned surveys, or when the team notices an increase in condenser makeup flow, they use several different techniques to pinpoint leaks. A simple, inexpensive temperature gun works well for locating elevated pipe temperatures downstream of valves. Ultrasonic probes are effective for detecting hot- or cold-water valve leakage.

An infrared camera is sometimes used as well, although pipe insulation makes it difficult to detect temperature differences across valves. Since downstream drain-valve piping may still be hot because a valve is open during startup, the team performs leak surveys after allowing time for piping to cool.

Results. The pond system provides several significant benefits:

- Eliminates storm-water runoff to local waterways.
- Reduces groundwater consumption. For example, the 6 million gal collected during one unusually high-rainfall month was sufficient to support plant operation for about 100 hours.
- Provides the community with a manmade wetlands park that supports recreation and wildlife conservation. One local conservationist even donated wood-duck and bluebird houses.
- Produces no point-source discharge. This means no NPDES (National Pollutant Discharge Elimination System) permit. Cooling-tower blowdown is discharged to the city under a POTW (Publicly Owned Treatment Works) contract. Also, the facility qualifies for a "no exposure" storm-water permit.

A routine leak survey provides benefits as well. On one recent occasion, condenser makeup rate elevated to 40 gpm, and a subsequent leak survey identified several faulty valves. This allowed personnel to order required parts on time for the plant's upcoming planned outage. The makeup rate returned to a normal value of 7 gpm following repairs.

Project participants:
Shawn Flake, operations manager
Bob Flicek, maintenance technician

Improving drainage, monitoring of water in HRSG steam header

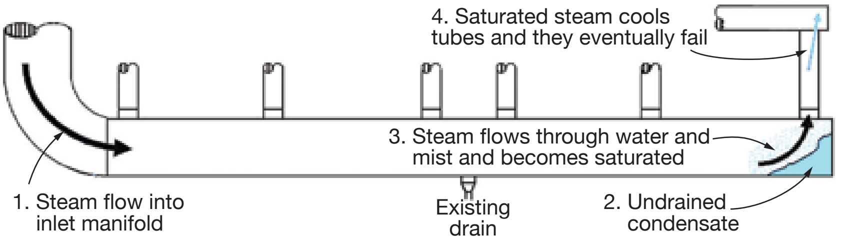
Challenge. Faribault's heat-recovery steam generator (HRSG) had experienced several reheater tube failures, all at the end of a tube bundle next to the outer HRSG wall (Fig 4). The plant is designed to cycle frequently, which creates stress on boiler tubes during startup and shutdown. Plant personnel found tube failures on both the upper and lower portions of the secondary reheater downstream of the desuperheater-spray injection point.

The design of the lower header included only one 2-in.-diam drain line in the center. This did not allow adequate drainage, resulting in an accumulation of water in the far end of the header (Fig 5). It was clear this excess water was collecting in the lower header under the tube bundle.

However, we couldn't tell if it was blocking the steam flow, causing the affected tubes to overheat, or whether the tubes were saturated, causing them to remain cooler (and shorter) as the other tubes in the bundle expanded.

4. Several tubes failed in the HRSG reheater bundle next to the outer wall of the unit

In either case, staff knew it had to improve the drainage from the header as well as eliminate the cause of the tube failures. To add to the challenge, there were no access doors near the repair sites, which significantly prolonged the forced outage. It took 8 to 12 hours at each end of the work to cut



5. Root cause of the failures in Fig 4 was water collecting in the lower header at the end of the tube bundle

6. Problem solved with new automated drain line and addition of access doors

access holes and then weld the wall material back in place.

Solution. Faribault personnel worked directly with a reputable HRSG engineering firm to minimize (or eliminate) these tube failures and reduce the amount of time spent in outages. To validate staff's suspicion that the outer tubes were remaining cooler and thus being stretched by the hotter tubes in the bundle, temporary thermocouples were installed on multiple tubes on both the upper and lower headers along with a data logger. The data confirmed our suspicion, showing a significant temperature difference between the outer tubes and those located four to five tubes in.

Based on the data, the following modifications were made in timely fashion:

- Tapped a second 2-in. drain line into the lower header on the far end where water was collecting and tied it and associated expansion loops into the existing drain pipe.
- Automated the controls and incorporated a means of detecting water in the pipe. This included (1) replacing the manual drain valve with an automatic one for easier control, (2) installing a level transmitter and condensate pot for moisture detection so staff could monitor water level in the lower header, and (3) installing a thermocouple in the drain line so staff would know to close the valve after water was removed and before steam flows through the pipe for an excessive amount of time.
- Installed access doors to both the upper and lower header locations for inspection and repair.
- Installed an access platform to allow easy entry for inspection and repair.

Results. The new lower-header drain effectively removes entrained water from the header, and the new instrumentation allows the control-room operator to verify that the drain is performing as designed (Fig 6). The instrumentation further benefits the plant by allowing operators to quantify increases in water drainage that could indicate a possible desuperheater valve leak or spray-nozzle failure.

Since automating the drain system, plant has experienced no additional cracked tubes—or costly forced outages. The two new HRSG access doors on the top and bottom of the header allow convenient, routine visual and NDE inspections of the suspect tube-to-header areas. Fig 6 shows the new lower access door on the side of the HRSG.

Project participants:
Bob Burchfield, plant manager
Shawn Flake, operations manager
Ben Garrison, maintenance manager

Monitoring, detecting, addressing combustion-dynamics anomalies

H L Culbreath Bayside Power Station

Tampa Electric Co

1800-MW, gas-fired, two 3 × 1 combined-cycle units located in Tampa, Fla

Plant manager: Scott Cannon

Challenge. H L Culbreath Bayside Power Station generates approximately 1800 MW of combined-cycle and 200 MW of simple-cycle power for Tampa Electric Co (TECO), an Emera company. The plant has seven 7FA.03 gas turbines (GTs) equipped with DLN 2.6 dry, low-NO_x combustion systems. The GTs began commercial service in 2003 and 2004.

The two combined cycles are monitored remotely by GE Power Services' Monitoring & Diagnostics (M&D) Center in Atlanta. GE, including the Atlanta M&D Center, has supported Bayside under a contractual services agreement since 2003.

In 2015, TECO began participating in a remote M&D pilot project spearheaded by GE's Power Services business and its Intelligent Platform's Smart Signal predictive diagnostics software and services team. As part of this cross-business M&D initiative, GE conducts weekly conference calls to update TECO team members on Bayside equipment performance. The M&D Center focuses on the station's gas and steam turbines; Smart Signal on most of the balance-of-plant equipment, plus some turbine and generator data.

Prior to the existence of GE's M&D Center, many combustion and other issues might not have been detected until they caused hardware damage or a unit trip. Up until a few years ago, most plants had to rely on their own M&D teams to detect and analyze issues such as combustion dynamics. Also, prior to the development of remote combustion tuning capability via the M&D Center, field specialists had to travel to the plant for this purpose.

The proactive collaborative relationship between utility and service provider to focus on remote M&D paid off in May 2015 when GE's detection system identified combustion-dynamics anomalies in two Bayside GTs.

Solution. On May 21, GE's monitoring analytics triggered an alert to the Atlanta M&D Center regarding elevated pressure pulsations in the combustion chambers (dynamics) on Unit 2D. A week later, the OEM's proprietary analytics detected an anomaly in the exhaust temperature readings of Unit 1B. Because these anomalies involved GT combustion systems, the Atlanta M&D Center took the lead. It has the visualization and analytical tools to evaluate dynamics and other operational data, as well as staff experienced in data analysis.

The GE Remote Tuning Group, based at the Atlanta M&D Center, works with plants to remotely adjust fuel flows, thereby tuning the unit to achieve optimal emissions, combustion dynamics, and flame stability. M&D specialists collaborate with the remote tuning team to resolve combustion operability issues.

In response to the Unit 2D alert, an M&D specialist determined the unit required a seasonal retune to improve flame stability and reduce dynamics. The alert on Unit 1B was triggered by a shift in some of the exhaust thermocouples. M&D staff traced the exhaust-temperature anomaly to combustion can 12.

Upon receiving GE's report, Bayside personnel collected NO_x emissions data for Unit 2D (the M&D Center does not have direct access to this information) and presented it to an OEM combustion expert. The M&D Center's initial conclusions were confirmed by these data and a remote seasonal retune was scheduled.

NO_x data from Unit 1B also were reviewed, along with the unit's operational, tuning, and inspection history. M&D experts concluded the temperature anomaly traced to combustor 12 did not merit action at that time. However, the analysis did reveal that the unit was operating with a relatively lean fuel-to-air ratio, like Unit 2D, so a remote tune was scheduled for that machine as well. In-service remote tuning of each unit took about six hours.

Results. Tuning successfully improved flame stability, thereby reducing the risk of unit trips from lean blow-out. It also reduced the elevated combustion dynamics on Unit 2D, which if not corrected, could have contributed to premature failure of the combustion hardware.

Quick response to the issues affecting both GTs enabled Tampa Electric to be proactive in keeping its Bayside plant operating during the critical summer months.

The retuned units contributed to Bayside's record generation in July and August, 2015. The new record for July was more than 967 GWh; August nearly 939 GWh. The previous record for July, set in 2009, was 906 GWh.

Project participants:

- From Bayside, Chip Whitworth, manager of engineering and maintenance; Tiller Mills, maintenance specialist
- From the GE Power Services group, Justin Eggart, GM fleet management; Christopher J Held, engineering manager; M&D center team led by Mansoor Dar

Rathdrum

Elimination of traffic-flow exposure during hazmat offloads

Rathdrum Power Plant

Owned by Tyr Energy

Operated by NAES Corp

275-MW, gas-fired, 1 × 1 combined cycle located in Rathdrum, Idaho

Plant manager: Gary Allard

Challenge. As an OSHA VPP facility, Rathdrum Power Plant management challenges the facility's team members to be vigilant for identifiable safety-related improvements. An identified hazard was submitted detailing the inherent risks of allowing continued vehicular traffic flow during chemical and hydrogen-gas offloading.

The facility's access roadway flows around the main power-block building (see plant photo) with traffic expected to follow in a one-way clockwise route. This path exposes traffic to potential hazards associated with the transfer of hydrogen gas and ends with potential exposure to the facility's process chemical and ammonia offload area.

Solution. Without a manned security gate, plant personnel determined a method for effectively restricting traffic flow to one direction or the other during transfer evolutions was necessary. After reviewing numerous suggestions, the team decided on placing chains or cables across the roadway at four points to restrict traffic from the two identified areas.

Next decision: Which material would serve best in an industrial environment—a painted chain or cable? Because the chemical offload station was close to the cooling tower and its challenging environment, the team decided on cost-effective, high-visibility, safety-yellow plastic chain to avoid the maintenance associated with metal.

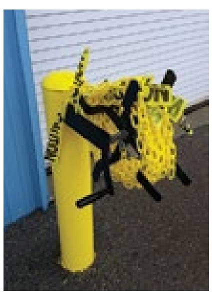
Storage and ease of access was the next consideration. The team did not want to retrieve the chains prior to each use and opted for a permanent mounting to simplify deployment when required (photos). This was achieved by mounting hose reels at the four locations. This solution also provided a clean method of chain storage and allow for easy retraction once the evolution was completed.

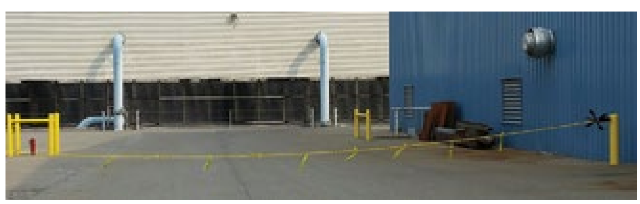
Results. The maintenance department ordered the necessary materials and once installed the plant had effectively eliminated the associated hazards posed to visitors during the transfer of hazardous materials.

The CRO still identifies the optimal route to be taken when visitors enter the facility, but we no longer risk having the visitors being exposed when exiting, as they might have been had their chosen route taken them near hazardous materials and environments.

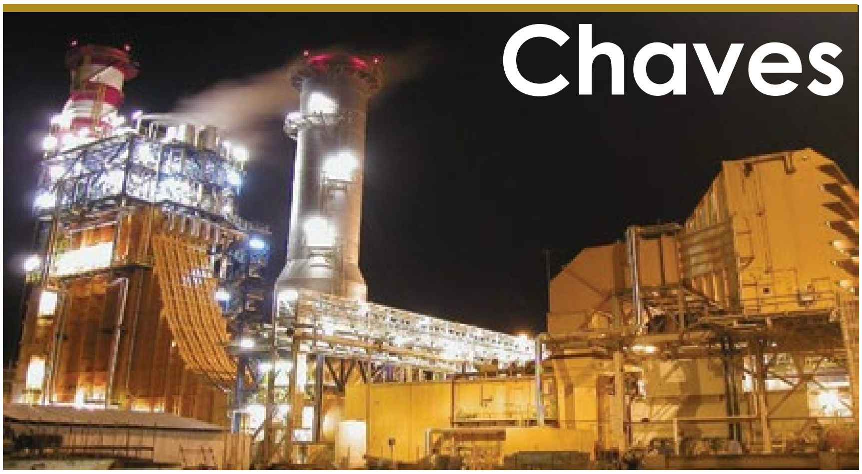
Project participants:

Steve Woolley, EHS compliance supervisor
Don Kendal, maintenance technician





Simple solution. Lightweight plastic chain is easy to see and deploy to prevent exposure to hazardous materials during unloading operations



Aureliano Chaves Power Plant

Owned by Ibiritermo SA

Operated by Petrobras

226-MW, gas-fired, 1 × 1 combined cycle located in Ibirité, MG, Brazil

Plant manager: Eloisia Barbosa de Almeida Pinto Coelho

Reduce startup time with condenser vacuum pump

Challenge. A goal of management at the Aureliano Chaves Power Plant was to improve starting reliability and reduce the time to breaker close, both important to the facility's financial success.

As designed, the plant's hogging steam-jet ejector was expected to pull vacuum to enable fast starting. However, it took approximately 2.5 hours to reach the desired vacuum. Plus, the starting steam ejector required a high level of operator intervention. In sum, Chaves startups using the supplied steam ejectors were too long, starting reliability was poor, and resources (fuel, cooling water, personnel time, etc) were wasted.

Solution. Chaves technical staff analyzed the available technologies to identify the best alternative for pulling vacuum on startup. It was to install a vacuum pump in parallel with the existing starting steam ejector (Fig 1). Note that the vacuum pump is operated only during startup; the more-efficient steam-jet evacuation system is used during normal plant operation to hold vacuum.

To implement the project, electricity supply was provided through an MCC panel, sealing water to the pump through a service water line, and operational control through the plant's DCS (Fig 2).

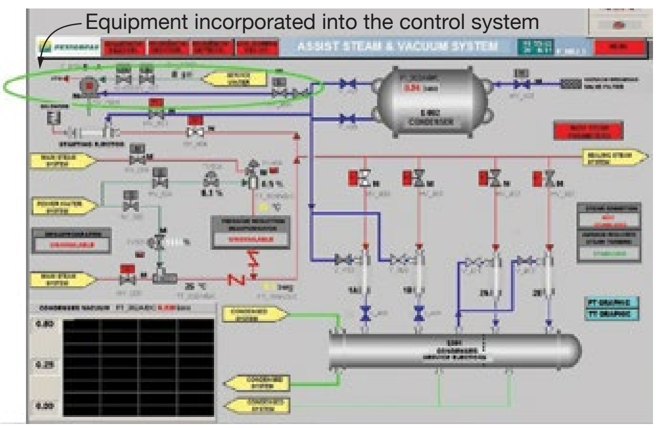
1. Vaccum pump was installed to supplement the starting steam-jet ejector and reduce the time to breaker close

Results. The proposed solution to install a vacuum pump and significantly reduce the time for unit startup resulted in a two-hour saving plus other benefits (Fig 3). The details:

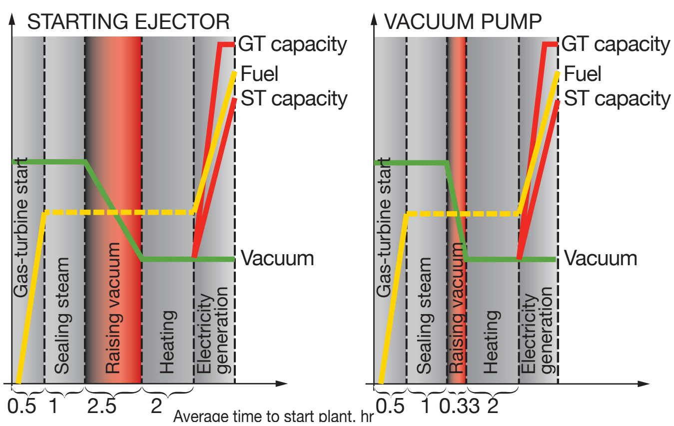
- Plant starts before installing the vacuum pump took about six hours; after, four hours.
- It took 2.5 hours to pull vacuum before modifying the air-evacuation system, 20 minutes after.
- Fuel gas required for vacuum-raising during startup was reduced by more than 90%.
- Demin water consumption was nearly 90% lower.
- Cooling-water requirements were 20% of what they were for the as-designed system.

Additional project benefits: Automation of vacuum raising and maintenance was improved; operator intervention was reduced; starting reliability and safety were improved significantly.

Project participants:
Eduardo Lúcio Nahass de Alcântara, electrical engineer
João Victor Santos Miranda, electrical engineer
Jaime Roberto Gapski, automation engineer
Eldon Zica Mendonça, mechanical engineer



2. Equipment incorporated into the DCS to provide tighter control over vacuum-raising is highlighted in the diagram



3. Starting time with air ejector pulling vacuum (left) required about six hours; with vacuum pump (right) about four hours

Heating blankets, startup agility package enable faster starts

Colusa Generating Station

Pacific Gas & Electric Company

668-MW, gas-fired, 2 × 1 combined cycle located in Maxwell, Calif

Plant manager: Ed Warner

Challenge. Colusa Generating Station is an F-class 2 × 1 combined cycle in PG&E's asset portfolio. A company goal is to remain on the leading edge of renewables integration, which demands that conventional generation assets be as flexible as possible to compensate for the relative unpredictability of renewables.

With this goal in mind, engineers were challenged to enhance the flexibility of combined-cycle assets—in particular to reduce their startup times to base base or minimum load, thereby enabling the plants to follow the real-time needs of the generation market.

Solution. Colusa implemented the OEM's OpFlex startup agility package and steam turbine/generator (ST) heating blanket. The plant's agility package features improved startup automation—including advanced control software to enable fast, reliable, and repeatable ST hot, warm, and cold starts. Benefits include the following:

- Improved capability to meet start-time commitments.
- Reduced gas-turbine (GT) startup fuel costs and emissions.
- Lowered the risk of overstress conditions, vibration trips, and radial and axial rubs.
- Improved operator interface with modified and new HMI screens.
- Enabled ST rapid starts following an overnight shutdown (when the HP bowl upper metal temperature is at least 880F).
- Provide true ST "push-button" auto start in which the operator selects load and decides when to start. The ST control system then automatically executes the entire start.
- Allows combustion turbines to achieve emissions compliance before loading the ST if the startup dispatch/sequence requires it.
- Reduces combined-cycle overall start time to achieve the desired load—approximately 25 to 30 minutes.

For the ST heating blanket, a power console is designed to provide individually controlled zones of low voltage, high current outputs to resistance heaters. There are 24 zones of control on the shell to provide the necessary stable temperatures required to ensure even heating for all three sections of the turbine:

- HP end section (heating starts at 650F).
- Inlet/barrel section (heating starts at 975F).
- IP end section (heating starts at 550F).

Results. The OpFlex startup agility improvements for the ST have been extremely beneficial. We've coordinated weekly calls between the OEM's agility team and the Colusa O&M team to discuss the previous week's starts and worked to fine-tune starting processes and to streamline ST roll and forward-flow permissives.

Times when we've seen the heating blanket come into service we've maintained sufficient shell temperatures to begin the approach for a hot start rather than warm, further reducing time to base load. This has reduced our startup time to the point that the steam turbine is no longer our limiting factor to base load; GT emissions requirements are now "critical path" on a hot or warm start. Some tangible benefits of these enhancements include the following:

- Reduced hot/warm start times from 81 minutes to less than 60.
- Allowed faster loading of the ST, reducing the ramp time by approximately half.
- Saved an average of 66 million Btu in fuel per start.
- Reduced CO emissions by an average of 52.5 lb per start.
- Reduced NO_x emissions by an average of 75 lb per start.

Project participants: Entire O&M staff with special recognition to our advanced powerplant technicians who coordinated the implementation process with the OEM: Jon Bohn, Earl Giffin, Chris McMains, Dean Linville, and Mike McLellan.

Blankets for heating the HP cylinder (left) and crossover (right) to enable faster starts

Eight Bells: Charlie Zirkelback, 77

News of Charlie Zirkelback's passing on July 8, 2016 reached us only recently. The Pascagoula (Miss) native, a graduate of Mississippi State University (1965, mechanical engineering), died at his home in Port Lavaca, Tex, after a long battle with Parkinson's disease.

Charlie Zee was a "character." He both taught and entertained at Frame 6 User Group meetings where Charlie may have been best known professionally outside Union Carbide/Dow Chemical. He worked at UC/DC for 39 years and was recognized by the chemical giant with the title of Corporate Fellow for his valuable contributions. Charlie was a "plant guy," traveling to company facilities worldwide as a trouble-shooter and problem-solver. He experienced most everything having to do with power and process operations and maintenance in his career.

Charlie believed there was nothing he couldn't fix or make work better. CZ put industry icon Marmaduke Surfaceblow to shame, Rube Goldberg as well, with his creative solutions. And once he got control of the mic at Frame 6 meetings it would be non-stop Charlie until the next scheduled break or meal. Loved and respected by colleagues, he was honored with the Frame 6 User Group's 2006 John F D Peterson Award for his contributions to the industry and the user organization.

Top-entry ball valves facilitate maintenance

Conval Inc's Camseal® metal-seated, cartridge-style, top-entry, zero-leakage ball valves are designed for long life and inline access to internal components for ease of maintenance and repair. A recently released 12-page brochure provides plant managers,

engineers, and maintenance personnel all the information required for purchasing decisions—including Cv values, operating torques, working-pressure charts, dimensions, materials, fire-safe test data, quality certifications, etc. Download your brochure at www.conval.com. While on the site consider viewing the short video (less than four minutes) posted in the News Spotlight; it brings key points in the brochure to life.

Inspection guide for drum-level instrumentation

The 2017 edition of "Boiler Inspection Guidelines for Drum Level Instrumentation," issued by Clark-Reliance Corp, concisely presents inspection requirements for ease of reference by O&M personnel. The basis for the seemingly indestructible, spiral-bound 5.5 × 8 in. book is Section I of the ASME Boiler & Pressure Vessel Code (current edition). It includes requirements for water columns, water gage valves, gage glass, remote level indicators, magnetic water-level gages (MLGs), and water-column isolation shutoff valves.

New to the guidebook this year is content pertaining to the use of MLGs, a topic which may have generated confusion among plant personnel in the past. The standard use of MLGs available from most manufacturers could result in a Code violation and safety hazard. Code compliance is assured by following guidelines presented in the Clark-Reliance publication.

The information presented is completely up-to-date and incorporates the 2015 Code changes and CSD-1 requirements, as well as recommendations from Section 7. Additionally, it identifies the most common non-compliant drum-level equipment arrangements and recommended solutions. The book is free to qualified recipients; visit www.boilerinspectionguide.com.

Duct balloon protects gas turbine during layup

This is not news to industry veterans, but newcomers might benefit from a review of this best practice for gas-turbine protection during layup. A major international company in the oil and gas industry was dealing with materials wastage and other issues in a gas turbine located at a refinery near the seacoast and subjected to long-term layups.

The existing inlet damper was ineffective and a duct balloon was installed to stop the ingress of moisture-laden air and sea salts. A dehumidification system was added to increase the level of protection and together they are doing the job intended. Installation of the balloon takes only minutes and removal is quick and easy (photos). Dekomte (UK) Ltd subsidiary, Intech, handled system installation for US supplier G R Werth & Associates Inc.

Duct balloon of this size certainly is easy enough for one person to install and remove

Emerson makes the virtual powerplant a reality

With the introduction of what Emerson says is the industry's first integrated control and simulation platform, the company has positioned plant owners to fundamentally change how they operate their facilities. Emerson reports that sales of Ovation™ high-fidelity embedded simulation have more than doubled in the past year, confirming significant interest in the "virtual powerplant" and its value in minimizing operational risk and in improving reliability.

In the virtual plant, the Ovation simulator runs in parallel with the Ovation control system. This allows operators to test control logic changes in advance, based on real-time plant data, ensuring those changes won't disrupt operations. Other Emerson technologies—such as pattern recognition, Pervasive Sensing ™, and analytical tools—enhance the virtual experience.

Finding experienced operators for today's advanced plants is one of the industry's biggest challenges and an opportunity for Emerson given its controls advancements. Bob Yeager, president Power & Water, Emerson Automation Solutions, told the editors, "Emerson is improving operator effectiveness and confidence while reducing operating risks through intelligent control systems, more realistic training and simulation platforms, and easier-to-use technologies."

Mitsubishi Hitachi Power Systems update

The OEM reports that its global fleet of 146 advanced gas turbines had accumulated more than 4 million operating hours by the end of 1Q/2017.

Paul Browning, president/CEO of MHPS Americas, announced during Carnegie Mellon Energy Week that the university's new index measuring carbon dioxide emissions from the nation's powerplants reflects a cleaner environment, which is attributed to the replacement of old coal-fired units with efficient gas-fired capacity and renewables.

Grand River Dam Authority completes the first fire of its M501J-powered Grand River Energy Center, east of Chouteau, Okla, March 14. The engine is the first such machine to operate in the Western Hemisphere. The 495-MW 1 × 1 combined cycle is said to have the potential to become the most efficient plant of its type in the US when fully operational.

The M501JAC, an enhanced air-cooled gas turbine, is designed to produce 540 MW at 63% efficiency. As of mid-December 2016, the machine had demonstrated 99.5% reliability during 11,000 hours of commercial operation.

With an order for two M501J machines from Iberdrola SA's El Carmen combined-cycle plant in Nuevo Leon, Mexico, MHPS now has 47 J engines on order and 23 such units operating globally. The fleet had accumulated 335,000 hours of commercial service at 99.3% reliability through 2016.

Entergy Louisiana LLC orders two MHPS 501GAC gas turbines to power its 980-MW St. Charles Power Station, scheduled for operation in 2019.

MHPS expands its global relationship with OSIsoft to drive further development of the digital powerplant. The latter's PI will serve as the core for new interactive, cloud-based analytics services provided by the OEM. As part of this strategic alliance, the two companies will collaborate to define and promote new integrated digital solutions that add intelligence to powerplants worldwide, using best-in-class software while leveraging their respective knowledge.

Mike Hoogsteden, Advanced Turbine Support LLC's Director of Field Services (the handsome guy in the center of the photo) is all smiles participating in a Ride 2 Recovery event to raise money for wounded (visible or hidden) veterans. Team Hoogsteden raised $7000 (all participants combined raised $40,000 this day) to support rehabilitation programs

Dominion Virginia Power breaks ground for its 1588-MW Greensville County Power Station, which will be equipped with three 1 × 1 combined cycles powered by M501J gas turbines.

Thumbnails

ANZGT Field Services and Engine Cleaning Technology (ECT) sign a distribution agreement giving Air New Zealand access to ECT's efficient compressor technologies—including the R-MC family of gas-turbine cleaners, injection equipment, and inlet conditioning systems.

BASF Corp announces the availability of Camet™ ST, a sulfur-tolerant oxidation catalyst designed to prevent the deactivation of catalyst systems installed on units burning gas with fracked and biogas components.

Clarcor Inc's announced acquisition by Parker Hannifin Corp was completed at the end of February. The strategic transaction creates a combined organization with a comprehensive portfolio of filtration products and technologies.

NV Energy and Apple have agreed to build 200 MW of additional solar power generation capability in Nevada to support the latter's Reno data center. This is in addition to the 491 MW of universal solar resources in the state currently serving the utility's customers.

3M Industrial Group's Liqui-Flux® ultrafiltration modules offer an alternative to conventional treatment steps—such as flocculation, sedimentation, and multimedia filtration—to remove turbidity, suspended solids, and pathogens from raw water streams.

Heart of the Liqui-Flux module is the company's UltraPES™ polyethersulfone membrane which is said to reduce the potential for fouling. High caustic resistance and free-chlorine tolerance are two attributes of the modules, which can operate at pH values between 1 and 13.

Clark-Reliance Corp announces a new line of coalescing filter elements for the gas processing industry. VertexCore™ filter elements are designed to eliminate unsafe filter-element change-out techniques while increasing filtration efficiencies.

Power Services Group Inc, a provider of turnkey MRO solutions for steam and gas turbines, integrates the capabilities of its affiliated companies—Airco Inc, Turbine Generator Maintenance, and Orbital Energy Services—to serve the power-generation and process industries.

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