$15

1Q/2015

www.ccj-online.com

CCJ

COMBINED CYCLE Journal

User Group Reports

501D5-D5A Users...58

Focus of user and OEM presentations and discussions at annual meeting were reliability, availability, operational flexibility. Updates were provided on cracking of inlet-manifold splitter plates and struts; turbine axial rubbing; spin cooling; rotor and casing inspection and evaluation; new bolted compressor rotor; engine upgrade to permit black start; finding/eliminating gas leaks; exhaust-cylinder replacement

Western Turbine Users 68

WTUI turns 25, commitment to users resolute. Report features a historical perspective of the organization, profiles of best practices recognized with awards, updates on depot activities (ANZGT, IHI, MTU, and TCT), The Axford Report, and summaries of special technical presentations on HEPA filters, HRSGs, SCR catalyst, LM6000 maintenance, electronic logbooks, etc

ACC Users Group..110

Inspection guidelines for air-cooled condensers help identify, characterize issues. Inspection frequency, role of good photography in record-keeping, and safety awareness are included

Buyers Guide...103

Connect with equipment/services providers directly from the pages of the CCJ by scanning quick-response (QR) codes with your smartphone or tablet

Features

3 Editor's page: Not your father's Oldsmobile

6 Best Practices Awards: 2015 Best of the Best to Gila River (p 7), Gateway Generating Station (p 12), Amman East (p 16), Dogwood (p 20), and Waterside (p 26). Subject matter includes faster and more reliable starts, wastewater management, gas-line and evap-cooler maintenance, batteries, upgrades of liquid fuel systems and controls

30 The new electricity casino: Preparing your GT assets

34 Align SCR start/stop sequence with GT fast-start requirements

38 Wireless expands M&D to more of the plant

44 The case for rewinding rotors onsite

54 Guided-wave radar gets attention for more level measurements

56 Notes from recent plant visits, user discussions

91 Metallurgical aspects of joining Stellite 12 to Type 316L stainless steel

94 Grid-scale storage advocates prepare for a 'flood' of business

98 Rigorous protection scheme, proper maintenance help prevent over-fluxing

114 Stop complaining, budget training

118 It's a visual world: Training aids go 3D

121 IAPWS releases best practices for water chemistry

Register now for upcoming user group meetings

CCUG

2015 Conference and Discussion Forum
August 24 – 27
J W Marriott Grande Lakes, Orlando, Fla
Contact: Sheila Vashi
sheila.vashi@sv-event.net
www.ccusers.org

STUG STEAM TURBINE USERS GROUP

2015 Conference and Vendor Fair
August 24 – 27
J W Marriott Grande Lakes, Orlando, Fla
Contact: Sheila Vashi
sheila.vashi@sv-event.net
www.stusers.org

CTOTF™

2015 Fall Conference & Trade Show
September 20 – 24
The Coeur d'Alene (Idaho) Resort
Contact: Wickey Elmo, info@ctotf.org
www.ctotf.org

ACC Users Group Air Cooled Condenser Users Group

Seventh Annual Conference
September 21 – 24
Wyndham Gettysburg (Pa)
Contact: Sheila Vashi
sheila.vashi@sv-event.net
www.acc-usersgroup.org

GUG GENERATOR USERS GROUP

First Annual Meeting
November 4 – 5
NV Energy's Beltway Complex, Las Vegas
Contact: Sheila Vashi
sheila.vashi@sv-event.net
www.genusers.org

7EA Users Group

2015 Conference and Vendor Fair
November 9 – 12
Santa Fe (NM) Convention Center
Contact: Gregory Carvalho
hostmaster@users-groups.com
http://ge7ea.users-groups.com

INDEPENDENT VOICE OF THE GAS-TURBINE-BASED GENERATION SECTOR


HARNESS THE POWER
OF MANUFACTURING INNOVATION
RENTECH engineers build unmatched power and performance into every boiler we deliver. Our 80-acre manufacturing facility—the industry's most technologically advanced—includes heavy bay and light bay areas with direct access to rail, cross-country trucking routes and shipping facilities. We master every detail to deliver elemental power for clients worldwide. Take an expanded tour of our facilities today at www.rentechboilers.com/facilities.
HARNESS THE POWER WITH RENTECH.

Not your father's Oldsmobile

Do you remember that commercial? It dates back to 1988, a seminal year in the power industry. Engineers were discussing whether the transmission system could handle the competitive electricity supply concepts being introduced by some policymakers and their supply-side academic supporters. "The system just wasn't built to accommodate that," was the engineers' consensus.

That was a key (and long-running) episode in the battle for the backbone of the electric power industry. Would it continue along the "big iron" centralized model (bigger powerplants, longer and higher-capacity transmission lines, monopoly utility service territories, regulated rate of return, etc)? Or would it evolve towards a more distributed, competitive, and transactional model?

Fast forward to today. Tesla, an electric vehicle and battery storage company, is one of the darling stocks of Wall Street. Arch Coal, America's second largest coal company is a penny stock. Telsa is "cool," coal is not.

If you consider the totality of regulation governing electricity in California (itself the ninth largest economy on the planet), it's clear government is driving the industry to a distributed, carbon-free model. In markets where wind energy penetration is high, fossil plants—even large supercritical coal units—are paid primarily for their agility, not for capacity or energy.

The same companies providing stationary and mobile platforms for phone, email, Internet, social media, etc, are driving a new portfolio of home energy management devices. Established solar PV suppliers are combining their offerings with storage, leasing systems, and shared savings in the incentives and rates with residential and commercial customers. They seek to get in between utilities and their customers.

Industrial cogeneration plants are adding systems to capitalize on the market for competitive frequency regulation services to the grid operators (CCJ 2Q/2014, p 20). Wind plant operators are adding storage facilities, in part to solve the grid problems created by their intermittent capacity.

At many industry meetings today, storage and microgrids are on the agenda and a subject of continuing discussion during coffee breaks. Tesla, it seems, is visiting every utility C-suite which will allow them in. One of the most prominent EPC firms in the power industry, Black and Veatch, has installed a microgrid to serve the innovation pavilion at its Kansas City headquarters. The Pentagon is driving the microgrid market because its military bases worldwide need to be autonomous and resilient.

In an era of abnormally low electricity load growth and anemic projections for the next several decades, where is a utility going to find new revenue? Choose your answer from among the following:

A. Large base-load coal and nuclear plants.
B. Transmission line construction.
C. The largely regulated distribution side of its business.

Doubtful anyone picked A. The opportunity for B has largely been exhausted, but was good when FERC provided return-on-equity incentives for certain transmission line projects nearly 10 years ago. Distribution assets look to be the next big opportunity.

More than two years ago, Edison Electric Institute issued a report, "Disruptive Challenges: Financial Implications and Strategic Responses to a Changing Retail Electric Business," which, judging from how often it was referenced and discussed, instilled fear in the hearts of electric-utility executives.

The basic premise was technological advances and incentives (especially in solar PV, demand-side management, and distributed energy resources) at the distribution end, as well as "behind the meter," were driving utility customers towards onsite generation and net metering, leaving fewer traditional customers over which to spread the cost of grid upkeep. The promise of affordable distributed storage only aggravates the threats, or magnifies the opportunities, captured in that report.

At the same time, the centralized assets continue to do more with less, with advanced control and automation systems, wireless sensing (p 38), remote M&D facilities (CCJ, 4Q/2013, p 6) optimization and analytics algorithms, and other digital technologies a huge part of that effort.

Jason Makansi, president, Pearl Street Inc, a highly regarded consultant, believes the industry may be near a tipping point at which the distributed/transactional/no-carbon energy model begins to outrun the centralized paradigm. This is why CCJ is now running articles on energy storage (p 94), what happens to fossil plants in regions with considerable renewable resources (p 30), etc.

Going forward, we'll keep you current on microgrids, grid-scale storage (CCJ, 4Q/2014, p 27), distributed resources, powerplant agility, control-system modifications for more flexible unit operation (CCJ, 4Q/2014, p 16), etc—in addition to our regular coverage of gas and steam turbines, HRSGs, and other plant equipment.

CCJ's mission is to keep gas-turbine owner/operators informed and to serve as a connector among users. Many of the coming options are competitive to your facilities, some complementary. Even if you aren't considering them seriously, you can be certain your company executives are. The goal is for all of us to be in the water when the wave makes it to shore, even if we got here transporting our surfboards on the roof of a Cutlass Supreme.

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

Patricia Irwin, PE
Consulting Editor

Clark G Schwieger
Special Projects Manager
702-869-4739, clark@psimedia.info

Business Staff*

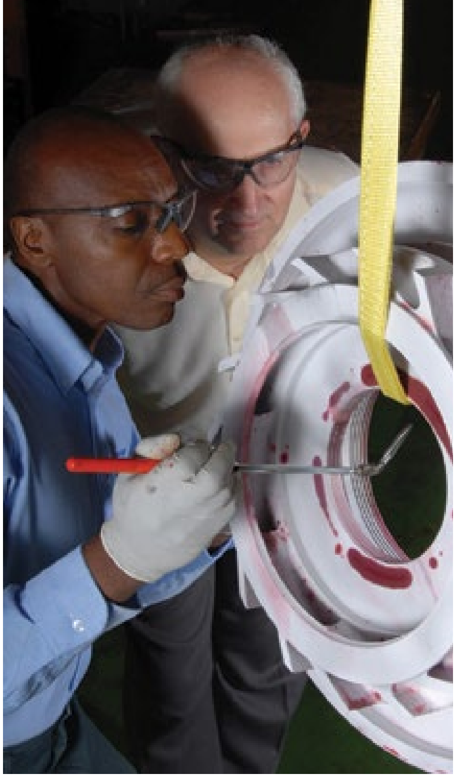
Susie Carahalios
Advertising Sales Manager
susie@carahaliosmedia.com
303-697-5009

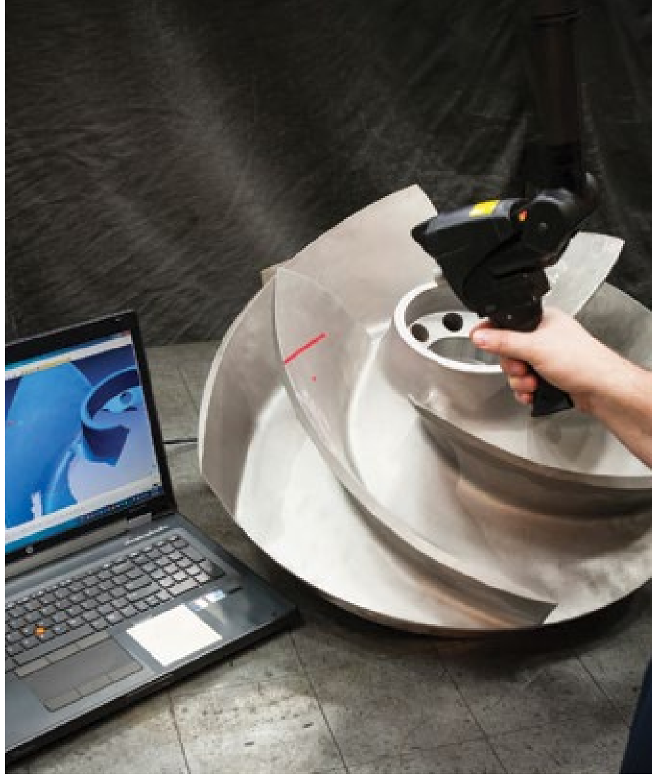
COMBINED CYCLE Journal is published by PSI Media Inc, a Pearl Street company. Editorial offices are at 7628 Belmondo Lane, Las Vegas, Nev 89128. Office manager: Robert G Schwieger Jr.

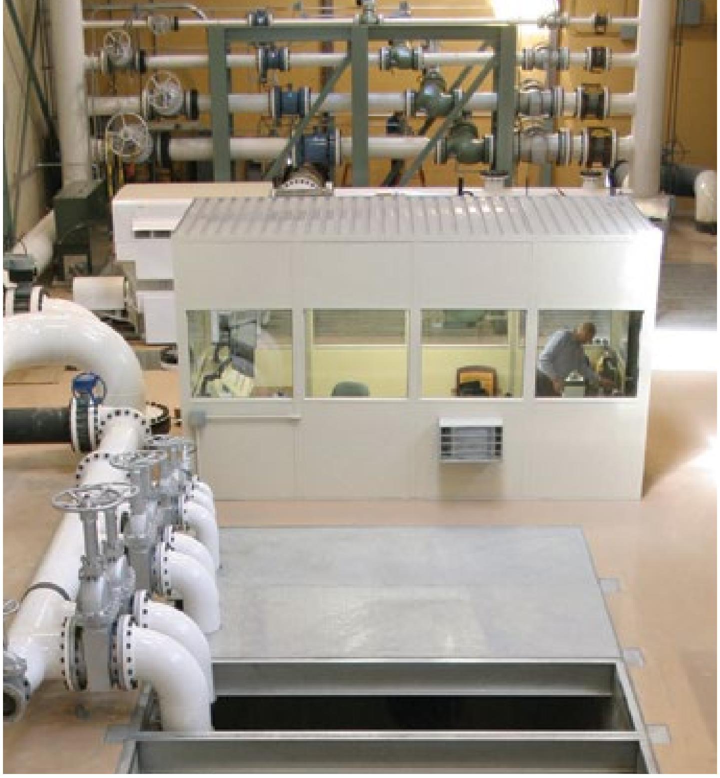
Telephone: 702-869-4739; fax, 702-869-6867.

*Carahalios Media is the exclusive worldwide advertising sales organization for the COMBINED CYCLE Journal. Business offices are at Carahalios Media, 5921 Crestbrook Drive, Morrison, Colo 80465.

To cancel or change your subscription, write scott@ccj-online.com







Pump Parts

When you require a part and are facing a long lead time, Hydro can meet your needs in a reduced time frame through our reverse engineering, patternless casting, and integrated manufacturing processes. Hydro's engineers review and evaluate all parts to offer important upgrades and apply new technologies that will reduce wear and improve reliability.

Pump Testing – Managing Risk

Ensure your pump will perform as required. Hydro's 5000HP Performance Test Lab is compliant to AP1610 and Hydraulic Institute standards and can text horizontal, vertical, and submersible pumps.

Training

Hydro teaches practical solutions and troubleshooting techniques for common pump problems and offers specialized hands-on training programs. View upcoming courses online at **hydroinc.com.**

To learn more about Hydro's comprehensive services for combined cycle plants please contact John Francis at jfrancis@hydroinc.com or call 8713-890-2117

Hydro®

Best Practices Awards

The **CCJ** Best Practices Awards program, now in its 11th year, has as its primary objective recognition of the valuable contributions made by plant staffs, and headquarters engineering and asset-management 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—such as fast starts, performance improvements, workforce development, NERC CIP, compliance, etc.

There are two levels of awards to recognize the achievements at individual plants: Best Practices and The Best of the Best. This year, five plants were recognized with Best of the Best awards, as voted by judges selected from the Leadership Committee of the Combustion Turbine Operations Technical Forum™.

Two of the top awards were presented for plant safety procedures, two for performance improvements, and one for fast-start methodology. Note that Best of the Best recipients are selected on the basis of points across all entries, not most points in a given category. The scorecard used by the judges considers business value, degree of complexity, staff involvement, external coordination, and duration of value.

Recipients of the 2015 Best of the Best awards are:

- Amman East Power Plant, for developing and implementing a series of operational procedures to decrease startup time, conserve both fuel and water, and reduce noise pollution.
- Dogwood Energy Facility, for minimizing the hazards often associated with testing and maintenance of station batteries.
- Gateway Generating Station, for a comprehensive inspection and preventive maintenance program that ensures gas-system components remain safe and reliable.
- Gila River Power Station, for innovative operating procedures that reduce fuel-gas use on startup, shorten the time taken to meet dispatch requirements, and improve extended turndown operation.
- Waterside Power Holdings LLC, for upgrading its HMI to enable automatic start of three oil-fired legacy aero peakers, allowing the plant to fast-start emergency dispatches without a failure.

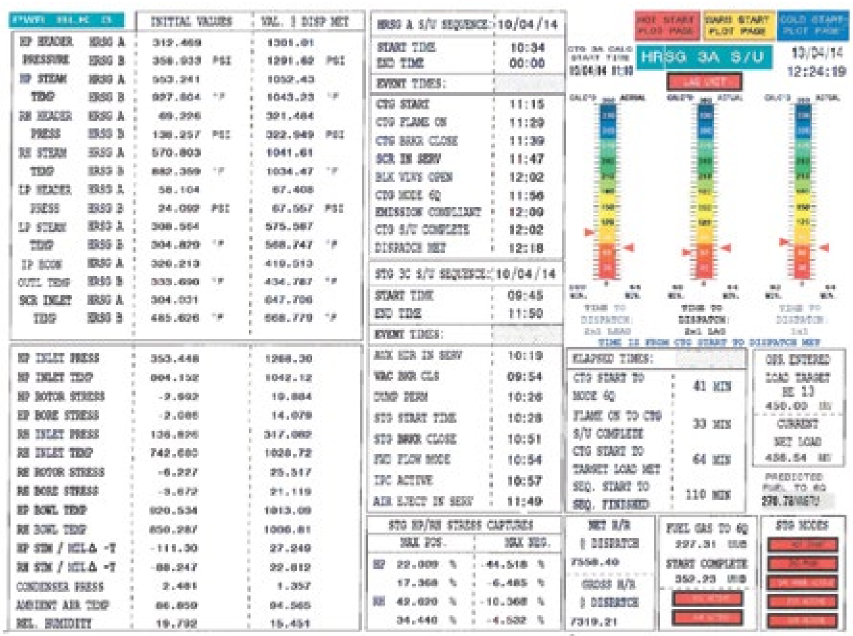
See the following pages for details on each of these best practices.

Plants participating in the 2015 Best Practices Awards program

Amman East Power Plant
AMP Fremont Energy Center
Athens Generating Plant
BASF Geismar
Colusa Generating Station
Dogwood Energy Facility
Effingham County Power
Emery Generating Station
Essential Power Newington
Faribault Energy Park
Gateway Generating Station
Gila River Power Station
Granite Ridge Energy
Green Country Energy
Hartwell Energy Facility
Hawk Road Energy Facility
Jack County Generation Facility
Klamath Cogeneration
Lea Power Partners
MEAG Wansley Unit 9
Michigan Power
Mid-Georgia Cogen
Monroe Power
Nueces Bay Energy Center
Oglethorpe Power CT Fleet
Paris Energy Center
PSE Ferndale Generating Station
Ripon Cogeneration
Riverside Generating Station
Rokeby Generating Station
Terry Bundy Generating Station
Walton County Power
Washington County Power
Waterside Power

Gila River

1. Startup sequence automation was improved to help prevent human errors



2. Startup "snapshot" allows CROs to see if they have met critical parameters—such as fuel burned to Mode 6Q, time to dispatch, etc

Gila River Power Station

Owned by Sundevil Power Holdings LLC, Gila River Power LLC, and Tucson Electric Power Co

Operated by EthosEnergy Group

2200-MW, gas-fired, four power-block, 2 × 1 combined cycle located in Gila Bend, Ariz

Plant manager: Douglas Cantrell

Improved GT starts reduce gas consumption, satisfy dispatch requirements

Best of the Best

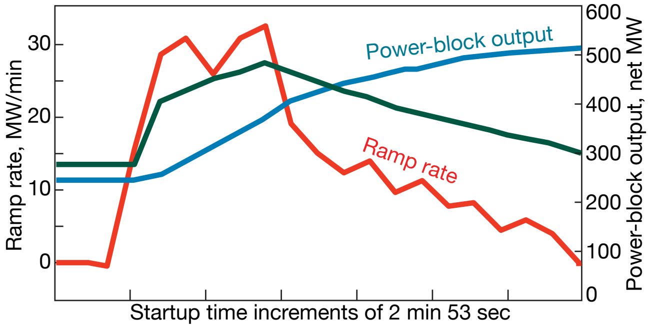
Challenge. Gila River Power Station has four 2 × 1 power blocks that cycle daily—each equipped with two GE 7FA gas turbine/generators (GT) and one GE D11 steam turbine/generator (ST). In a typical year, the GTs ring up more than 1200 starts; starting reliability is critical.

When a unit is dispatched, the control room operator's (CRO) primary goal is to start the gas and steam turbines and ensure key performance indicators are achieved. Startup objectives include the following:

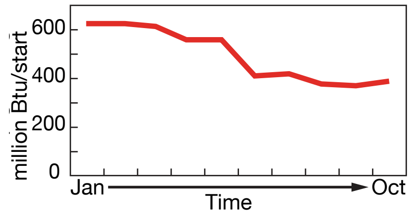
- Minimize fuel gas use during hot, warm, and cold starts.
- Minimize the time to meet dispatch while operating equipment within design parameters.

To satisfy these goals, the engineering team worked closely with operations to improve the control schemes for GT and ST starts. When reviewing opportunities for improvement, the engineers' challenge is to ensure that all modifications improve startup efficiency and the ability of the operators to effectively conduct the start.

Solution. The Gila River team approached the challenge by implementing process changes to improve GT starts. Enhancements to the startup procedure were implemented to satisfy the owners' goals of reducing gas consumption, meeting required dispatches, insuring against safety and environmental issues, and operating equipment within design constraints. Modifications included the following:



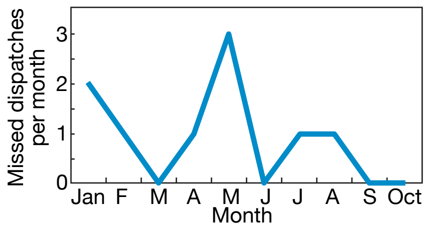
3. With gas turbines in extended turndown operation, the power block can be ramped to full load in less than 20 minutes (left)



4. Gas usage for a hot start in 1 × 1 configuration, from flame to Mode 6Q, was reduced by one-third (right)

- Startup sequence automation was increased to avoid human errors (Fig 1). Another mod limits GTs to Mode 1 operation until steam conditions are met. When the unit initially goes into Mode 3 exhaust CO is elevated. By preventing the gas turbine from reaching Mode 3 prematurely, the control logic maintains CO levels within permit limits (100 lb/hr during startup). The logic uses pre-selected load control up to the firing-temperature transfer point of Mode 3 to ensure CO emissions are held in check while minimizing startup time.
- A startup calculator is used to determine the GT start time based on predicted operating conditions, megawatts required for dispatch, and required dispatch time. Temperature-decay curves were plotted to provide expected reheat bowl temperature for cold and warm starts and HRSG HP steam temperature/pressure for hot starts.

  The DCS captures the last dispatch event, and based on the next dispatch time, the temperature decays are used to predict the amount of time necessary to reach desired steam conditions and dispatch load. The time directly correlates with the amount of fuel necessary to reach Mode 6Q as well as back-calculating a startup time.
- Created a startup "snap shot" (Fig 2) to allow the control room operators to understand if they have met critical startup parameters—such as fuel burned to Mode 6Q and "dispatch met," as well as the time dispatch was achieved. The operators have a recorded document of the performance of the latest startups as an immediate reference.
- The GT fuel curve schedule was increased from six to 12 points and changed to operate in a rich PM1 split schedule. The units were tuned to allow them to operate within environmental parameters (predominantly CO) at reduced output (extended turndown). Tuning of the GTs provides the capability to operate at 65 to 70 MW. The need to shut down and then restart the GT can be avoided. With the GTGs in extended turndown, the power block can be quickly brought to full load in 17 minutes (Fig 3).



5. Missed dispatches were reduced from an average of three per month to less than one during the critical summer run season

Results. Changes to the startup procedure have made significant improvements in the facility's ability to start power blocks quickly and effectively. These improvements have resulted in the following:

- Gas usage for a 1 × 1 hot start from flame to Mode 6Q, which averaged 600-million Btu, was reduced by 33% to less than 400 million Btu (Fig 4).
- Reduced missed dispatches from three per month to less than one per month during critical summer months (Fig 5).
- Extended turndown operation of the power blocks has improved the economics of overnight operation, resulting in fewer starts to meet morning peak operations.

Project participant:
Steve Reinhart, operations manager

Improved water management enhances overall ZLD process

Challenge. Gila River Power Station is designed for zero liquid discharge (ZLD) operation. The ZLD system has three brine concentrators (BCs) to process blowdown water from the power blocks and produce 300 to 400 gpm of distillate each. Additionally, the ZLD has a two-pass reverse-osmosis system (RO) for processing well water into 300 gpm of RO permeate. Water produced by the BCs and/or RO units is stored in a 600,000-gal demin feed tank. Water from the demin feed tank is processed through demineralizer trailers and stored in a 700,000-gal demin storage tank.

Gila River performs over 1200 starts annually. During startups, demineralized water supply to the heat recovery steam generators (HSRGs) is critical to ensure that the power blocks can be started effectively. The challenges the team faced were these:

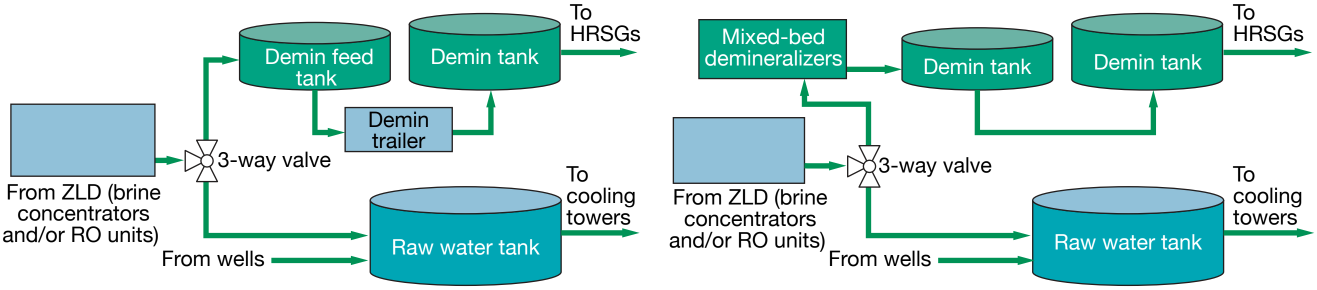
- How to increase demineralized-water storage capacity.
- How to improve water quality while reducing the cost to process ZLD water.
- Which method to implement containment for the demineralizer systems.
- How to control flow through the demineralizer system.

Solution. The Gila River team approached the challenge by implementing several changes to enhance the overall ZLD process. The primary change was the installation of new headers inside the ZLD to allow processing of water produced by the ZLD to demin quality.

The original design at Gila River was to store the ZLD distillate and RO permeate in the demin feed tank, then process the water through a demin trailer equipped with a strong-acid cation resin bed, a strong-base anion resin bed, and two mixed beds. In lieu of demineralizer trailers, the team looked into alternatives capable of supplying water of comparable quality at equal, or lower, cost. Three options were considered:

- **Maintain status quo.** Over the last 12 years, demin trailers have proven capable of supplying Gila River high-quality demineralized water. However, because of their physical size, the trailers had to be located where there was no containment for any water that might leak from the

6. Mixed-bed demineralizer vessels replaced demineralizer trailers, challenging personnel as to their location and hook-up. They were installed adjacent to the ZLD system



7, 8. Water flow pattern before the mixed-bed demineralizer vessels were installed is at the left, after at the right

trailers.

Temporary containments were required and they had to be rented. The cost of the demin trailers and temporary containments were a significant operational expense (approximately $1.20 per 1000 gallons). The evaluation team did not support this approach.

- **Purchase and install demineralizers** that can be regenerated onsite. This option also was not chosen because the capital cost of the infrastructure was too high. There also were safety concerns regarding possible personnel contact with the sulfuric acid and sodium hydroxide needed to regenerate the demineralizers.
- **Lease mixed-resin-bed vessels** as a direct replacement for the demin trailers. This option was chosen for the following reasons: (1) product water quality was equal to the quality of water from the demineralizer trailers, and (2) rental costs were significantly lower.

After the team determined that the facility will be changing from demineralizer trailers to mixed-bed demin vessels, the team was further challenged with choosing a location for the new vessels and how to control the flow through them (Fig 6).

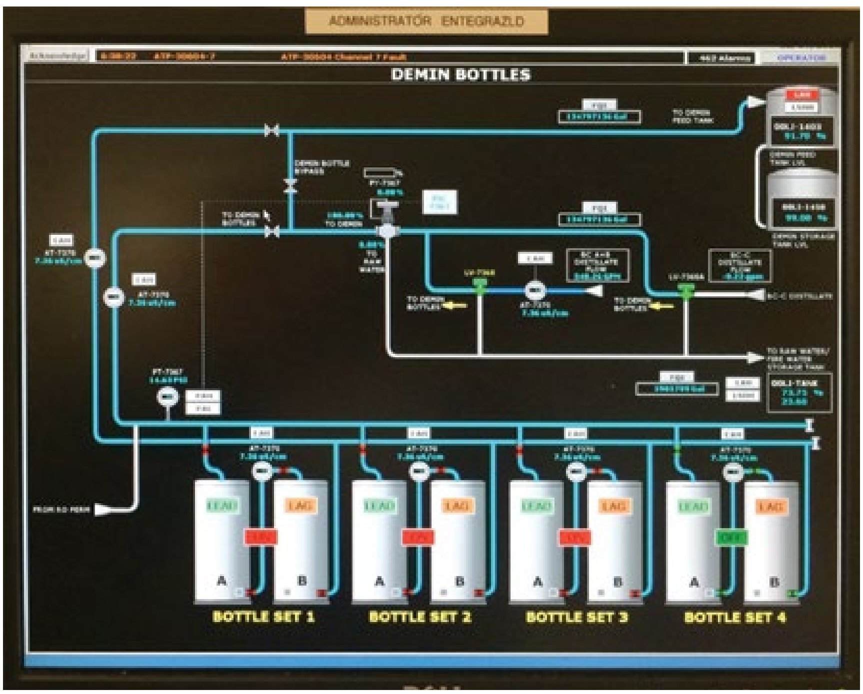
Results. By switching from demineralizer trailers to mixed-bed vessels, Gila River reduced the cost of demineralized water by 40%, to $0.72 per 1000 gallons. The quality of the water improved from a silica content of 9 ppb to 4 ppb, with a conductivity of less than 1 μmho. The mixed-bed vessels were located at the ZLD, which provided containment because of the existing drains and sumps at that location.

The original water flow diagram is in Fig 7. Note the three-way valve located within the ZLD. It allows all the water to flow to the demin feed tank and be processed into demin water, or to the raw water tank for use in the cooling towers. To control the flow of water through the vessels, the team decided to modify the existing three-way valve by adding a new positioner and 4-20- mA communication.

Additionally, by relocating the mixed-bed demin vessels to the ZLD, the demin feed tank supply becomes demineralized water, increasing demin storage capacity from 700,000 to 1,300,000 gallons. The new flow pattern is illustrated in Fig 8. The HMI to control the new system required a new screen (Fig 9) and new control logic. Online analyzers have been added to ensure water quality is maintained.

In summary, the new system for processing BC distillate and RO permeate into demineralized water provides Gila River the following benefits:

- Reduced cost to produce demineralized water, a 40% saving to $0.72 per 1000 gal.
- Increased demin storage capacity by 85% to 1.3-million gallons.
- Improved water quality (reduced silica levels to 4 ppb and conductivity to less than 1 μmho).
- Added continuous monitoring of water quality (silica and conductivity).
- Added containment for demineralizer vessels.



9. HMI required a new screen and control logic to serve the improved water treatment process

Project participant:
Steve Reinhart, operations manager

Gateway Generating Station

Comprehensive gas-line preventive maintenance program

Best of the Best

Gateway Generating Station

Pacific Gas & Electric Co

600-MW, gas-fired, 2 × 1 combined cycle located in Antioch, Calif

Plant manager: Benjamin Stanley

Challenge. Gas-line safety is a very important issue at PG&E. For the industry's combined-cycle plants, it is typical for a gas-line preventive maintenance program to include cathodic protection monitoring, cursory inspection, and reactive maintenance, and not much else.

Solution. The plant O&M staff solicited the help of PG&E's Applied Technology Services (ATS) to team up and develop a comprehensive program that included the inspections and preventive maintenance necessary to keep the gas system safe and reliable. A plan was developed to accomplish the following:

- Assure gas supply equipment is properly inspected and maintained.
- Confirm that all regulations applicable to gas systems are included in plant procedures.
- Assure that current and suggested maintenance tasks align with industry standards and best practices.

ATS reviewed guidelines from such agencies as the Dept of Transportation (DOT) to understand how new improved inspection methods could be applied inside the plant, so long as there were no conflicts with standards that did apply inside the plant boundaries.

The scope of this inspection effort covers the following equipment:

Gas yard. All piping, valves, regulators, gauges/instrumentation downstream of the main gas regulator and meter within the gas yard (Fig 1).

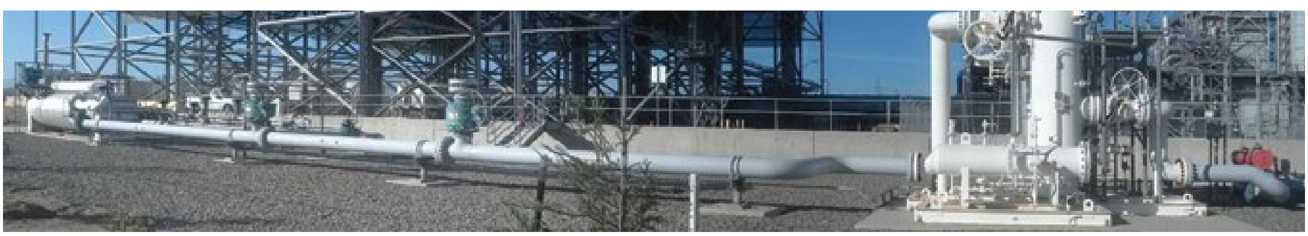
Gas-turbine supply piping and performance heaters. All piping, valves, regulators, gauges/instrumentation from where the gas-supply pipes surface from underground through to the GT inlets.

HRSG duct burners. All piping, valves, regulators, gauges/instrumentation in the gas-supply system serving the duct burners.

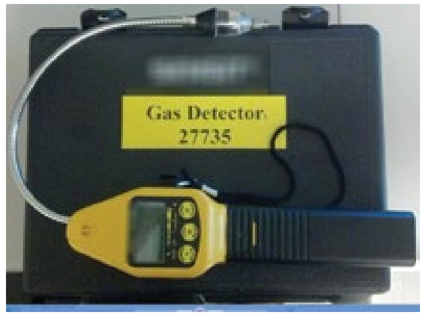
As a result of this effort, the following preventive maintenance items were created and entered into the work management systems:

Coating and surface inspections:

- Conduct a visual inspection of coating condition and film thickness, with adhesion testing where necessary.



1. Gas-line inspection and preventive maintenance program at Gateway includes all equipment and components in the gas yard



2, 3. Remote Methane Leak Detector (above) and other reliable methods of gas detection are available to the Gateway team

- Inspect for corrosion and surface chalking, and measure the depth of pits in pipe surfaces, flanges, and valves—especially at soil-to-air interfaces, pipe supports, and deck penetrations.
- Look for corrosion under thermal insulation.
- Inspections should be performed by a NACE Level II inspector.

Below-grade piping inspection:

- Assess effectiveness of the installed cathodic protection (CP) system.
- CP testing and findings review.

Mechanical inspections:

- Ensure supports are properly carrying pipe loads.
- Confirm all components are labeled properly.
- Confirm all drains and vents are properly capped so there are no open pipes or lines.
- Ensure all valves perform as designed.

Leak detection. Regularly check for gas leaks at all connections, components, and devices within the gas yard and turbine supply areas—monthly by the plant O&M staff, annually by ATS. Gas leaks above 10 ppm are tagged and entered into the work management system for quick resolution.

Valve testing/preventive maintenance. Test the plant's emergency stop valve on an annual basis (at a minimum) and confirm proper operation of all of hard-wired inputs—such as emergency test button, high pressure trip switches, etc.

In addition to the work performed in coordination with ATS, plant staff contributed to the following program enhancements:

Remote gas-sensor calibration. Gas sensors in turbine enclosures are impossible to calibrate while the unit is operating, because of the high temperature. The plant I&E staff installed a remote calibration system so that the sensors can be safely calibrated from outside of the enclosure. This ensures that the sensors stay in calibration year-round without having to shut down the turbine to perform this task.

Remote methane leak detectors/handheld gas detectors:

- With the support of PG&E's Leak Survey & Damage Prevention Dept, the plant obtained a Remote Methane Leak Detector (RMLD, Fig 2).

  Plant O&M staff received training on the proper procedures and operation of the RMLD, which provides a safe and reliable method of identifying gas leaks up to 100 ft from the source. This is especially useful when checking for leaks on an operating GT since leak detection can only be safely done from the door of the turbine enclosure.
- In addition to the RMLD, the plant has several reliable methods of gas detection (Fig 3) and staff members receive comprehensive training on the safe operation, calibration, and use of these devices (Fig 4).

4. Comprehensive training is provided to ensure safe operation and calibration of gas-detection instruments

Results. The collaborative efforts of the PG&E team led to a comprehensive program that ensures gas-system components remain safe and reliable. Any issues found are addressed quickly and all of the history is properly documented in the work management system. Having a combination of support from subject-matter experts and plant employees ensures that everyone is involved in the process and key activities are performed in a timely manner.

Project participants:
Stephen G Royall, director of fossil and renewables
Ben Stanley, senior plant manager
Steven Anderson, maintenance supervisor
David Poffenbarger, technologist, ATS

Amman East

Amman East Power Plant

AES Jordan PSC

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

Plant manager: Meftaur Rahman

PDCA methodology reduces startup losses

Best of the Best

Challenge. Jordan, a rapidly growing country lacking indigenous energy resources, relies heavily on imports to meet its growing demand. Natural gas is brought in from Egypt via pipeline, fuel oil from Saudi Arabia via ship.

AES Jordan's Amman East Power Plant, a 420-MW, 2 × 1 combined cycle located in Al Manakher and designed for base-load service on gas, is now starting daily and operating on fuel oil because gas is not available. When the plant burned gas it averaged about 10 starts per year; today, operating on oil, it starts about 240 times annually.

Startup losses are significant on oil and the Amman East team studied how to reduce them, beginning with a review of current procedures and manuals; also, by benchmarking their operation against plants in Jordan as well as in other Middle Eastern and European countries.

According to AES Jordan's Power Purchase Agreement (PPA), the plant is not limited on the number of annual starts. This affords an opportunity to improve performance beyond typical market metrics. Bear in mind that frequent starts and stops create many challenges in plant performance—for example, heat rate, water consumption, and noise for the local community.

Some challenges were observed during the frequent startups on oil, including these:

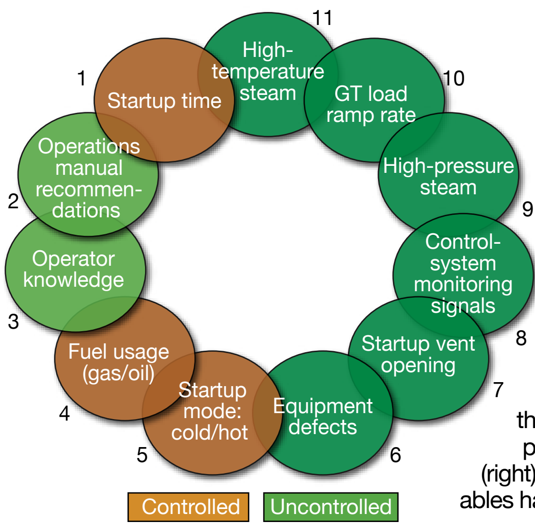
- Lower efficiency (higher heat rate) at low load, increasing fuel consumption.
- Increased water use attributed to high-pressure steam loss from the startup vent.
- Although the business meets World Bank guidelines regarding startup noise, the frequent starts disturb the local community—especially during the early morning hours.

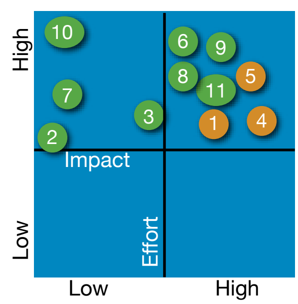
The plant's goals were the following:

- Reduce heat-rate losses during startup to save $70,000 to $100,000 annually.
- Reduce water consumption by 1300 to 2600 gal per start.
- Determine how to reduce noise during startup by 2 to 7 decibels (dB).
- Reduce startup time by 20%.
- Develop a more cost-effective startup procedure for operations personnel.

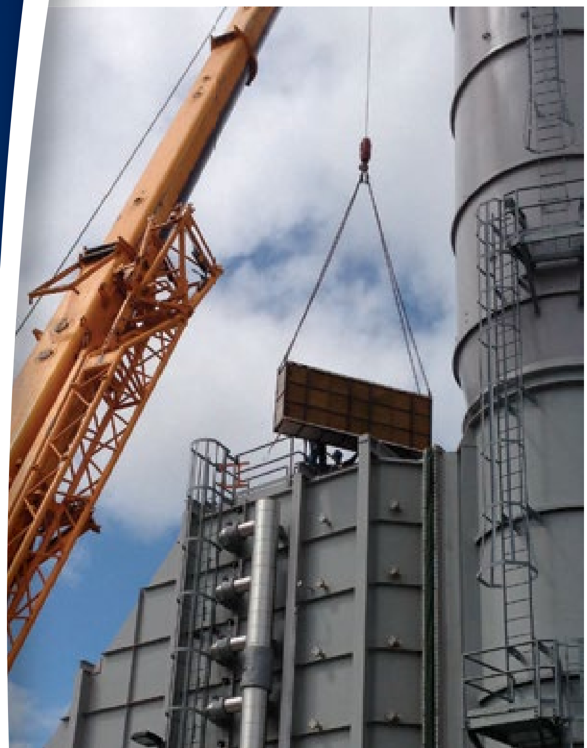
Solution. The team used "Plan, Do, Check, and Act" (PDCA) methodology and related tools, such as Ishikawa and brainstorming sessions, to meet the stated goals. The 5W2H technique was subsequently used to support the analysis with specific targets, because of the various issues raised.

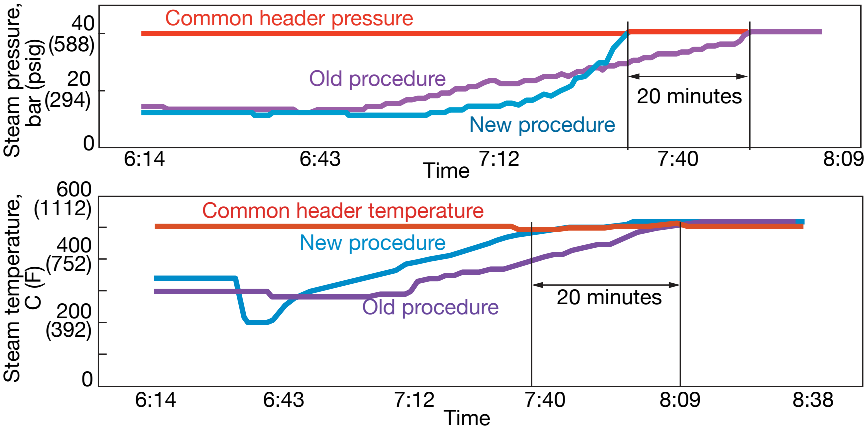
The PDCA method then was applied to test proposed solutions, ensuring their impact and sustainability. Plant management engaged the operations staff to analyze the situation and find an innovative solution. The results illustrated teamwork and process. After identifying the variables impacting startup performance, the team used a cause-and-effect diagram to find the most significant factors affecting the startup process (Fig 1).



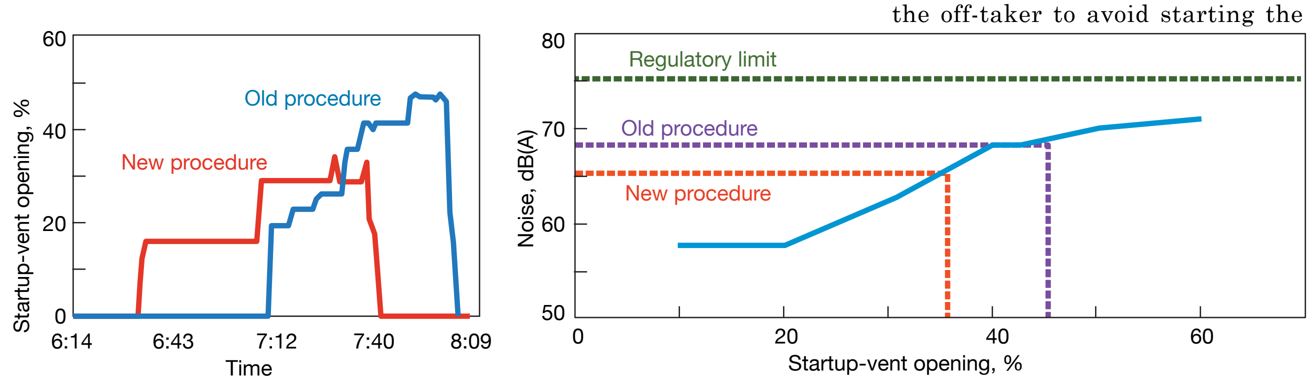


1. Brainstorming sessions identified key factors affecting startup performance (left) and the relative impact each of these parameters has on that process (right). The matrix shows which variables have greatest economic impact, which are easiest to improve





2, 3. Gas-turbine load ramp rate was lower than suggested in the OEM's operating manual, stretching out the startup and increasing the time required to raise steam pressure (above) and steam temperature (below) to the so-called merge values required in the header supplying the steam turbine



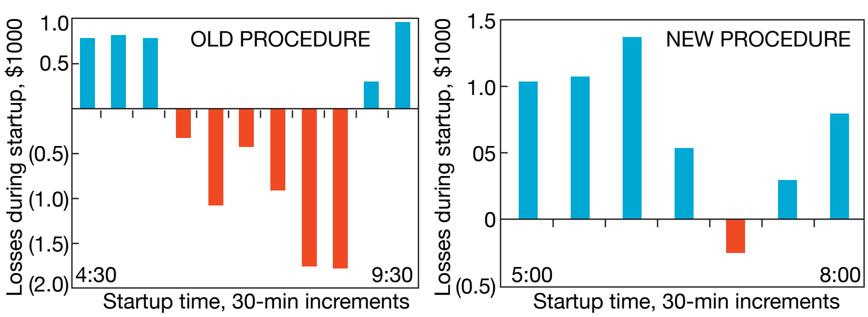
4, 5. Startup-vent operation in the old procedure initiated later in the startup process than with the new procedure (left); plus, the valve opening was greater in the former (47%) than in the latter (35%). Thus the new procedure reduced both water consumption and noise (right)

These four root causes of startup performance loss were identified:

- Gas-turbine load ramp rate was lower than recommended in the operations manual, increasing the time required to start up and the time required to raise steam pressure and temperature to the 588-psig/932F required for steam from both HRSGs to merge and flow to the turbine.
- Operations personnel were opening the sky vent wide (45% of full flow) late in the startup process, thereby releasing to atmosphere a large quantity of high-pressure steam. This procedure contributed to high water consumption and excessive noise.
- Operations staff knowledge and awareness of heat-rate losses during startup was shallow and needed improvement.
- Distributed control system (DCS) monitors did not show ramp rates for pressure, temperature, and load, nor indicate startup duration.

Solutions implemented included the following:

- Increase GT load ramp rate from 0.27 to 0.38 MW/min by increasing the ramp-rate set point. This helps to reduce the startup time by 20 min (Figs 2, 3).
- Open the sky vent to 18% of rated flow when the GT is synchronized; then follow the curve in Fig 4 until pressure and temperature reach the 588-psig/932F merge values noted earlier.
- Increase operator awareness regarding startup losses and ways to control them by conducting both training sessions and day-after discussion of the previous day's startup.
- Added ramp rates in the control screen for pressure, temperature, and load.



6. Losses during startup associated with the old procedure are at left, new procedure at right

Results. With the development of, and efficient startup procedures for, cycling on both oil and gas, staff has become more knowledgeable and efficient regarding the startup process and loss minimization. Implementation of these solutions successfully saves around $100,000 annually and reduces startup duration by 20%. Also, the solutions can be replicated across the eight combined-cycle plants in Jordan.

From an environmental perspective, Amman East now saves around 650,000 gal/yr of water, ensuring the plant will not exceed permitted consumption. Noise pollution is mitigated both by optimizing opening of the startup vent, which reduces noise by 5 dB, and collaborating with the off-taker to avoid starting the plant during late night and early morning hours. Plus, plant personnel decided to install a vent silencer at the next outage. The plants success in controlling startup losses is profiled in Fig 6.

Project participants:
Meftaur Rahman, plant manager
Anas Diab, performance manager
Implementation team: Khaled Titi, Mohammad Yacoub, Mohammad Zaghal, Ahmad Khalil, Ahmad Kteifan, Ahmad Abu Gosh, Anas Ayajneh, Abdrahman Ismail, Hussein Sanee, Zaher Hasan

Dogwood

Continuous monitoring system improves battery safety, maintenance efficiency

Best of the Best

Dogwood Energy Facility

Owned by Dogwood Power Management LLC

Operated by NAES Corp

650-MW, gas-fired, 2 × 1 combined cycle located in Pleasant Hill, Mo

Plant manager: Steve Hilger

Challenge. When Dogwood Energy Facility placed an order for a new vented lead/acid battery system management decided to investigate the benefits of supporting that purchase with a continuous monitoring system. O&M personnel typically agree that battery systems are among the most labor-intensive devices in the plant concerning monitoring and testing. This is ironic given their static nature and infrequent use. But because of the importance of batteries during emergencies, and the amount of monitoring and testing required by regulatory authorities, they are heavily scrutinized during NERC audits and are an easy target for violations.

Solution. Dogwood Energy looked into the benefits of installing full-time monitoring. Most obvious was the convenience of collecting in one location bank voltage, cell voltage, float amps, and cell temperature; however, staff wanted to justify monitoring based on more than just convenience. Plant personnel learned that continuous monitoring offered significant safety benefits as well.

Like many powerplants, Dogwood has a battery arrangement where the upper row of cells is set above and stepped back from the lower row. The person taking readings often requires a ladder to reach the upper row and then has to lean across the lower row of cells. This must be done for each of 30 individual cells. Any time you are dealing with individual cells there is the risk of shorting one or more cells by contact with the posts of the batteries.

Maintenance of vented lead/acid batteries includes taking specific-gravity readings frequently. This means dealing with the electrolyte, an acid. Protective gear is required to protect against chemical burns and other injuries. So how does having a monitoring system address taking samples for specific gravity and dealing with the electrolyte? IEEE 450-2010 states that "For technologies other than lead antimony, if battery float charging current is not used to monitor state of charge, specific gravity must be checked [number of cells depends on the periodicity of the test being performed]."

Dogwood wanted its diagnostic system to monitor the float current of the plant's lead/calcium batteries. This would eliminate the need for personnel to perform regular testing of the electrolyte—thereby eliminating the chemical hazard as well as the chance of inducing a short in the battery system by reaching over cells.

Another benefit is the increased efficiency of data collection attributed to pure convenience. The system would allow personnel to download data for regular trending and reporting over long periods. The monitor also can be programmed to alarm at a specific value of a specific variable.

Results. Dogwood decided to install two monitors on its new lead/acid batteries for the steam turbine system, based on the decisions mentioned above. Plans are in place to extend the monitoring capabilities to the control room this year. Also, monitors for the gas-turbine battery systems will be installed in 2015, concurrent with battery replacements on those units. Even though readings will be made remote from the location of the actual batteries, it is Dogwood's philosophy that battery monitoring does *not* replace the need to conduct regular local visual inspections; however, the personnel risks associated with regular visual checks have been eliminated or greatly minimized.

Project participant:
Glenn Brons, maintenance coordinator

VRLA to VLA battery replacement

Challenge. Dogwood Energy personnel tested the plant's valve regulated lead/acid battery system (VRLA) in April 2013, finding that its performance had degraded to approximately 82% on Bank 1 and 85% on Bank 2. The configuration of the battery system was two VRLA batteries in parallel, tied into the DC system through battery disconnects.

The loads on the battery system are the steam-turbine emergency lube-oil pump, steam-turbine emergency seal-oil pump, relays associated with the steam-turbine electrical system, and emergency backup to the DCS power supply via a converter.

IEEE 1188 suggests replacing the battery system once performance levels drop to 80%, Dogwood's stance was to make that decision at 85%.

Dogwood Energy had experienced a thermal-excursion event with its VRLA battery system in 2007 at which time both battery banks were replaced in kind. Given the emergent nature of this event, no time was available for researching the viability of alternative options.

Solution. Tests conducted in 2013 enabled plant personnel to plan the replacement of the existing battery system during the 2014 calendar year, allowing time to research technology options. Other goals included the following: Assure (1) the new battery system was configured and rated properly for the expected load, (2) the adequacy of ventilation requirements and other peripheral considerations, and (3) proper budgeting.

These three technology options were the focus of attention:

- **VRLA**—the original battery system for the steam turbine/generator and the option having a capital-cost advantage over the two alternatives. This sealed system often is promoted as being fairly maintenance-free because there is no need to check specific gravity or deal with electrolyte additions. Given a VRLA system already was installed, existing racking would work with an in-kind replacement and no changes would be required to the room or environment. Further, because maintenance practices already were well established there would be no change to the PMs and no additional training would be required.

  However, experience at Dogwood indicated the overall effective life of a VRLA system was only about seven years. Plus, load testing, a major expense, is required every other year. Furthermore, the possibility of a thermal excursion exists with these batteries, and there is the likelihood that individual jars would require replacement during the system's expected lifetime.
- **VLA**—vented lead acid (or flooded) battery. Dogwood had VLA battery systems installed on its gas turbines. Thus staff was familiar with VLA maintenance, which requires regular specific-gravity tests—unless battery monitoring and float amperage are available. Refilling of the jars with distilled water is necessary, but with load testing it can be pushed out to a five-year periodicity. Existing preventive-maintenance procedures for the GT systems would be rolled over to the new system.

  But before a VLA could be considered for the steamer, adequacy of the ventilation system would require confirmation and hydrogen monitoring added. New battery racks would be needed and they would have to fit within the existing space. A benefit of VLA systems is longevity. They should provide at least 15 years of reliable operation with proper maintenance; many systems last for two decades.
- **Nickel cadmium.** NiCad batteries are considered the most reliable of the three battery systems evaluated for the steam turbine/generator and they have a lifetime well beyond that of the VLA. They are much more forgiving of variations in operation temperature than the alternatives discussed above, but ventilation would be a concern for this retrofit project and require verification. Adequate space is another concern. Other requirements include new battery maintenance procedures and training.

Results. An ROI analysis revealed the NiCad system was not a viable option because of its high first cost. The only remaining questions concerned the changes required to accommodate VLA batteries as opposed to staying with the VRLA. The battery-room ventilation system was tested and found to meet VLA requirements. Hydrogen monitoring would be needed and staff proposed installation of a very early smoke detection apparatus (VESDA) system to sample for hydrogen accumulation along the ceiling.

Next was to determine if the battery room was large enough to accommodate VLAs, which require more space than VRLAs. It was. Rigorous analysis suggested Dogwood switch to VLAs.

The new system has been in operation since spring 2014 and has operated flawlessly. The Dogwood staff was able to roll over the PMs from the GT battery system directly to the new system for the steam turbine/generator with no additional training.

Project participant:
Glenn Brons, maintenance coordinator

Startup flexibility enhancements

Challenge. With the startup cost for an F-class gas turbine ranging up to about $15,000, combined-cycle plants often are forced to choose between efficiency and flexibility to capture opportunities in the power market. Startup fuel costs can vary widely because of dated control automation schemes and degraded field equipment/ instrumentation. Even with mechanical advancements to the starting and loading capabilities of the gas turbine, the HRSG and steam turbine operation still impose startup constraints.

Solution. Dogwood Energy undertook a project starting in fall 2013 and continuing into spring 2014 to upgrade and merge five existing plant control systems into a single consolidated platform. Dogwood worked with Siemens Energy Inc to implement this solution.

The enhancement strategies at Dogwood were based on Siemens' SPPA-P3000, coupled with advanced automation control schemes to provide operational benefits and startup fuel savings through dynamic GT ramp rates that considered the following: maximum allowable stress for HRSG components, corrections to improper bypass operation, and changes to the HRSG steam-drain operation to enable faster turbine roll.

The process of optimizing powerplant operation is particularly demanding if it is to be achieved without costly modifications to mechanical equipment with the objective of reducing startup costs. The Dogwood solution met expectations with a pure software-oriented approach to optimization.

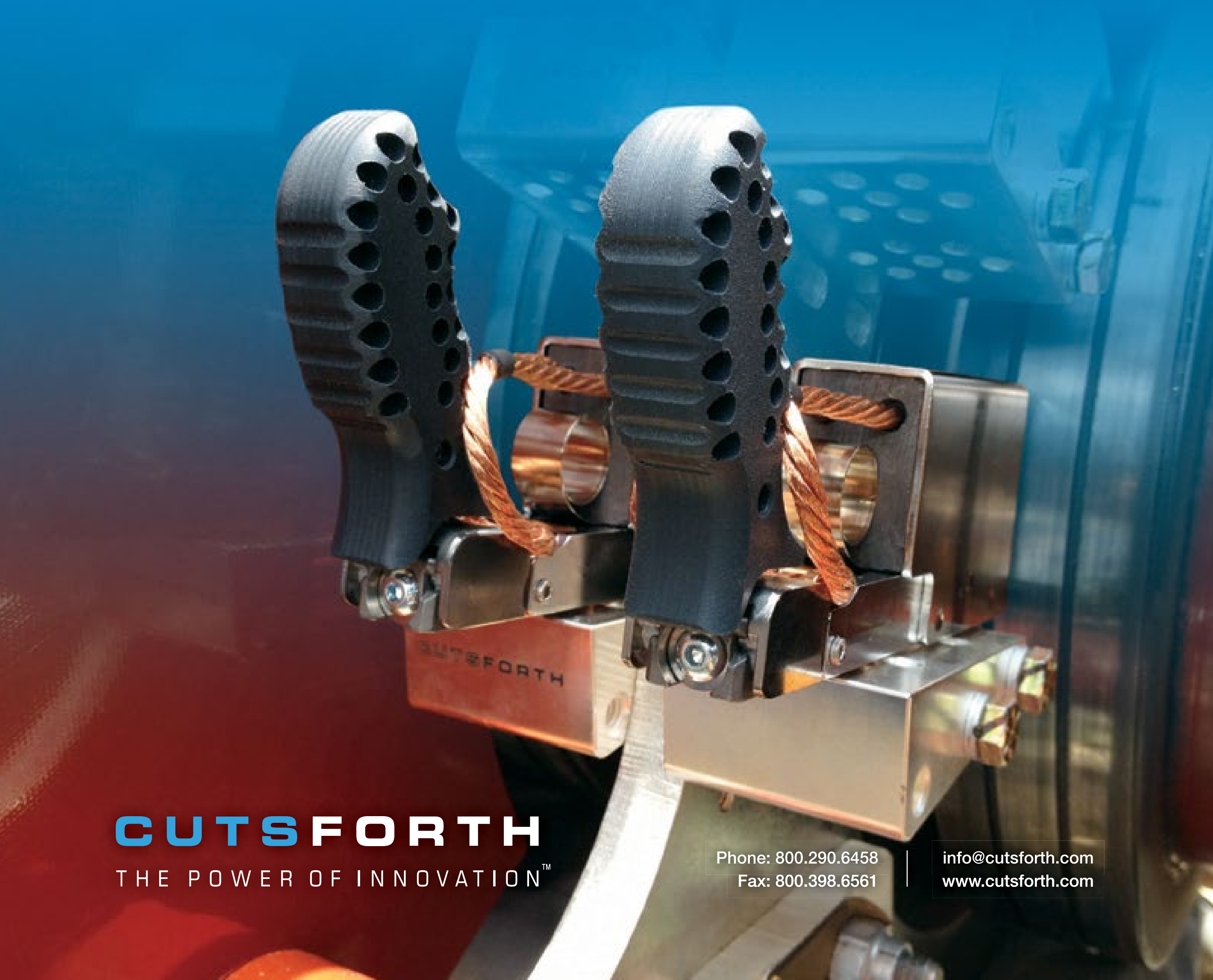
Startup optimization reduces costs

Change The Way You Change Brushes

Cutsforth has replaced more than 20,000 OEM and after-market brush holders with the EASYchange® removable carbon brush holder. Not only do our holders make brush changes safer and easier to perform, they also reduce or eliminate many of the operational and safety problems that plague turbine generators. Call us today so we can show you the benefits of EASYchange®.

---

*For more information about the Cutsforth EASYchange® Carbon Brush Holder, visit us online at **www.cutsforth.com**, or contact us at **800.290.6458**.*



CUTSFORTH
THE POWER OF INNOVATION™

Phone: 800.290.6458
Fax: 800.398.6561

info@cutsforth.com
www.cutsforth.com

through fuel savings, startup consistency, and a predictable dispatch startup timeline. At Dogwood this was achieved by increasing the level of automation, improving legacy automation schemes, and process optimization. Here are the details:

Increased level of automation

- Manual operation was replaced with an automatic solution for coordinated pressure control.
- Automating drain-valve operation reduced the inconsistency among operational teams.
- Blend in/blend out of the lag CT was automated to reduce fuel consumption.

Improved legacy automation schemes

- Advanced drain-valve automation.
- Advanced main-steam (HP) and hot-reheat (HRH) bypass concepts.

Process optimization

- Controlling boiler stress at selected thick-walled components with a predictive load margin computer (PLMC).
- Advanced HP and HRH temperature control concepts with stress-based control of steam- temperature ramp rate.
- Fuel-cost reduction from GT ignition to combined-cycle operation.
- Modified and optimized break points in the loading profile during startup.

The optimization system computes thermal stress and calculates permissible operating margins based on the material properties the process conditions. The stress and the corresponding margins are displayed and are used to influence the dynamics of the unit. To minimize thermal losses it is desirable to operate as close as possible to these limits.

The PLMC is a prediction tool which calculates the optimal process conditions at the current point in time, allowing use of all of the allowable stress margins while not exceeding them. This enables plant personnel to make earlier operational adjustments.

Results. Having all plant components under one controls umbrella—including gas and steam turbines and balance-of-plant systems—allowed the project team to improve operational flexibility, reduce startup times, and minimize fuel consumption for cold-, warm-, and hot-start conditions. In sum, a faster startup provides economic benefits by reducing costs and environmental impacts while increasing dispatch opportunities.

Through the 2014 summer operating season, Dogwood personnel conducted 176 cold, warm, and hot starts and attributed the following benefits to the startup flexibility enhancements:

- Reduced fuel consumption by 154,954 million Btu, thereby saving $658,553 during the first few months of the program.
- Fuel consumed by the lead GT under for warm- and cold-start conditions was reduced by approximately one-third, and blend-in of the lag GT from ignition to unit coupling was reduced by nearly 50% under warm-start conditions.
- Dogwood's startup times were reduced for lead-unit cold starts by approximately three hours, by about 80 minutes for warm starts, and by approximately 10 minutes for hot starts.

Project participants:
Chuck Berg, plant engineer
Rob Glesmann, VP engineering
John Sorrick, Lead ICE tech
Dave Zalfen, Lead ICE tech
Mike O'Reilly, Lead ICE tech
Dwight Beatty, O&M manager
Glenn Brons, maintenance coordinator
Karl Schultz, CRO
Mike Curry, CRO
Jeff Hamrick, CRO
Mike Davis, CRO
Shawn Swinney, CRO
Entire NAES plant O&M staff
Siemens Energy Inc controls group

Evap-cooler preventive maintenance

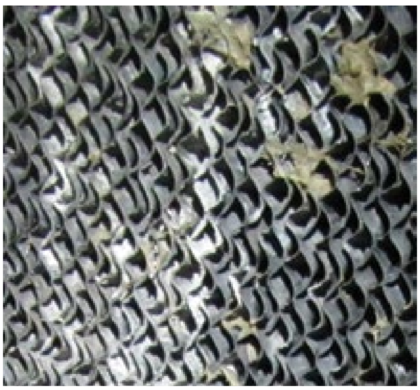
Challenge. The leading edge of evaporative-cooler media was beginning to plug from a combination of outside air contaminants and evaporation salts, increasing pressure drop and reducing efficiency. Air contaminants also were plugging holes in the distribution pipe and creating water distribution issues (Fig 1). Evaporative salts were building up in areas with poor water distribution as well as where the leading edge of the media was experiencing water starvation (wet/dry conditions) during operation (Fig 2).

Solution. To return evap-cooler media to good condition and maintain optimal operation going forward, the following inspections and corrective actions were undertaken by plant staff:

- Detailed inspection revealed a few of the filter housings were cambered during installation, allowing air to bypass the media and permit contaminants to enter the compressor. This installation error was corrected.
- Distribution pipes were cleaned to assure proper water distribution across all media.
- Control and monitoring measures were implemented to maintain dissolved solids within the specified range.
- Inhibitors are added to the system water to prevent scale build-up.
- Control logic was revised to allow evap-media water pumps to operate for 60 minutes after unit shutdown to clean the leading edge of the media. If this does not promote proper cleaning, plant personnel can use a foaming chemistry to achieve desired results.

Results. The evap media in each unit is running at design pressure drop, thereby recovering the efficiency losses originally experienced.

Project participants:
Mike Curry, CRO
Chuck Berg, plant engineer
Dwight Beatty, O&M manager



1. Contaminants removed from outside air deposited on the leading edge of evap media and also were plugging up holes in the water distribution pipe, reducing cooling capability

2. Evaporative salts build up in areas where water distribution is poor and where the leading edge of the media experiences water starvation

Waterside

HMI upgrade to auto start dramatically improves reliability

Best of the Best

Waterside Power LLC

Owned by FREIF North American Power I LLC

Operated by Consolidated Asset Management Services

72-MW, oil-fired, three-unit, simple-cycle peaking facility located in Stamford, Conn

Plant manager: William Jolly

Challenge. Waterside Power, an emergency oil-fired peaking plant located in Stamford, Conn, is equipped with three trailer-mounted TM2500s. ISO New England (ISO-NE) requires this facility to meet the grid's generation requirement within 30 minutes of an electronic or telephone dispatch. The site recently reduced staff from five employees to just three, including the plant manager.

Waterside generally took about 15 minutes to reach full load, and with manual operation required for some systems, that time increased after losing two operations positions. The only operator on shift would have to leave the control room at critical times during the startup process to energize various systems manually. Also, with fewer people on staff there was a greater chance of a missed communication and a lost generating opportunity.

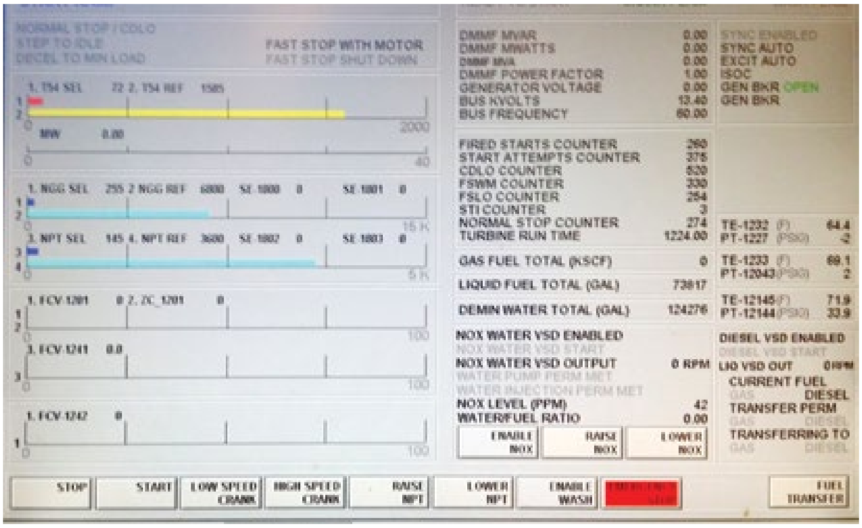
Additionally, ISO-NE recently implemented much stronger penalties for not meeting the 30-min dispatch requirement and for the failure to provide reserve. This is a relatively small project and the inability to meet grid needs even one time could jeopardize the plant's future.

To better understand the business risk associated with continuing to operate the plant in the usual manner with the reduced staff, think of one person performing the following functions using the existing startup process: Operator receives a dispatch, confirms the dispatch, and manually starts each unit while tending to auxiliary systems—some with automatic functions, some manual operation only. This might not sound so challenging until you look at the details for some of the steps involved. Consider the following:

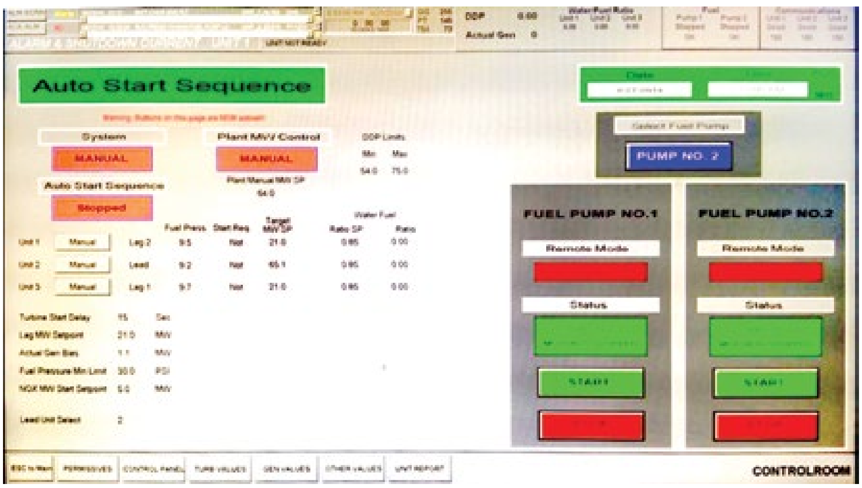
Operator confirms the dispatch and then walks down to the fuel building to energize the fuel pumps. That task complete, the operator returns to the control room to verify all permissives have been satisfied. Now he can start the first of the three gas turbines, then the second, and finally the third (assuming all units are required).

Bear in mind that when the operator is ramping up one unit, another GT (or both units) is in a different stage of the startup process, requiring the operator to switch screens and tend to other needs based on a given unit's stage of operation at that time. There's more: While all this is in progress, the NO_x system had to be started manually and the water-to-fuel ratio maintained manually to stay within air-permit limits.

Needless to say the foregoing regulatory requirements and equipment limitations created a high-stress environment for operations personnel.



1. Original HMI allowed CRO to monitor and operate Waterside's three gas turbines on an individual basis only



2. Upgraded HMI enables CRO to operate all plant systems from a single screen

Solution. The HMI was upgraded to automatically start the plant, reduce start time, and keep the operator focused on safe operation while meeting required real-time dispatch requirements.

Total automatic-start capability is one feature of the upgraded HMI. It works this way: When a dispatch directive is received electronically, the HMI can initiate the start sequence to meet the specified output requirement anywhere in the range from 0 MW to the desired dispatch point (DDP). One

Solving the Gas Turbine Back-up Liquid Fuel System Reliability Issue

Addressing system inadequacies is a fundamental part of improving the overall reliability of the liquid fuel system and its related components. High system and environmental temperatures naturally create a situation ideal for coke formation. Operationally compromised control system components are responsible for the inability to start on liquid fuel or transfer from gas to liquid fuel.

Check valve failures, flow divider failures, fuel system evacuation, exhaust temperature spreads and other related turbine trips have been resolved with an array of patented designs developed by JASC including:

- Water cooled valves for prevention of coking formation.
- Water cooled 3-way purge valves with a water cooled flange for use on DLN turbines using primary and/or secondary liquid fuel.
- Smart Fluid Monitor providing leak detection and automatic shut-off of cooling water to valves and flame detectors should faults occur.
- Multiple-use crush gasket technology which replace O-rings and are rated for 750°F ambient at 2000 psi.

These system specific products have three common design goals. First, provide reliable valve function and system operation for a minimum of 32,000 hours or until a scheduled turbine service interval is reached.

Second, the valves must maintain better than ANSI Class VI sealing capability from installation until removal for refurbishment. Elimination of combustion gas back-flow results in back-up fuel system availability and reliability typically exceeding 98%.

Third, incorporation of JASC's new metal to metal seal fitting design serve as replacements for O-rings and other elastomeric materials.

The "Tee" designs can be used on standard or DLN fuel nozzles, they are SAE J1926 compatible, provide adjustable orientation for easy connection interface to existing piping and are rated for continuous service at 750°F ambient and 2000 psi.

JASC's solutions are configured to be interchangeable with the turbine's existing hardware. This minimizes project cost and time associated with performing a fuel system upgrade.

Transferring from gas to liquid fuel, starting on liquid fuel and executing these sequences without tripping the turbine allows systems to be exercised regularly with no negative impact. Case studies of power plants which have performed JASC fuel system upgrades reveal that after five years of operation, maintenance typically consists of normal refurbishment of the JASC check valves.

Two decades of innovative product development and implementation demonstrates that gas turbine owners can realize significantly reduced operation and maintenance costs when a JASC fuel system upgrade is performed.

Learn more about JASC's unique products and services by contacting your local Power Generation representative: http://jasc-controls.com/about/partner-alliances

Positional "Tee" with liquid fuel check valve and purge air check valve

JASC®

of the two 100% fuel pumps is started and shutdowns are cleared. Start permissive received, the HMI brings the lead unit online. This process is repetitive for all units and happens simultaneously.

The full-auto start option, although not preferred over the alternatives, is used mainly when the operator on shift is not at his post or is making rounds when the dispatch request is received. In this mode, when dispatched, the plant will start to come online. The operator may hear the plant starting up or he may receive a verbal dispatch order along with the electronic dispatch. In any event, he has sufficient time to return to the control room, verify a dispatch has been given, and based on that information, continue with the startup process—or not, if the dispatch order cannot be verified.

Alternatively, the DDP, equipment-manufacturer operating limits, and regulatory commitments are input manually before putting the system in auto mode. These manual inputs are as follows:

- Select a lead unit. This unit will cycle load to maintain various load changes that are received during a plant dispatch.
- Select lag units. These units will ramp to a specified "max MW" set point. This number is based on machine operating parameters and contractual commitments with the dispatch authority; the operator can change status based on de-rates or site-specific needs at that time.
- Select a minimum and a maximum DDP set point that complies with contractual commitments and machine capabilities. The purpose here is to not allow a false start to an erroneous DDP, or run the machines outside their design capabilities.
- Select NO_x water-to-fuel ratio to meet permit requirements; also, set the NO_x-water pump to start at a desired output. This is 5 MW based on the current SOP (Standard Operating Procedure), but the plant did want the capability to adjust that because operating conditions can change.
- Select actual generation bias. The intent here is to ensure the plant is meeting its dispatch requirement. To illustrate, assume the DDP specified by ISO NE is 46 MW. If the plant is producing less power at the 30-min mark on a reserve dispatch, the site's performance factor would be reduced. The operators generally use a 500-kW bias; that is, no matter what the DDP, the plant tries to produce 500 kW more than the dispatch request.

Auto-start operation is initiated manually when the CRO receives and confirms a dispatch. Operators typically favor this option because it gives them the ability to verbally confirm a dispatch prior to toggling the manual/auto switch to auto. All presets and start functions are the same as for fully automatic operation, except that plant's auto start is based on a DDP change.

Manual operation is virtually the same as the original HMI starting process, but once the plant is stable, the CRO can switch to auto to follow DDP changes automatically.

Finally, the auto-start functions are duplicated locally in each unit's control cab. This way, if the operator has to go to any unit for monitoring and/or troubleshooting, he or she can monitor, start, stop, and/or adjust any of the GTs from any unit's local control room.

Results. Since the HMI automation project was completed, Waterside has responded to 29 fast-start emergency dispatches without a failure and made 40 successful starts without an operator error or a trip of any kind. Based on the plant's historical data, these are records. The operators are less stressed today and have confidence in the system. It has allowed for more freedom to walk systems down during a dispatch, even with the staff reduction.

The plant has reduced to 10 minutes the total time from dispatch to DDP. In sum, the HMI upgrade has contributed significantly to Waterside's success and reduced the chances of missing a dispatch.

Project participants:
The Waterside plant staff

Automating a fuel forwarding system

Challenge. Reliable starting and operation are critical to Waterside's success. Two areas of the plant, in particular, that, if not functioning properly, could compromise Waterside's ability to meet its grid commitment are the fuel forwarding system and switchyard/main in-service GSU. Plant staff looked into what could be done in these areas to offset the staff reduction, reduce starting time, and mitigate risk to the degree possible during a fast-start dispatch.

The fuel forwarding system has two 100% pumps arranged for lead/lag-type operation. If fuel pressure drops below that required by the gas turbines because the lead pump is lost, the lag pump will start. If there is a failure to start, or an operator cannot get to the fuel forwarding building quickly when needed there, Waterside may not meet the 30-min fast-start requirement.

Regarding the switchyard and main in-service GSU, any failure in this area would render the plant totally out of service.

It is important to keep in mind that the cost to the project for failing to dispatch when called upon would be severe.

Solution. Evaluation of the fuel forwarding system identified several areas that could mitigate some risk and reduce response time even with the smaller operating staff. One of the proposed changes was to automate the pumps so the operator could start, stop, and switch pumps on the fly (if need be) from the HMI. This option would alleviate the need for an operator to leave the control room during critical operating modes, allow the monitoring of pump pressure and flow from the control room, and enable the operator to visually confirm a failure to start.

The facility opted to automate this system. The automation consisted of pulling 16 new conductors (wires) through existing conduit, from the fuel forwarding building to the control room about 400 ft away. Plus, installing a PLC in the control room to accommodate the new operation and have enough spare points for additional systems as needed.

The PLC communicates with the HMI through an installed Ethernet cable. The HMI upgrade created a screen for personnel to start, stop, and monitor system conditions in the control room. After modifying the lead/lag control in the local fuel-pump control panel, both pumps can be left in the automatic mode and controlled by the PLC.

Results. Since implementation, the plant has reduced its start time by 90 seconds. With a fast-start reserve unit responsible for being at a DDL in 30 minutes, every second counts. The operator can stay in the control room, start the pumps, and monitor all plant activity—and answer phone calls during high-stress situations—without leaving his post. The operator also can start, stop, and monitor the fuel forwarding system from the HMI, where previously he would have had to leave his post to change pump status.

This upgrade, along with several others, has reduced total start time at the facility to 11 minutes with a 50% reduction in operations staff.

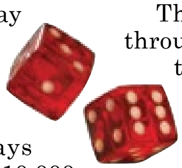
Project participants:
The Waterside plant staff

The new electricity casino: Preparing your GT assets

Editor's note: This article is based on an in-depth conversation with managers of a large gas turbine (GT) fleet in an area with heavy wind penetration.

By Jason Makansi, Pearl Street Inc

Over a long period of time, if you are "in" the stock market on the best days, and avoid the stock market on the worst days, your overall returns are astronomically higher than if you just put you money in and go away for a few decades.



This truism of playing the market has many variations but here's one: If you missed the best 40 performing days between 1993 and 2013, a $10,000 investment in the S&P 500 shrunk to $8149; if you avoided the worst-performing days during that period, your $10,000 investment would have been almost 900% higher.

Twenty years ago, I used this example in an industry presentation to illustrate for an audience of control-system engineers where electricity deregulation was headed. Today, this reality has come to pass, but with a few unexpected twists.

Imagine you are responsible for a fleet of simple-cycle gas turbines and combined cycles. The wind energy penetration in your balancing area is rising past 40%. Coal units are being retired because of uneconomic environmental investments.

Your GT assets are operating in a casino-like environment, and wind enjoys the house odds. What's more, your ability to make money when you are "in the market" (dispatched and online) is less than the chance of losing your shirt if you *say* you can be online and you fail.

In other words, it's about reliability. You make money filling in around wind producers. Value isn't about producing energy or getting paid for capacity. It's about being able to start when you say you're going to start, putting online whatever load the balancing authority demands, and remaining online until told to shut down. There is no wholesale market; it's all day-ahead and real-time. Real time means pushing the start button within 30 seconds of receiving the call from the system operator.

It's about extreme flexibility. In this world, it might be that a simple-cycle Frame 7 starts and stops up to seven times a day; three starts is a regular "day at the office." Such GTs must be capable of 10-min start times, because that's the threshold set by the system operator.

This need for flexibility ripples through the supply chain. The gas transmission folks are managing your starts and stops too. Your fuel contracts probably aren't optimized for 20 separate one-hour fuel deliveries over the course of a week.

Your large coal-unit brethren in the fleet are cycling from minimum to maximum load *within an hour,* and the smaller coal units start and stop daily. Every fossil unit in the fleet, in fact, operates with wind energy as its master.

You don't really know from day to day or hour to hour if you are going to make any real money. What everyone does know is that the wind guys and gals get $38/MWh because of the federal and state subsidies. Their risk has to do with the weather, not whether they're going to get paid.

What the GT fleet manager also knows is that the penalties for not "doing what you say you're going to do" are severe. You can lose an unbelievable amount of money in a few hours. In this balancing area, whole groups pulled their GT fleets out of the market because of losses incurred for "over-promising and under-delivering." In other words, they took their money and left the casino licking their wounds.

Good luck to you if your combined cycle (CC) was intended for base-load operation. A CC that came online at the end of 2004 was designed for 40 to 50 starts per year and had an LTSA with the GT vendor to cover the expected high number of equivalent operating hours and high capacity factor. The plant likely includes a separate startup boiler and a relatively long startup/warmup period. It was not designed for cycling.

Under the new market/balancing area regime with significant wind penetration, the value of the combined cycle's two gas turbines changed dramatically. Both units had a total of 20 starts one year, 34 starts last year, and half of that so far this year. One reason is that starting costs are high, since these units were never designed to start frequently; they were designed to be efficient at their maximum load point (like all base-load units).

In the brave new world of casino electricity, the GT units in the aggregate have been dispatched for energy only during one unseasonably hot summer over the last three years. F-class Frame 7s, capable of delivering 150 MW, might start up just to deliver 25 MW within 10 minutes, run for an hour, and shut down.

Thus, the term "peaking machine" could become a misnomer. These are ancillary-services machines, *despite historically low natural-gas prices.*

What price O&M? Maintenance philosophies have to adapt when your assets essentially pick up the chips falling from the table. Plus, GT OEMs care less and less about supporting and servicing old peaking machines. Management is likely to allocate funds commensurate with your run time—that is, not much.

You need to find and hire the kind of people who can solve problems and fix equipment, comb through historical outage reports, and develop a long-term maintenance plan and strategy.

Controls are a good place to start. Replacing old fuel valves with more flexible ones helps reduce start times. Electronic valve control assists to accelerate ramps on synchronization.

Watch for dead spots in the hydraulics. They can plug up when a unit sits for months on end without operating. It may not be efficient to maintain a higher-than-normal lube-oil temperature when units are offline but it helps keep the machine ready when called upon.

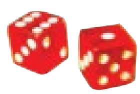
Consider conducting borescope inspections semi-annually. Increase

the frequency of electrical testing, especially for critical circuits, beyond the maintenance guidelines or even beyond what the failure history might suggest. The same holds true for combustion hot-gas-path inspections, generator testing, and rewinds. Be proactive about starting-package issues. In some cases, new control systems or changes to the existing control logic and permissives may be required to ensure that a GT can participate in the 10-min-start market.

Also critical is to adapt your maintenance strategies based on the larger fleet for that particular engine model, not just the operating history of your unit, or the like machines within your ownership. Failures and equipment maladies experienced by other owner/operators should be factored into operating, inspection, and maintenance routines. The value of participating in user groups cannot be under-estimated here.

Been here before. As a historical note, the casino electricity market may be relatively new to the electricity industry but the need for new powerplants to adapt to changing realities on the ground is not. In the 1970s, a fleet of large supercritical coal-fired units, also designed for base-load operation, were added to the grid. Many of these units were almost immediately relegated to cycling because of the nuclear units coming online (which were not allowed to cycle) and a reduction in electricity demand growth caused by recessions, energy crises, and the general economic malaise of that decade.

More recently, dozens of combined cycles installed in the 1997-2005 period were intended for base-load operation, or at least reasonably high capacity factors.



They also were built when the forward price curve for natural gas was "reasonable." The economy tanked in 2001, 9/11 occurred, and by 2007, gas prices were as high as $14/million Btu. Many of these brand new facilities were soon operating at capacity factors around 10-25%, rather than the expected 60-80%.

However, today's situation is unique because of (1) higher renewable-energy penetrations in many parts of the county and (2) greater market mechanisms being applied in the balancing areas. The reality is that intermittent, less-predictable renewable energy assets are favored and are given highest priority for remaining online. They are replacing highly predictable, dependable base-load nuclear, coal, and gas-fired powerplants at the top of the queue.

Until further notice, renewable assets enjoy house odds. CCJ

1. Turlock Irrigation District's Almond Plant added three fast-start LM6000PG peakers, but had to modify the SCR control logic for compatibility with 10-min start and remote dispatch

Align SCR start/stop sequence with GT fast-start requirements

The control of critical subsystems must be compatible with today's fast-start peaking gas turbine/generator units capable of remote dispatch. Turlock (Calif) Irrigation District's Almond Plant (Fig 1, sidebar) learned that, while its three new 54.2-MW LM6000PG units were designed for 10-min start capability, the sub-controls for the emissions-reduction systems were not.

"Fortunately," says TID's Jeff Warner, "we were able to make the necessary changes to the controls in the Ovation™ balance-of-plant DCS."

According to Warner, who presented at last year's Ovation Users Group Conference, the control design articulated by the emissions-reduction unit (ERU) vendor and third-party controls specialist was incompatible with the way the plant would operate in at least two respects: It did not account for the units being started and stopped by TID's dispatch SCADA system, and it interfered with the 10-min start capability.

"The SCR controls were handled separately," notes Warner, "though in fairness, these machines were serial numbers 1, 2, and 3 of the PG series." That meant, for one, that temperature profiles and other operating characteristics important to the SCR design changed. And the remote dispatch kind of threw everyone for a loop. What worked on previous models or projects wasn't appropriate for this one.

The new engines are equipped with water injection for NO_x control and a downstream selective catalytic reduction (SCR) unit downstream for polishing. Water injection is handled within the MicroNet™ GT controls. Although the SCR is intimately tied to GT operation, the controls were handled by a third-party specialist interpreting the SCR vendor's requirements.

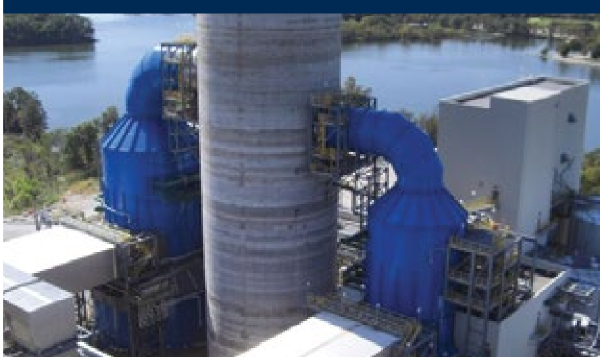
"The 27 pages of SAMA (Scientific Apparatus Makers Assn) and discrete logic from the ERU vendor, used to create 16 pages of control narratives and logic in the BOP software, were confusing and conflicting," Warner said. "Obviously, there's no time to troubleshoot confusing logic within a 10-min start period."

Much of the incompatibility centered on (1) the tempering-air subsys-

INDUSTRY BRIEF
5

MITSUBISHI HITACHI POWER SYSTEMS

NOW ONE Solution for Existing & Evolving Energy Needs for and in the Americas



Maximizing availability, reliability and profitability is the continuing goal of **Mitsubishi Hitachi Power Systems** for existing and evolving energy needs – with a significant local presence of personnel and state-of-the-art manufacturing, maintenance and repair facilities in support of our world class products and services.

World Class Solutions

- Reliable and Efficient Gas Turbine Technology
- Advanced Steam Turbine Technology featuring SRT 50 (large 50" blades)
- Air Quality Control Systems (ACQS) reducing emissions and operating cost while increasing reliability and turndown
- Manufacturing and Maintenance Services from resources based in the Americas

Mitsubishi Hitachi Power Systems Americas, Inc.
www.mhpowersystems.com

tem necessary to keep the GT exhaust to the SCR catalyst within a prescribed temperature range and (2) the ammonia (NH_3) purge requirements for the SCR (Fig 2). More specifically, following an emergency shutdown of the ERU (mostly for personnel protection during an upset), Almond engineers realized that the tempering-air (TA) fans would turn off, overheating the catalyst.

"There were over 250 combinations of transition 'states' in the logic, which is unmanageable," notes Warner. In other words, the logic was not deterministic." However, the ERU control philosophy still needs to protect personnel first and equipment second, from chemical exposure (NH_3 leakage), explosion (loss of proper purge), and electrical and mechanical failures.

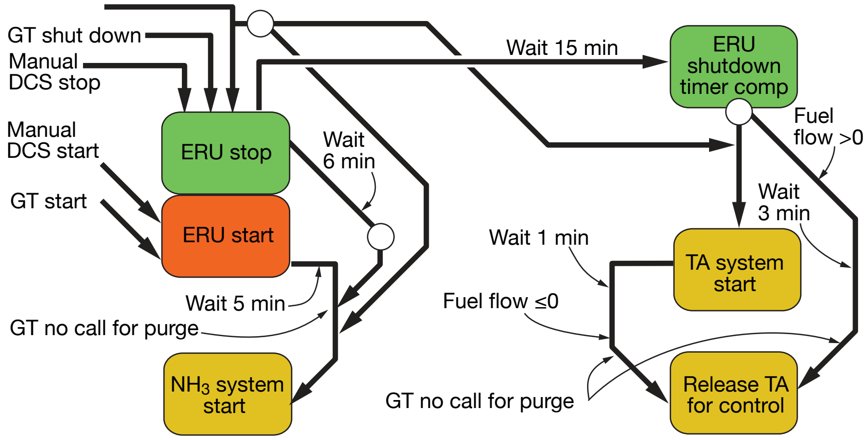
In addition, the ammonia purge cycle times were incompatible with a dispatch-driven plant startup and shutdown, especially in the event of a restart after only a few minutes. "While this is a situation we expect to occur only occasionally, we still have to be prepared for it," stresses Warner. In other words, start/restart within a few minutes is something to avoid but the dispatcher has authority to do so in an emergency.

Although the gas turbine would eventually shutdown on high GT exhaust temperature with the tempering-air fans inoperable, "the catalyst could still be fried" by this time, cautioned Warner.

The solution (Fig 3) proved to be modifying the state transition logic so that the emergency stop also signals the DCS (BOP controls) to close the NH_3 flow stop valve. Energy hazards in the ERU are mitigated in the lockout/tagout procedures, explosion hazards are handled with proper purge and hardware interlocks in the turbine controls, and the possibility of NH_3 leakage is managed with detectors around each ERU. "If ammonia is detected," Warner stressed, "we initiate an ammonia shutdown from the control room."

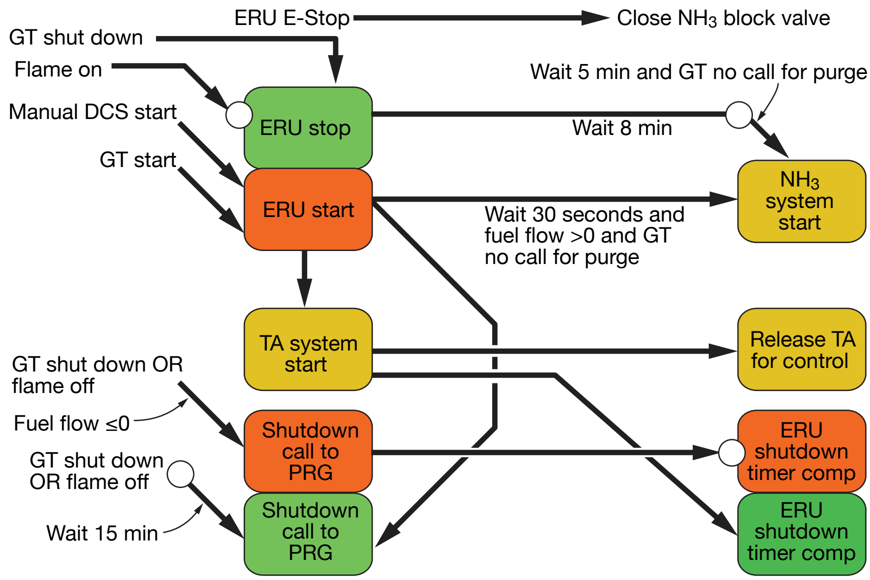
The new logic sequences are much easier for the plant to follow. According to Warner, the modifications have performed flawlessly. "The most important attribute is that the new logic is so much easier to troubleshoot. That's critical when time is of the essence." Ease of troubleshooting stems from the ability to create new logic in Ovation and run it in parallel with the existing logic. "We can test new logic and run it while the plant is running with the existing logic to validate it before making the actual tie-ins."

Running "what if" scenarios has been touted for several years as a key benefit of the latest Ovation platform. TID's Almond Plant is reaping those benefits. "The old logic took hours to troubleshoot," said Warner. In addition, the "state" of the plant is always visible to the operators in the HMI (control room computer screen). CCJ



2. Old SCR control logic allowed hundreds of state combinations and was not "deterministic"

Abbreviations: Prg, purge; GT, gas turbine/generator; ERU, energy-recovery unit; TA, tempering air; DCS, distributed control system; Comp, completed; Man, manual



3. New state transition logic in Ovation is compatible with fast start/stop and remote dispatch, is far easier to troubleshoot, and allows testing and validation of logic mods online

Almond Plant backgrounder

The three new LM6000PG peaking units were commissioned in July 2012 alongside an existing 2003-vintage, 49-MW LM6000PC with heat-recovery steam generator (HRSG). All four gas turbines have MicroNet™ controls.

The original balance-of-plant (BOP) controls, a Bailey Network 90 (now ABB), were replaced with Ovation™ in 2010 as part of the expansion; this activity took place six months before work on the new turbines began. Importantly, the new controls incorporated the original field terminal modules. Complete replacement took only two weeks, according to TID's Jeff Warner.

Data links to the Ovation BOP controls include programmable logic controllers (PLC) at the water treatment unit, fuel gas compressors, anti-icing system, absorption chiller, switchyard relays, weather station, and the MicroNet GT controls.

Among other things, the PG model includes a gearbox which allows more power output. It also requires a tempering-air fan system to protect the catalyst.


NOx/CO Catalyst
Meet **emission standards** with two catalysts in one
Is your plant struggling to meet emission standards without sacrificing performance and profitability? If so, consider the GTC-802 NOx/CO reduction catalyst.
The GTC-802 combines two catalysts in one, delivering both superior NOx reduction and outstanding CO and VOC oxidation. Low pressure loss, limited SO_2 oxidation, and reduced ammonia slip add up to fuel savings, increased production and fewer cold-end maintenance issues. And positioning downstream of the ammonia injection grid will save you costly layout space.
www.topsoe.com
HALDOR TOPSØE

Wireless expands M&D to more of the plant

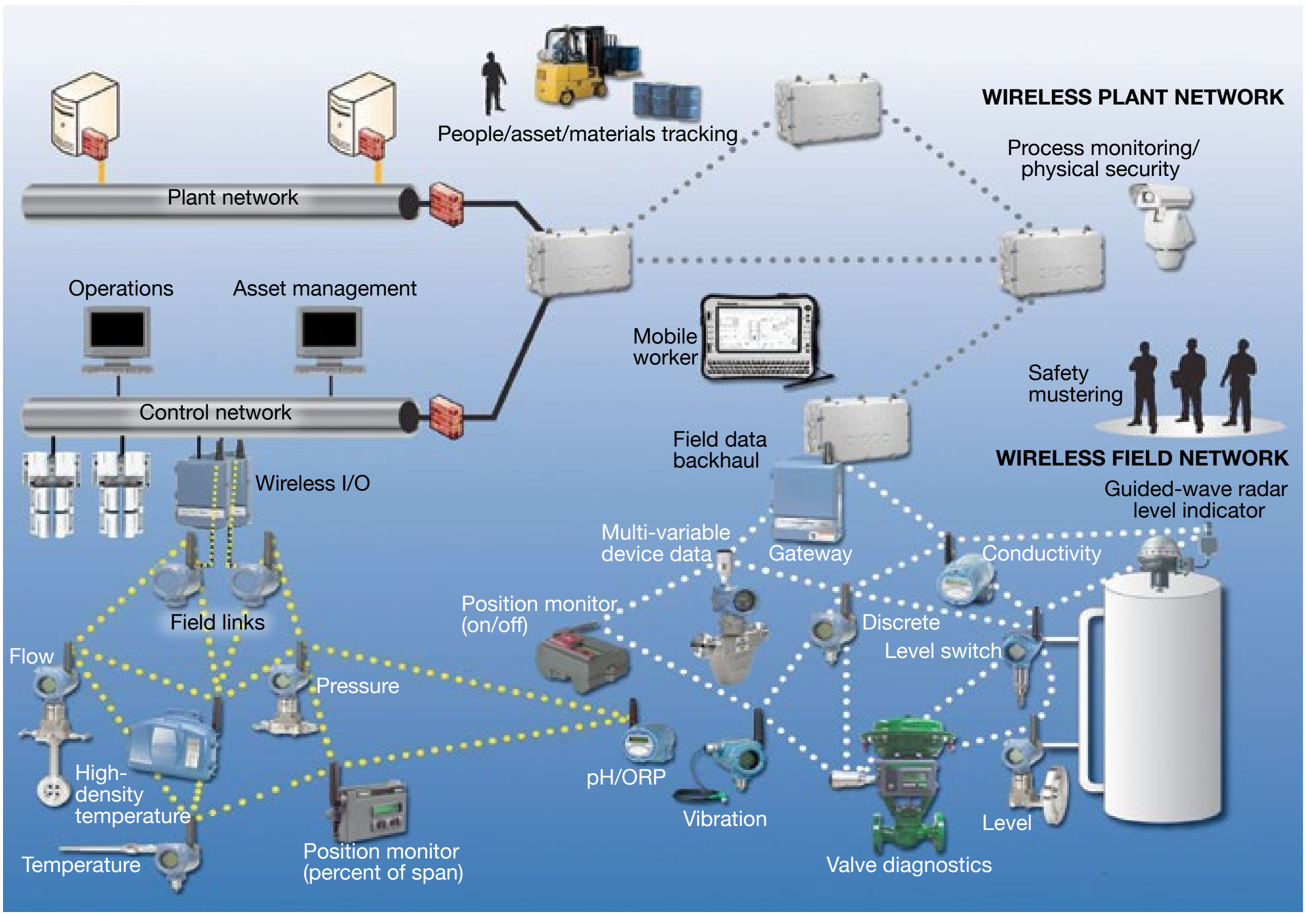
Wireless control devices, sensors, and networks are bringing new M&D capabilities to more of the powerplant footprint, just like cellphones and wireless computing devices have changed the way we live. Use of wireless today, in fact, is probably limited only by imagination, budget, and cybersecurity concerns.

Most anything in M&D that can be hardwired can now be done with wireless (Fig 1), even if plants are not quite ready to give up "the landline." Probably the best way to think about wireless at the plant level is this: You don't have to "make the rounds" to read gages; the gage readings come to you. Of course, the data also can go into the control and automation system as well. That's the point. The data can go anywhere as long as a network can pick up the signals and the transmission is secure.

Virtually all of the plant's performance metrics—safety, productivity, efficiency, environmental compliance, and reliability—can be enhanced by adding wireless M&D at strategic locations. One reason is because wireless M&D brings data to you in real or near-real time, or at the very least much faster than an operator on his/her periodic rounds. Thus operators are able to focus on other things, like conducting maintenance and checking out issues indicated by M&D.

From a practical standpoint, wireless is often an inexpensive way to add M&D capability to an existing facility. Good examples are the cooling-tower area, the water-treatment unit, tanks situated away from the turbines and boilers, and fuel supply pipelines. Just like a security camera gives you "eyes" into different areas of a building, live video and audio feeds for critical process areas can be transmitted wirelessly, too.

At last year's Ovation User's Group (OUG) meeting, Scott Stofan and John Blaney, Emerson Process Management, Power & Water Solutions, gave a "top to bottom" review of wireless applications.



1. All of the typically measured parameters important to control and M&D can be monitored wirelessly with today's technology

The first step is to understand the basics. Wireless is based on sending and receiving signals in the form of waveforms and it takes power in the form of MHz or kHz to send those waves long distances. You use existing unlicensed wave spectra, like the Industrial Scientific and Medical (ISM) spectrum running at standard 2.4 or 5 MHz, or customized licensed spectrum bands.

Think of the wireless "system" in three buckets: The field devices and links, the network infrastructure, and the solutions, or what you actually do with the monitored points. The links and infrastructure (Fig 2) are industrial, ruggedized versions of similar equipment you use at home or in the office.

Each field device has an antenna which transmits a signal through an industrial-grade point accessing a "mesh"—a wireless field in which each signal strengthens every other signal through the use of what's called repeater devices to add communications pathways.

A wireless local area network collects and manages all the signals from the field devices. A wireless-network server provides a system view for radio frequency (RF) planning and management. Security and intrusion prevention are, of course, necessary parts of this system.

The field instruments (Fig 3) available today span the gamut of what every powerplant monitors in real time. It's worth pointing out that even corrosion monitors and gas/flame detectors are included.

According to Stofan and Blaney, some of the latest elements of a wireless system from Emerson include the following:

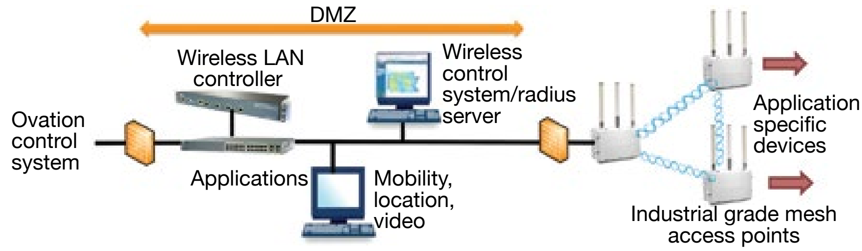
- Broad selection of wired and wireless pressure transmitters with different capabilities and functionalities at different price points—that is, more diagnostics deliver higher value but for higher cost.
- Guided wave radar technology for sensing tank levels more accurately, especially when there is stratification of fluids and/or when better overfill protection can enhance safety and reduce environmental risk.
- Smart wireless gateway. It combines (1) wireless HART, based on IEC62591 (a non-routable protocol which allows the process sensor devices to communicate through a mesh network through a gateway to host systems, such as a DCS) with (2) wireless WiFi, based on IEEE 802.11, the global wireless routable Ethernet-based communications standard to connect tablets, laptops, cameras, and RFID tags to plant-wide application standards.

As a reminder, routable protocols contain a device address and a network address. In theory, this allows information packets to be transmitted anywhere through an open communications system. A non-routable protocol allows information packets to be transmitted only to another device through a closed communications system.

- Distributed remote terminal units (RTU), used to collect data from distant locations—such as a cooling-water intake or distant pipeline metering/supply station.
- Wireless multi-variable transmitter, capable of providing the primary measured parameter (for example, flow) as well as secondary parameters used in the primary-parameter calculation (pressure and temperature, for example).
- Advanced totalizer, a simple connection to a turbine meter measuring average flow and totalized volume.
- Network manager, a logistics coordinator of sorts, which examines the radio spectrum frequencies, monitors strength (dB levels), determines the appropriate communications pathways, and ensures signals get to where they are supposed to go
- Security enhancements ensure the system complies with NERC-CIPS and/or other higher-order security frameworks.

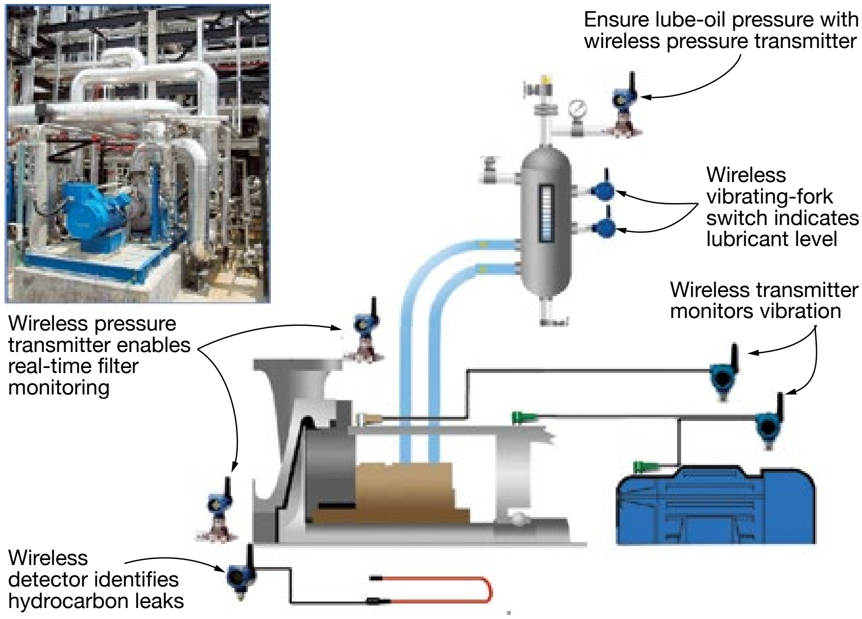
All capabilities available at a stationary human machine interface (HMI) screen can be delivered through mobile devices via remote desktop—including alarms, trends, reports, engineering analysis, and laboratory data.

At the same time, all the wireless



2. The three "buckets" of a wireless system: (1) Field devices/links communicating through a mesh wave field; (2) the infrastructure level, a wireless LAN controller, server, and terminal to collect and manage the data and RF requirements; and (3) the applications

3. The range of wireless M&D available to a powerplant essentially is limited by your imagination (and cybersecurity concerns and budget limits, of course)



4. Wireless M&D options for a single pump include filter monitoring (pressure), leak detection, vibration monitoring, level sensing, and lube-oil pressure

devices and infrastructure can be maintained via Emerson's AMS Suite Intelligent Device Manager. All wired and wireless HART devices can be calibrated, configured, troubleshooted, and documented on the go or from wherever you happen to be (within range of the network).

For example, suppose you have a critical pump, or a non-critical one that isn't well-spared (or not spared at all) or poorly instrumented. Wireless monitoring options (Fig 4) include vibration, lube-oil pressure, filter monitoring, lube-oil supply level, and fluid leak detection.

The cost for adding such monitored points is relatively low. To illustrate: Adding wireless HART to a cooling tower (often a poorly instrumented area of the plant) would cost nominally $25-50K, which would include several field devices, access points, and a mesh network gateway. Recognize that, to actually use the data, the host system has to be configured with a secure connection interface, database, and graphics.

The typical gateway handles up to 100 field devices, so there's plenty of room for expansion. Installation time for the wireless devices and gateway (excluding the physical process connection) generally is not more than a few hours. The physical process involves mechanical changes—for example, the instrument has to be connected to the pipe where the measurement is desired. Connecting the wireless part of the system to the wireless network involves software changes which take little time.

One caution: Wireless monitoring capability must be designed and implemented using a team of instrument specialists, host system administrators, and security experts to ensure compliance with all security protocols.

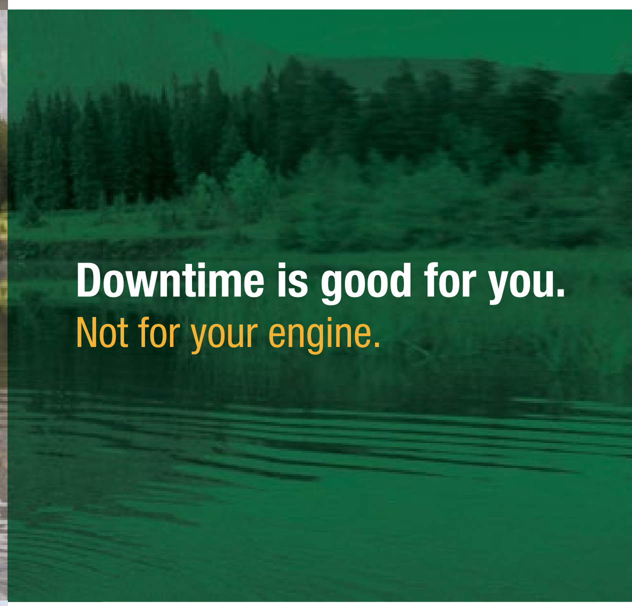
Wireless capabilities also should be assessed in the context of more predictive capability through "big data" solutions, algorithms which crunch and correlate reams of PI or historian data to predict whether and when a component could fail. On the one hand, more monitored points could feed such real-time analytics. On the other hand, better M&D through direct measurement could lessen any dependence on such analytics.

Beyond the busy plant areas (turbine deck, HRSG area, water treatment building), wireless can be applied for such diverse applications as monitoring inlet cooling water or feedwater flow and return outflow discharge temperatures and flows for regulatory compliance, wastewater treatment basins, cooling towers, air-cooled condensers, materials delivery and inventory, and perimeter security.

Once you get into the guts of the signals, communications protocols and standards, firmware, adapters (used to allow 4-20 mA HART-enabled devices to communicate with wireless networks), gateways (the wireless equivalent of marshalling panels and junction boxes), security details and patch requirements, ports and gateways, and configuring and building points, there are versions and revisions and procedures best left to the I&C and digital specialists.

Keep up with advancements in I&C technology by attending the upcoming Ovation Users Group conference, July 26-30, in Pittsburgh's Westin Convention Center Hotel (users only). CCJ

TRS
GLOBAL SERVICES



TRS Global Services is a highly specialized provider of stationary component repairs for 501F and 7FA engines. With customized service, outstanding quality, cost-effective pricing and fast turn times, TRS is a full-service provider of repairs and services for engine owners around the globe. We restore parts to their original form and function – at considerable cost savings to you.

Keep your engines running with TRS.

www.trsglobal.com

The case for rewinding rotors onsite

By Patricia Irwin, PE, Consulting Editor

A generator may require one or more rotor rewinds during its service lifetime, work that's typically done in a shop for all but the largest rotors. However, onsite overhauls can make economic sense for small, medium-size, and larger rotors when there is adequate workspace on or near the turbine deck and a crane is available.

Onsite major maintenance of generators is not unusual. Paul Heikkinen, director of generator services for Turbine Generator Maintenance Inc (TGM®), Cape Coral, Fla, reminded that "Generator stators generally are rewound in the plant because it is too difficult and risky to send them out. Once owner/operators consider all the factors, they typically decide to bring the tooling and supplies onsite and perform the rewind right on the turbine deck. These are the same factors to consider when a rotor must be rewound," he said.

Very large rotors usually are rewound onsite because of the difficulty in moving such a heavy component, and the associated liabilities. Heikkinen illustrated the point this way: If you have a 1000-MW generator down for a major and the field rolls off the truck on the way to a rewind facility, it can take three or more years to get a replacement rotor.

Planning an onsite rewind

A rotor rewind is a major undertaking and detailed planning is critical when it is done onsite because standard shop practices may not apply. But there's plenty of time for planning, according to TGM's Pat Welch, because you can anticipate the need for a rewind well in advance of when the work must be done—provided you are monitoring and testing your generator online and offline as recommended by the OEM and suggested by industry best practices.

A "tell," he said, is degradation in generator output, which can be caused by failing dielectric, turns, and crossovers. You can observe this over time and plan accordingly.

Ample laydown space is a key requirement for a successful onsite rewind. The turbine deck typically is used for this purpose, but because rewinds generally are performed during a major outage in conjunction with a lot of other work, it might not be available (Fig 1).

A warehouse, or suitable temporary building, is a viable alternative to the turbine deck (Figs 2, 3). But keep in mind that wherever the work is done a crane is required. Plus the workplace should have temperature and humidity controls.

How much space is available in a given plant—or nearby—often depends on the facility's age and location, Welch explained. Old plants built by electric utilities typically are sized generously and overhaul space is readily available. But plants built in the deregulated era often are right-sized for operation and not for overhaul activities that might be required once a decade or less frequently; the same is true for plants installed near population centers where land is at a premium.

1. Depending on plant layout, and the extent of work scheduled during the outage, laydown space on the turbine deck can come at a premium

Personnel and tooling

Once a suitable work area is identified and prepped, personnel, parts, and tooling are brought onsite. Because tasks generally are more mechanical in nature than electrical, machine tools (lathes, mills, etc) and specialty equipment often are required for work on retaining rings, blocks, and wedges. For example, water-cooled induction heaters are used to remove the retaining rings.

Adequate floor space is important when the individual coil segments are extracted. They must be staged somewhere accessible to personnel responsible for moving them to the various rehabilitation stations. Depending on the rotor, the crew may build specialty jigs and racks to hold the windings (Fig 4).

Removal of debris is another important consideration—more so for rotors than for stators. Heikkinen offered the following comparison: "For a stator rewind, the heavily insulated copper

2. This rings-off recondition was performed in the customer's warehouse, on the deck of a flatbed (left)

3. Generator rotor is positioned inside an enclosure on the lower level of the plant (right)

Nucla backgrounder

Nucla Generating Station may sound familiar to industry veterans, particularly those who relocated to combined-cycle facilities from coal-fired steam plants. The nominal 100-MW Unit 4, which began commercial operation in 1987, is equipped with the world's first circulating fluidized-bed boiler.

Tri-State Generation & Transmission Assn developed the plant, near the town of Nucla in the southwest corner of Colorado, in the late 1950s with three stoker-fired units rated 12.5 MW each. The old coal-fired boilers have been retired.

is scrapped and new copper is formed and insulated. The story is different for rotors. As you are unwinding and removing rotor coils, the insulation can very quickly be stripped away and discarded. The copper is usually in good shape and just needs some grit blasting or hand polishing to remove residue.

"Economically, rotors and stators are on either side of the spectrum when it comes to the rehabilitation of the existing copper. Stator coils are generally replaced. Rotor coils are cleaned, and new turn-to-turn insulation, ground wall insulation, and retaining ring insulation installed," says Heikkinen. Test equipment is also necessary, since the rotor windings are tested before, during, and after the rewind process.

Onsite advantages

An onsite rotor rewind offers several advantages as outlined below:

No transportation. First, since the rotor is not being transported offsite, the risks associated with shipping do not apply. "Shipping is not without risk," Heikkinen stressed. "You cannot predict what might happen between your plant and the rewind shop. The rotor could roll off of the truck, the truck could be forced off of the road, an accident could occur, etc."

Another point to remember: Rotors are hygroscopic—they absorb moisture—and must be sealed in waterproof packaging before return shipment. Otherwise, an as-received Megger test may indicate the rotor is grounded if the trip included driving through a rainstorm or snowstorm.

Also, transportation takes time. "Depending on how far the plant is from the workshop, it can take more than a week to transport the rotor one way. There might also be a delay at the shop, depending on the service provider's schedule," noted Welch. "Further to this point, if a rotor is transported by water, the duration could be much longer. The other alternative to highway transport is air. Travel time is cut dramatically, but the trade-off is a freight cost of easily six figures."

Engagement. Rewinding onsite allows participation of plant personnel in the process without having to travel to a repair facility. If the plant manager wants to monitor each step, he only has to walk out of his office to the staging area. He can interact with the people who are performing the rotor rewind throughout the process and any issues can be addressed in real-time.

Cost. It is difficult to directly compare the cost of an onsite rewind to work done at a shop but, typically, they are about the same. It is more expensive to rewind onsite because the tools and equipment have to be brought to the plant and the technicians have to stay locally during the project. On the plus side, there is no transportation cost for the rotor, the expense of sending plant personnel or a representative to the repair facility to monitor work is eliminated, and a more favorable onsite overhaul schedule may enable revenue opportunities.

Shorter schedule. Onsite rotor rewinds can take less time. That said, if the major outage has been scheduled well in advance and the plant will be out of service for a long time, getting the rotor rewound quickly might not be an advantage. However, during a shorter outage, it might be a significant benefit.

4. Technicians recondition the copper. It is then insulated and reinstalled in the generator rotor

Disadvantages

One possible disadvantage to rewinding a rotor at the plant: There is no way to perform high-speed balance test without transporting the rotor offsite. This may or may not be an issue. Welch offered this advice: "If the rotor has a history of instability, not related to the winding, then a high-speed balance should be performed."

But if the balance was fine until rotor shorts developed, there is no compelling reason to incur the cost and risk of a high-speed balance. The argument that a high-speed run is necessary to determine if any shorts were created during the rewind has little merit according to TGM personnel: If the work is performed correctly, they said, there should be no shorts to worry about.

Heikkinen added, "Very large generator rotors, those one might find at a nuclear powerplant or a large coal-fired facility, typically are rewound onsite. It would be atypical to see one of these rotors transported to a facility for rewind. There are proven procedures and processes that are routinely employed in the successful onsite rewinding of rotors, without the need for high-speed balance. These very same procedures and processes are applicable across the entire size spectrum of generator rotors.

"In sum, generator rotors need not always leave the site to be rewound. Owners and operators have more than one option."

Onsite rotor rewind at Nucla

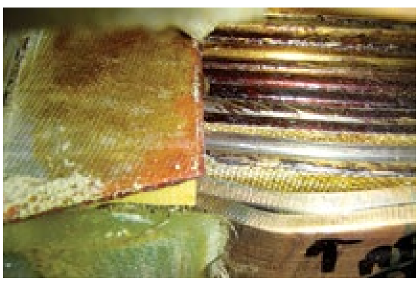
A lightning strike at Nucla Generating Station (sidebar) early in October 2014 caused a power surge that over-excited the plant's 73-MW generator. Vibration amplitudes recorded on the machine's two bearings, which had been about 2 mils since commissioning, suddenly doubled. Load was halved and hydrogen pressure increased to maintain pre-strike vibration amplitudes. All indications pointed towards a thermally sensitive rotor.

The unit was taken out of service while operations personnel decided how to proceed. Tim Jones, TGM technical director/generator specialist, and his team, including a vibration expert, were dispatched to the plant to conduct diagnostic tests. These included thermal VAR swing, online AC impedance, and online Repetitive Surge Oscillograph (RSO) tests.

Jones said, "We concluded that the unit was thermally unstable and that the increase in vibration was related to thermal regulation, megawatt loading, as well as reactive power (MVAr). Also, electrical testing indicated that there were shorted turns within the main field in coils 1 and 2."

5. Pulling the rotor—all 63,000 pounds of it

6. Significant damage to the retaining-ring insulation, including coil imprinting, and material transfer was in evidence. This indicates that the main field windings were axially bound



7. Excessive radial deformation of the top turns was observed

TGM told plant owner Tri-State Generation & Transmission Assn it possibly was looking at a condition referred to as "slip-sticking." This can occur when the rotor heats up and the copper expands faster than the steel forging. The hot copper slides out of the slot exits and when it cools, for one reason or another, it is unable to slide back into position. In short, the copper stretches and then it binds.

Diagnostics complete, it was clear the 63,000-lb, 30-ft-long rotor had to be pulled (Fig 5). Greg Keller, Nucla's maintenance superintendent, explained, "We knew that we had shorted turns, but we wouldn't know the extent of the damage until we pulled the rotor and removed the retaining rings. When that was done, we confirmed the slip-stick condition."

Damage identified, the decision was made to perform the rewind onsite. Keller said, "For me, I prefer work be done onsite when possible, particularly when it involves critical components. I don't like to ship those components over the public highways because of the risks. If anything happened to that rotor, it would have been absolutely catastrophic."

Challenging disassembly

TGM began removing the retaining rings before the end of October, but the job proved more challenging than expected. "This particular rotor has a removable coupling," Jones said. Some Westinghouse rotors have a tapered end. A straight shaft goes over the top of the taper and the coupling is held in place by anti-rotation pins. This is a very robust design, but removing and reinstalling the coupling, in and of itself, is a very difficult and costly job. So, we didn't remove it.

"This is one way we saved time and money for Tri-State. Rather than removing the coupling, we removed the retaining ring and suspended it around the shaft extension on a frame we built


MISTRAS
One Source for Asset Protection Solutions
Online Stator Monitoring
Acoustic Combustion Turbine Monitoring System
CRACKING
CLASHING
RUBBING
FOD
•Real-Time Fault Detection •All Gas Turbine Manufacturers and Models
Call +1.609.716.4000
Visit MonitorMyTurbine.com
Scan this 2D code with your smartphone's barcode reader for more ACTMS™ information.

8. **Main field coils are extracted.** Note the specially built frame to support the copper

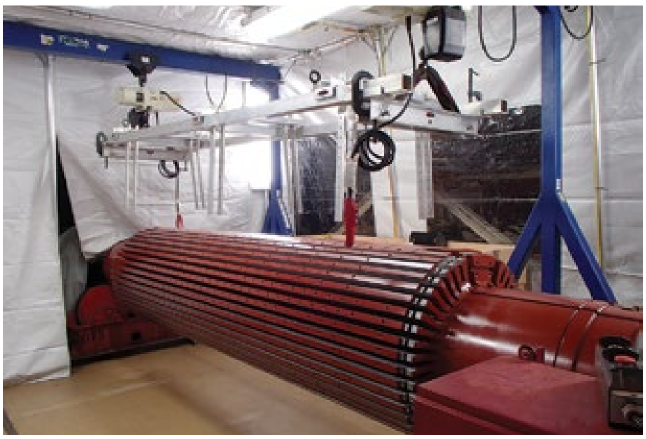
onsite," Jones continued.

Once the retaining rings were off, the damage was apparent. "The slip-stick damage to the copper conductors was so significant that there was an increase in diameter equal to about three quarters of an inch at the slot exit. That prevented the conductors from moving back into the slots. The only way to repair it was to remove all the copper conductors, straighten, and reinstall them," Jones explained. Figs 6 and 7 provide perspective.

Samples of the conductor copper were sent to a lab for metallurgical analysis to determine chemical composition and mechanical characteristics. Fortunately, the copper was able to be requalified, and as such, the main field coils were cleaned, reshaped, and reused.

Since the work was done in response to a forced outage, there was little time to prepare. Lead-time for certain critical insulating materials, combined with extreme inclement weather, created minor yet manageable delays. Also, this being the first time TGM had worked on this specific rotor series, several tools, jigs, and fixtures had to be built.

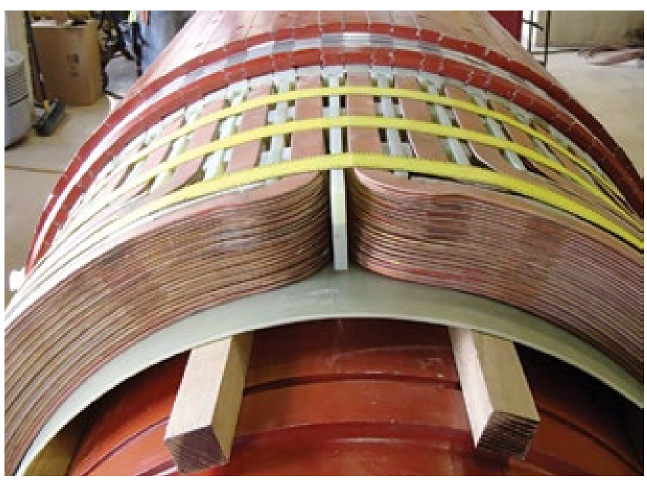
The biggest was a press fixture with a gross weight of about 26,000 lb, which TGM used to compress the fully reinsulated and rewound main field windings during the thermal processing operation. TGM also built a site-specific clean room, as well as rotor-specific snap-ring pliers, coil hanging racks, coil carts, insulation



9. **The fully reconditioned rotor** body forging is prepared for rewind in a clean room built onsite

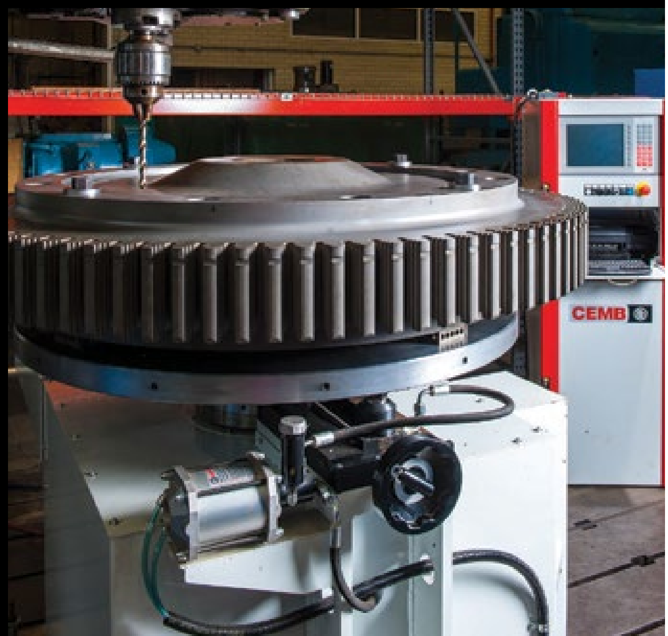
10. **Specially designed de-tensioning** device is used to disengage the snap rings during retaining-ring removal

11. **Hand-cleaning** the main field coils after glass-bead blasting and prior to being placed in the clean room



12. **Main field endwinding** as the associated blocking is installed





CEMB

13. Electrical testing during generator rotor reassembly

14. Reinstalling the rebuilt rotor into the generator

materials, and the temporary winding fixtures needed to shape the windings (Figs 8-10).

Tri-State and TGM held daily meetings. Keller points out, "We were able to observe the technicians doing the work. That was significant to me because I could see the care and commitment that went into the process—attention the entire management staff could witness [Figs 11, 12]. That would not have been possible had the rotor been shipped to an offsite facility."

All repairs complete, technicians started testing and reassembling the machine in mid-December (Figs 13, 14).

Up to speed

"If you rewind a rotor onsite, you cannot do a high-speed balance test," Keller said. "We knew that and it was a concern. So we carefully brought up the machine for the initial spin-up. The plan was to spin the rotor, identify balance problems, allow the turbine time to cool down, remove the upper end bells, and make the balance adjustments."

None of that was necessary, the maintenance superintendent continued. "We rolled the generator rotor up initially on just air and had really good balance numbers. It was running smoothly, so we put it on hydrogen, and ran it up for an overspeed check and then back down to its operating speed of 3600 rpm.

"It was amazing; it ran so smoothly. For the two bearings that historically had vibration issues, we detected approximately one mil of vibration. So, the rotor is now running with less vibration than before it was taken apart. This is amazing, considering the amount of work performed for a rotor rewind."

Work was declared complete just before Christmas; the plant had been down for 77 days. CCJ

Guided-wave radar gets attention for more level measurements

A common observation about today's automation practices is that we're all dazzled by the digital and computer advances but the technology behind the primary sensors and final control devices doesn't change, or at least not nearly at the same pace.

At last year's Ovation Users Group (OUG) meeting, Paul Yankello and Bill Pace of Emerson Process Management's Rosemount Div, challenged that assertion. Their presentation covered general level-measurement applications and technology selection, but the expanding applications for guided-wave radar (GWR) technology were a highlight of the message. Keep up with advancements in I&C technology by attending the upcoming OUG conference, July 26-30, in Pittsburgh's Westin Convention Center Hotel (users only).

The 2013 edition of Emerson's "Engineer's Guide to Level Measurement for Power and Steam Generation," available online, gives the basics of GWR. Access this useful reference by scanning the QR code with your smartphone or tablet.

GWR works this way: "The GWR (source) is mounted on the top of a tank or chamber, and the probe usually extends to the full depth of the vessel. A low-energy pulse of microwaves, traveling at the speed of light, is sent down the probe. At the point of the liquid level (air/liquid interface) on the probe, a significant proportion of the microwave energy is reflected back up the probe to the transmitter. It measures the time delay between the transmitted and received echo signal and the onboard microprocessor calculates the distance to the liquid-level surface."

GWR, note the authors, is independent of liquid density but the steam dielectric constant (DC)—important in many powerplant applications—can cause up to 20% error and will vary with pressure. For this reason, a technique called dynamic vapor compensation (DVC) is employed. A reference reflector measures the steam DC. The distance to reflector is fixed. As microwaves travel through steam, the DC impacts the speed, making reflector distance appear further away. The distance between the physical and "electrical" distance is used to measure the DC and automatically correct for surface distance. DVC can limit the error rate to less than 2%.

GWR was specified for this feedwater heater to provide reliable, accurate level measurement to protect against water induction into the steam turbine

The guidebook lists the following benefits of GWR:

- It is good for tanks of all sizes and tight geometries.
- Advanced versions work in turbulent and low-DC fluids.
- Can be installed directly in the tank or in a bypass chamber.
- No compensation is required for density or conductivity.
- Changes in temperature and pressure have no impact, nor do most vapor-space conditions.
- There are no moving parts; minimal maintenance is required.
- A direct, "top down" measurement is provided, as opposed to prevalent indirect methods.

The authors claim that GWR is "best practice" for the following applications:

- Condenser hotwell (vacuum-to-positive pressure range, density changes of water during condensation).
- Lube-oil tanks (clean, low-DC fluid; typical location next to turbines can pose vibration issues for alternative instrumentation; works in skid-mounted and small tanks with limited access).
- Boilers, steam separators, and feedwater systems (steam and water density and DC changes with temperature and pressure, magnetite buildup issues with other options). Photo shows a GWR installed on a feedwater heater.

GWR works well in solids level measurement, too, although there are few applications in combined-cycle plants.

Probe selection is the principal caution in GWR applications, according to the guidebook. Coaxial style probes are the most versatile, especially because, unlike other types, the limitation of not being in contact with any metallic object is lifted. Single-lead probes are best for fluids which pose stickiness or coating issues.

Advanced versions of GWR can include the ability to detect buildup on the probe. Like all state-of-the-art microprocessor-based instrumentation, they can be equipped with the latest digital automation diagnostics and health monitoring. Wireless-based products are also available. Other industry sources suggest GWR, though a relatively young technology, presents a formidable challenge to more conventional differential pressure (DP) measurement. CCJ

Notes from recent plant visits, user discussions

Combined cycles will run more when the *true* costs of cycling coal plants are factored in. One owner's engineer said some people are not being "honest" about coal-plant startup and cycling costs based on analyses his company has conducted.

Frame 7s. One user confided that his engines cycle "all over the place." In peak season, the units may operate at base load; other times they may start and go to minimum load for an hour or so and then shut down. Intervals between combustion inspections have been reduced to 450 starts to match fallout experience. This person characterized Frame 7s as "tough machines."

More wind capacity than coal is likely a few years down the road, an employee of a Midwestern utility told the editors. But not everyone in the company is comfortable with this prospect, he continued. In fact, the plan to retire upwards of 1000 MW of coal capacity this year has been moved forward because of system reliability concerns.

New peaking capability versus upgrade of existing assets was the topic of one conversation. A user mentioned his company had investigated the purchase of a few LMS100s to cope with the idiosyncrasies of large wind penetrations in its service area, but passed on the opportunity in favor of reconditioning old peakers. The generator caught up on deferred maintenance for less than the cost of one LMS100 and restored confidence in more than 750 MW of mature simple-cycle engines in the company's portfolio.

Improvements in wind turbines likely will cause more challenges for GT fleet owner/operators going forward. The latest models are able to harvest more of the wind's energy and raise the capacity factor of these assets; the new machines can withstand wind speeds of up to about 60 mph, according to the user sharing information made available to him.

Ouch! Some GT mods in one power producer's long-term plan are getting a second look. The user speaking with the editors said OEM bids are "out of the ballpark." He added that the company's budget for maintaining the availability and reliability of existing GTs over the next three years was low compared to bids received.

Predictive analytics for GTs. One owner/operator mentioned it was not actively pursuing predictive analytics for the company's gas turbines—but perhaps it would when control systems are upgraded. The user did offer that analytics are helping on the generator's coal-fired units.

Frustration was the feeling conveyed by one user who said his plant has experienced a "terrific number of technical problems" with its 501FD2 gas turbine/generators since commercial start about 10 years ago. He had the impression that his engines were seeing certain problems earlier than others in the fleet, but didn't elaborate. The Aeropac generator took the brunt of his criticism. This machine is a topic of discussion at most meetings of the 501F Users Group. Next meeting of this independent user organization, chaired by Russ Snyder, plant manager, Arcadia-1 Power Station, will be Feb 21-24, 2016, at the La Cantera Hill Country Resort in San Antonio.

Oil-mist lubrication helps protect against hot bearings, a combined-cycle O&M manager told the editors during a plant visit. He said the Alemite system, used for years in refineries and now at his facility, relies on continuous oil/air flow and positive pressure to keep dirt and other contaminants out of the bearings while helping to maintain optimal lubricant flow at all times.

During a discussion on analytics, a plant O&M manager offered that, in his opinion, Cycle Watch wasn't "doing the job" in providing predictive intelligence for GT start-ups, mirroring the experience of at least a few others and reported earlier by **CCJ.** However, he said, his plant has benefited from the GE SmartSignal® "Shield" product. The software-based remote monitoring service was said to have averted trips from gas inlet temperature stemming from issues with fuel gas heaters. Confirming what several others have said at user-group meetings, such as CTOTF™, predictive analytics software continues to identify "lots of instrumentation issues." In fact, more than 50% of the so-called "catches" are associated with instrumentation.

The value of RCM was summarized this way by a maintenance manager at a combined-cycle facility that had implemented a rigorous and extensive reliability-centered maintenance program:

- Infrared windows have been installed "everywhere," so 4.16-kV electrical components and other equipment can be monitored easily to provide information for predictive maintenance.
- PdMA Corp's MTAPs data acquisition portals have been installed on all critical motors to allow safe online health assessments without LOTO restrictions, resulting in "big cost savings and safety improvements."
- The plant has not lost an RO pump, once a key headache, since the RCM program was implemented.
- Persistent damage to circ-water-pump discharge expansion joints was traced to an improper procedure calling for startup with valve closed.
- Failures of cooling-tower fan gearboxes have been mitigated by (1) balancing the fans, (2) replacing the original 12-blade design with a fan having six blades, and (3) more precise bearing lubrication. Fan drivers are now cycled automatically based on run hours. Also, all

risers have been equipped with motor-operated valves (MOVs) and system pressure is maintained as a constant via bypass valves to avoid broken pipe downstream.

- The RCM pointed to improper layup of evap coolers in winter based on a significant media fouling event in summer.
- Closed cooling-water circuitry serving the gas turbines was eliminated. GT cooling water now is tied into the cooling-tower circuit. The original system "always ran hot" and posed limits on generator cooling during hot summer days, as well as on lube-oil coolers. The closed cooling system also was linked to GT trips at a cost of $500,000 each.
- Information gathered as part of the RCM program also suggested the following improvements, which were implemented: (1) Installation of Cutsforth brushes to improve safety and protect against trips; (2) replacement of MOVs with air-operated attemperator block valves to protect against leakage of water into steam lines; and (3) use of a new digital device and software for roving operators to record rounds data and facilitate its transfer into the eDNA (InStep Software LLC) data historian server located outside of the plant's firewall.

Safety never sleeps. A recent report from newspapers nationwide reveals that a man delivering sheet rock to a construction site was killed when a tape measure, weighing about 1 lb, fell 50 stories and hit him in the head after ricocheting off equipment located 10 to 15 ft off the ground. Lesson relearned: Delivery personnel, like contractors, must wear appropriate safety gear when inside plant boundaries.

Heat stroke is the most serious form of heat injury and is a medical emergency. Staff at one plant visited advises that if you suspect someone has heat stroke—a/k/a sunstroke—call 911 immediately and cool the patient until paramedics arrive. With summer coming, be aware that the hallmark symptom of heat stroke is a core body temperature above 105F, but fainting may be the first sign. Other symptoms may include: throbbing headache, dizziness, lack of sweating despite the heat, muscle weakness or cramps, nausea and vomiting, rapid heartbeat, rapid shallow breathing, behavioral changes (including confusion, disorientation, staggering), etc. CCJ

Fleet focuses on reliability, availability, operational flexibility

Operations personnel involved in today's fiercely competitive electric-power business should be aware that if their conventional generating units don't run when called upon, the owner doesn't get paid. This means that starting reliability, availability, and operational flexibility are critical to success. Of course, expectations also must be met regarding emissions, performance, and safety.

All of these topics were on the agenda of the 501D5-D5A Users 2015 annual meeting in Tucson, June 2-4, which integrated OEM, third-party, and user presentations, open discussion forums, and a vendor fair with participation from nearly three-dozen companies.

There's no time for daydreaming at this conference. First-timers (one-third of the nearly 40 Tucson attendees) can get "lost" on unfamiliar topics, but user-only discussions strategically positioned between the OEM sessions provide the background and perspective on important issues to ensure all attendees benefit from the information disseminated. No question goes unanswered.

Perhaps the biggest news for this tight-knit group came shortly after the meeting concluded when Lonnie Grote, the compliance coordinator for NAES at Rocky Road Power Station, resigned as a director of the group. He had attended every one of the annual meetings since 2006 in Memphis, and most—if not all—of the mid-year meetings. Grote was honored in Tucson for his outstanding and unselfish service. Gabe Fleck, manager of gas plant operations for Associated Electric Cooperative Inc, and Barry Mayhew, maintenance manager at Capstone Infrastructure Corp's Cardinal Power, continue as the chairman and co-chair, respectively, of the organization.

Save the dates on your 2016 calendar to attend the 20th annual meeting, June 7-9, at place to be determined.

OEM presentations

The 501D5-D5A Users and Siemens Energy work well together. There are squabbles to be sure, but the group's steering committee has been working closely with key members of the Siemens team for the last decade, allowing the participants to develop meaningful professional and personal relationships.

Program development for the users' meetings is a collaborative process with the information needs of owner/operators as the primary objective. OEM presentation topics for the mature D5 and D5A engines lately are rapid-fire updates on equipment solutions in development and continuing issues, making the program lively and compelling.

To illustrate, Siemens speakers covered four topics in an hour on one morning (including Q&A), six more in an 80-min afternoon session, and then a few more, plus a vibrant open discussion session, in two hours the following day. All the material presented is available to registered users via the OEM's Customer Extranet Portal; if you are unsure how to access the CEP, contact your Siemens representative.

Fleet stats, technical advisories. The first Siemens speaker reviewed the program and updated attendees on fleet-wide statistics for the 82-unit D5 fleet and the 61-engine D5A fleet. Reliability, availability, and starting reliability continued to meet expectations, he said. Technical advisories were reviewed next—including upgrade of the exhaust bearing removal tool, publication of a technical bulletin on the rubbing issue associated with the last three rotating stages of the turbine section, and recommendations for dealing with rotor vibration. Last includes relocation of the exhaust-bearing vibration probes.

An update on cracking of inlet-manifold splitter plates and struts experienced by some users included a reminder on the availability of an inspection service bulletin (SB4-13-037-GT-EN-01) as well as enhancements to mitigate cracking. A cutback mod to minimize the probability of splitter-plate cracking is available for side-entry units, the group was told; a solution for top-entry units is under development. The mod has been used successfully on 501F and G engines. Likewise, the bolted-strut mod for 501F and G engines also is available for the D5 and D5A fleets.

Turbine axial rubbing has been experienced by some users. The OEM's investigation of the issue, which began more than three years ago, indicates rubbing is the result of a permanent loss of axial clearance caused by vane deflection and blade-ring distortion. Also that rubbing occurs primarily during startup because of the thermal growth differential between the turbine shaft and the casing.

The ongoing project suggests the following operating changes may help affected owner/operators mitigate rubbing:

- Over-cool disc cavities 2 and 3. This is believed to reduce the rate of permanent displacement.
- Follow OEM guidelines regarding a hold at full-speed/no load during startup.
- Slow down the engine load ramp rate.

Work continues in the monitoring and analysis of data and of evaluating potential improvements.

A tutorial on combustion system basics closed out the morning session. The drawings and explanations of system design and operation were particularly valuable for first timers, but also a good refresher for most of the others. The value of automated combustion tuning was part of the discussion.

Spin cooling and turning-gear operation took center stage after lunch. Tough to keep attendees engaged following a D5-D5A noontime feast that included a dozen or more dishes, but this was a hot topic of interest to virtually all attendees. Spin cooling was recommended to help avoid possible rotor thermal issues. Users were told the temperature gradient experienced when spin cooling is not included in the shutdown process can cause upward bowing of the cylinder and loss of blade-tip clearance at the rotor mid-section. Damage to airfoils and the casing can occur.

Recommended was a 5-min spin cool on shutdown, an hour on turning gear, another 5-min spin cool, and then turning gear until disc-cavity temperatures drop below 150F. Periodic turning-gear operation, or a high-speed spin for a few minutes before restart, likely will prevent high vibration on startup.

1. First bolted compressor rotor for a D5 ready to leave the shop for installation at Capstone's Cardinal Power in Canada (above)

The speaker suggested the following three options to maintain rotor health after cool down:

- Stay on turning gear (TG) to prevent rotor bow and keep the unit in a state of operational readiness. But keep in mind that extensive turning-gear operation can cause serious wear issues.
- Take the unit off TG. This can cause a temporary rotor bow, requiring pre-start measures. Recommendation: 12 hours on turning gear before restart, or one hour on TG followed by a 5-min spin.
- Turning-gear time reduction by periodically moving the rotor 180-deg from its previous position. One unit using this method over the last several years reduced its time on TG by more than 95%.

Rotor and casing inspection and evaluation. Ongoing work in RCIE indicates that at about 100,000 hours of service, wear and tear of rotor components becomes noticeable. The speaker said that's the time to get the rotor into the shop to "reset the clock." Here are some of the things that might be found at the second major:

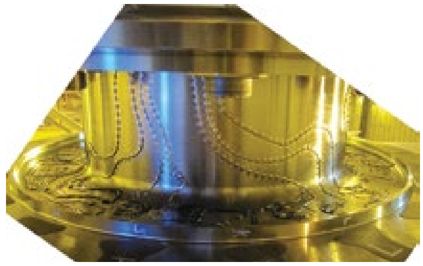
- Torque-tube indications.
- Baffle-seal groove wear.
- Compressor disc embrittlement—

specifically in the 12Cr material used to make discs for Rows 12-19. The users were told embrittlement reduces a material's resistance to crack propagation and that crack-initiation events may include one or more of the following: forging inclusions, low-cycle fatigue (LCF), heavy corrosion, foreign or domestic object impact on airfoils or the wheel, disc migration.

Data from RCIEs are compiled by the OEM and analyzed to help both Siemens and customers make better risk assessments and better decisions regarding component repair/replacement.

Moisture reduction in the casing is important to reduce deterioration of units forced to spend long periods of time on standby. A warm-air purge was one solution recommended. It reduces the humidity of air inside the GT during turning-gear operation by raising the temperature of air (electric heater) circulated through the unit. Another method is to use a desiccant wheel to pull moisture out of the air inside the GT (used on one 501G). This requires installation of a damper or deployment of a duct balloon inside the inlet air house.

Bolted compressor rotor. Compressor rotors for D5 and D5A engines have shrunk-on discs—not conducive to fast starting. The first bolted rotor for the D5 and D5A frames (Fig 1), similar in design to the 501F rotor, has been retrofitted on the D5 at Capstone's Cardinal Power in Canada. Benefits include a straighter rotor, improved material (low alloy steel) and longer life, the capability to start within 10 minutes, and an a 2-MW increase in unit output with no change in heat rate. Commercial acceptance of the rotor was in May 2015.



2. Bolted-rotor instrumentation includes 64 thermocouples and 14 strain gauges to verify bolt loading, bolt vibrations, and rotor temperatures (right)

The Siemens presenter discussed the 64 thermocouples and 14 strain gauges installed on the rotor to monitor its performance over time (Fig 2). Data are transferred to the OEM's engineers via an advanced telemetry system. Siemens reported that all clearances, vibration, temperatures, and other parameters of interest were within specs.

Rocky Road. An OEM presentation on the last day of the meeting detailed the upgrade of the gas-only 3 (D5A) × 0 Rocky Road Power Station, East Dundee, Ill, to include black-start capability. The project, completed in only eight months (three days ahead of schedule), required a considerable electrical analysis and design effort to assure the functionality required by the grid operator (PJM). This work included identifying which of the existing electrical equipment could be reused.

The speaker noted challenges imposed by (1) cold weather, (2) the additional engineering and procurement effort required because of scope changes, and (3) having to perform the T3000 and E3000 retrofits in parallel. Here are some of the project highlights:

- Two diesel/generators were installed to power the nominal 2000-hp starting motors and 1000-hp gas-compressor motor drivers serving each of the D5As. Having two diesel/generators instead of one provides more inrush-current capability than one unit of equivalent output, the presenter said.
- Soft-start motors for the gas com-

pressors because the existing auxiliary transformers were not able to serve all auxiliaries at one time using standard motors.

- The compressor motor control center was arranged for dual feed.
- The diesel/generator delivers power to the 13.8-kV unit bus during a black start.

Lessons learned included the following:

- Do black-start test and commissioning plans early in the design review stage.
- Have separate site leads for I&C and electrical work (one person did both at Rocky Road) to improve onsite communication.
- Allow the installation contractor to schedule and manage selected onsite services to simplify project execution.
- Avoid design changes after contract award to not jeopardize on-time delivery of equipment. At Rocky Road, design changes caused the short-circuit study to become the critical path and delayed peer reviews. The delayed short-circuit study results also forced schedule delays for onsite services.
- Consolidation of day-to-day MV switchgear functions with black-start functions created challenges for installation and control schemes.

User presentations

User group meetings without meaningful presentations by owner/operators may not be providing a program of maximum value to attendees. Sure, users learn from the OEM, consultants, and third-party equipment and services providers, but there's nothing like a presentation by an owner/operator on a subject of interest to the fleet to lay out the cold, hard facts and help others avoid having to relearn lessons already paid for.

There were several valuable user presentations at the 19th annual meeting in Tucson. A few suggested that the work of vendor personnel be very carefully scrutinized by plant staff or an owner's independent expert during controls-upgrade projects. The takeaway from these experiences, which involved the migration from legacy control systems to T3000, reinforces the notion that at least some programmers could benefit from collaboration with station personnel regarding the possibility of operational idiosyncrasies before making critical decisions.

Ray Martens, plant manager of Klamath Cogeneration and vice chair of the 501F Users Group, alerted the industry on some of the same problems experienced by these 501D5-D5A users in a CCJ article six years ago (access using the search function at www.ccj-online.com). Sometimes owner/operators must speak in unison to get the attention necessary for issue resolution. User groups provide the necessary platform.

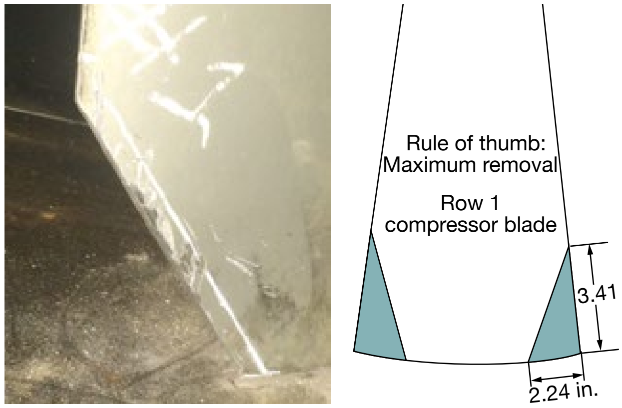
What follows are some of the editors' notes from the presentations/discussions on control-system migration in the closed user-only sessions during the three-day D5-D5A event:

A planned 10-day conversion from WEStation to Siemens T3000 for a 1 × 1 combined cycle went into Day 19. One issue was that the speed probes on the steam turbine were passive and required converters for the new DCS. The unit was unable to get beyond 2200 rpm until active probes were installed. Another issue was that controls engineering had not been completed on the steamer and logic was being modified during installation.

Onsite leadership was weak, the speaker said, and communication with plant personnel inaccurate at best. Loop checks were disorganized, he continued; preliminary engineering appeared incomplete or, at times, not done at all. The user's conclusion: The

3. One airfoil in the first compressor stage was damaged by a foreign object (right)

4. Airfoil in Fig 1 was blended as recommended by Siemens engineering (below)



vendor was not prepared for the installation. Trending and logs were very challenging, the speaker added, citing automatic reporting as a fleet issue.

Another user described similar challenges at his plant.

Long-term participants in 501D5-D5A meetings may recall discussion of T3000 migration issues a couple of years ago. Referring to notes, the editors recall a user describing the conversion from TXP to T3000 as turning out quite well despite conflicting logic and control settings in the Siemens database versus what the plant had onsite. He strongly recommended that plants transitioning to new control systems verify all settings, conversions, etc.

The obvious takeaway is user groups are addressing the information needs of owner/operators on a continual basis, whether in face-to-face or online meetings, or via conference calls and forums. Chances are good that an issue confronting you has been experienced by others—especially in mature fleets—like the D5 and D5A. Use the network to full advantage.

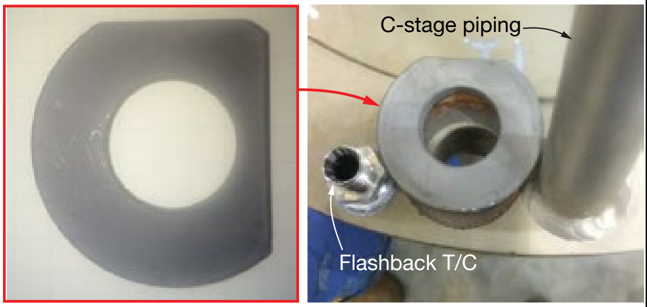
Blending of D5A R1 compressor blade. A routine inlet inspection revealed foreign object damage to one Row 1 compressor blade (Fig 3). A liberated icicle during the winter run is believed the cause. The unit had experienced as many as 70 starts and operated for about 500 hours with the damaged blade; Siemens engineering recommended blending the airfoil (Fig 4). This case history illustrates the ability of gas turbines to "ride through" minor damage and accommodate repairs you might not have thought allowable.

D5A gas leak. Operations personnel noted gas leakage when B- and C-stage (premix) fuel valves opened. This simple-cycle D5A is equipped with the OEM's four-stage DLN combustion system. Leakage increased over time. Detectors inside the enclosure registered 23 ppm at one point. Vent fans were turned on during operation to reduce gas concentration.

Troubleshooting activities located gas leaks around several support-housing hex-head screws. Eroded washers were replaced but the enclosure gas concentration

5. Most washers are machined on one side and must be carefully installed to proper fit-up against support-housing fillet (right)

6. One washer must be machined on two sides to fit between C-stage piping and the flashback thermocouple (below)



remained about the same. A technical advisory issued by the OEM 10 years ago suggested Siemens be alerted regarding such findings. In this case, its field-service technicians trued up flange-face flatness on combustor-portal sealing surfaces with some light stoning.

The speaker noted that the OEM offers a "no-gas-leak guarantee," provided you buy a spare- parts kit and contract required repairs and any additional field service work through Siemens. He then went on to discuss some of the finer points associated with locating and eliminating gas leaks on this specific equipment.

Example: The majority of the washers are machined on one side and care is required during installation to be sure they are not resting on the support-housing fillet (Fig 5). If fit-up is not precise, the screws will "torque out" before washers are seated properly and gas leaks will occur. Also, each support housing has one position that requires a washer machined on two sides to accommodate a fit between the C-stage piping and the flashback thermocouple (Fig 6).

The vendor performance critique incorporated into most user presentations was critical as most are; perfection is a user expectation. A couple of the comments made: Siemens did a great job once its personnel were onsite, but getting there was quite painful. Another: Parts did not meet specs in all cases, plus some were late arriving. The field engineer would have benefitted from more support in the corporate office. Most users probably would agree nothing mentioned by this speaker was anything different from what they have experienced, no matter what vendor is involved.

Exhaust-cylinder replacement. Lessons learned during an exhaust-cylinder replacement received a lot of interest from the group. To gain some perspective on the magnitude of this undertaking, refer to the Klamath Cogen experience detailed in the CCJ article referenced earlier. Here are some of the suggestions made by the D5A owner to attendees:

- It's critical to assign someone the responsibility of controlling hardware. Done correctly, this can be a full-time job. Bolts should be color-coded, cleaned up, and locked in bins to prevent loss.

- Weld in support rods to hold the downstream exhaust manifold in place before unbolting the exhaust cylinder.
- Remove the spigot fit on the torque tube to avoid having to remove the turbine cylinder during casing alignment. Make a tool to move the torque tube and ream new dowel holes once the final position of the torque tube is determined.
- Remove about ⅛ in. on the spigot fit to allow proper fit-up of the exhaust cylinder.
- Scribe a mark inside the exhaust bearing area when the top is in place, otherwise you will have no reference point to show the maximum position of the anti-rotation pin—thereby preventing installation of the exhaust cylinder.
- Replace the expansion joint when replacing the exhaust cylinder.

Discussion forums

The open discussion sessions at user group meetings are somewhat like "show and tell" was in grammar school: Listening to what colleagues have to say you get answers to questions you never thought to ask, and finding out about things you never knew existed. Plus, you have the opportunity to put a few photos up on the screen and ask the group, "Does anyone know what caused this?"

Often, the open discussion sessions are what attendees remember best. Everyone is equal and the only dumb question is the one not asked. These user-only forums typically begin with collaboration among owner/operators on topics introduced by the OEM or third-party equipment and services providers earlier. Example: "So and so said this and that improved unit heat rate. Has anyone implemented this solution? What was the result? How difficult was the implementation? Where were the potholes on the road to success?" The only things *never* discussed are contract terms and costs.

After those questions are exhausted, the discussion leaders dig for the O&M pains plant personnel are suffering, ask for lessons learned, best practices others might find beneficial, etc. Here are some of the things learned on a broad range of topics from the 501D5-D5A users:

Staffing. Discussion on this topic can be endless. Nearly 10 years ago, one of the editors asked attendees at an E-class user group meeting how many employees they had at a 2 × 1 combined cycle. The consensus reply, by show of hands, was 30; today, the number typically is less than 20; tomorrow, perhaps even less. There is nothing being said in the industry today that would suggest staff *increases* are on the horizon.

One of the D5-D5A users said his company operates four 2 × 1 combined cycles and three peaking plants with a total of nine people to manage O&M for the 2700-MW fleet. While contractor personnel run the combined cycles, each of those facilities has a member of the operations-savvy corporate staff onsite. The more than 600 MW of simple-cycle assets are at unmanned locations until they operate. Then a member of the corporate staff becomes the CRO—the only person at the plant.

The question that remained after everyone had his or her say: At what point does the corporate strategy of "Do more with less" fall apart and wind up costing far more than a few salaries? Consider that the thinner your staffing, the greater the impact of a loss when a person moves on; particularly so, if it's a highly valued member of your team.

The chance of hiring someone with equivalent capabilities today is slim to none. In case you have been "off the grid" for the past few years, senior people are retiring at an alarming rate (sometimes because staff reductions have added significantly to their unpaid responsibilities); the armed forces have shrunk, dramatically reducing the prospective labor pool; qualified technicians can make more money in other industries, etc.

Plus, the shine is off the contractor apple. Where do the aftermarket services providers get competent people to operate and maintain your plant if you can't? Erosion of skills and lack of commitment calls for more supervision by owner personnel, not less. To illustrate this point, a user mentioned having a discussion with a vendor regarding "human performance issues" and the need to improve the rigor in factory acceptance tests for control systems. Do you dare allow a contractor onsite without staff supervision? But how can your people "supervise" if they don't have the requisite experience? Seems like a downward spiral with no good ending.

Mention was made of the deteriorating quality of new parts and of repairs to hot parts. One experienced user said he ordered two sets of turbine blades to get one satisfactory set. New OEM parts sometimes do not meet his company's QA requirements for repaired blades, he continued, suggesting all owners do rigorous incoming inspections because "minimum acceptance criteria" change over time.

Another experienced user said his plant had to reject three new R2 turbine blades during an overhaul. The location of the defect was unusual, he said. The OEM said it had never seen this before. Further investigation of parts in inventory did not reveal any other defects. A casting anomaly was determined to be the cause. The first question that comes to mind: Why wasn't the defect found earlier given the effort spent on six-sigma work processes and inspection practices?

This fact also was brought to light at the spring 2015 CTOTF™ meeting where a presentation by Aaron Frost, Allied Power Group's technical director, revealed the possible negative impacts to owners of cost pressures in the new parts and repair businesses. Caveat emptor: Owners need highly qualified personnel to write repair specs, review quotes, conduct repair-facility audits, and make decisions on contract awards. A low-price decision today can easily compromise expectations.

Cold-weather issues got some air time. Annual verification of adequate heat tracing, steam sparging, preheating of gas-turbine inlet air, and use of dampers or duct balloons to prevent a steady stream of cold air from flowing through the GT during shutdown are among the solutions to consider.

One user told of a low-temperature lock-out on his generator when the ambient temperature dipped below -4F. A colleague shouted, "Me too." The logic of having such a lockout made no sense to them—or to anyone else in the room—because the temperature in the generator compartment was 25 to 30 deg F higher. The OEM finally agreed, but it still took a year to get the issue resolved.

Experience with oil firing was brought to the floor. Interestingly, six or seven years ago some plants with dual-fuel firing removed distillate plumbing to simplify outages. Recently, the (1) dramatic drop in the price of oil, (2) declining quality of gas supplies, and (3) rule by some grid operators to require dual-fuel capability to qualify for capacity payments, have some gas-only plants adding oil firing capability.

Those users asked colleagues burning oil about their experiences. Coking of fuel lines and clean out of liquid-fuel lines on shutdown with water or high-pressure air after burning oil, sludge in oil tanks, controls issues, etc, were all mentioned. Among the possible coking solutions identified were water-cooled liquid-fuel valves from JASC and that company's ZEE product, which allows plants to exercise and monitor the fuel delivery and flow metering systems to the burners without firing liquid fuel.

Splitter-plate cutback mod. Siemens presented on its solution to mitigate cracking of inlet-manifold splitter plates and struts (see above). Here's what some of the users had to say:

- One plant's fix was to drill the crack and re-weld it. No further cracking issues since this was done several years ago, so the OEM's fix has not yet been implemented.
- An offshore plant identified minor cracking of splitter plates on two of its D5As. A conventional weld repair was made; no further action is planned unless it doesn't hold up.
- A user reported self-performing, with Siemens' guidance, the splitter-plate cutback and bolted strut mods on one unit last fall. Splitter-plate cracking was severe and horizontal struts were broken on one of the plant's two D5As, he reported. Modal testing revealed that the natural frequency of the struts was about 61 Hz. There have been no issues in the 3500 equivalent base-load hours of service since the repairs were completed.

Turning-gear (TG) operation was included in the OEM's presentations lineup. Here a few users share their thoughts:

- Intermittent TG timers were installed by one owner on its D5s and D5As. When a timer is enabled, jacking-oil pumps turn on and the turning gear is operated once a day for two hours; TG operates continuously when the timer is disabled. The user said its tests revealed startup vibration is not impacted by such intermittent operation when disc-cavity temperatures are below 100F.
- Another user said when immediate availability of a generating unit is not required and disc-cavity temperatures are acceptable, the TG is turned off and operated weekly for about a shift. This owner typically receives notification of intent to start two to four hours in advance.
- Yet another user offered the following TG program:

1. Run the turning gear 24/7 until the highest disc-cavity temperature drops to 120F.
2. Discontinue TG operation for 12 hours.
3. Initiate TG operation for two hours.
4. Discontinue TG operation for 12 hours.
5. Repeat steps 3 and 4 until called upon to operate.

If called to operate your gas turbine in the real-time market, immediately initiate TG operation and prepare for GT startup. If called to operate in the day-ahead market, initiate TG operation upon notice of day-ahead dispatch and prepare for GT startup according to plant-approved procedures. After shutting down the GT, start turning gear and proceed with steps 1 through 5.

Extended life hardware is a popular topic at every meeting. One user offered that his base-load units have had 16K combustion parts for many years and have completed several successful 16K runs—one stretched to 17K. Another owner reported working on a nominal 18-month overhaul cycle (13.2K fired hours) which has been pushed out to more than 15K hours when necessary. This operating paradigm has produced satisfactory results using old-style (not 16K) combustion parts.

However, the owner pointed out that its parts are not the industry norm. It specifies upgraded coatings/hard surfacing and tighter repair tolerances than the large majority of users. But the assets discussed traditionally have not run with wet compression. In the last couple of years, the user continued, wet compression has been used more often and more wear and TBC coating loss have been experienced—but not to the point of forcing reduced run times. The additional wear is believed responsible for an increase in combustor noise. CCJ

WTUI turns 25,
commitment to users resolute

Nothing much has changed at meetings of the Western Turbine Users Inc in years—certainly not in the last 10 that the CCJ editors have participated. In fact, the group's commitment to brainstorming, troubleshooting, sharing of ideas, problem-solving, and helping users help themselves and others predates incorporation and WTUI's first official meeting in Sacramento in 1991 (Sidebar).

Attendance has increased, however—and dramatically. By Treasurer Wayne Kawamoto's count 130 users, vendors, spouses, and guests participated in WTUI 1 (he was there); there were more than 1200 attendees at this year's meeting in the cavernous Long Beach Convention Center. Western Turbine is the largest independent gathering of gas-turbine owner/operators in the world. By the numbers, WTUI 25 attendees represented 18 countries, 42 states, and hundreds of companies—including nearly 200 exhibitors.

The event began Sunday, March 15, for early arrivers, with 128 playing the El Dorado Golf Course in the group's unofficial annual tournament and another dozen or so engaged in the tennis tournament, organized this year by Tina Toburen of T2E3 Inc, Kirkland, Wash, following the passing of long-time coordinator and former WTUI president Jim Hinrichs.


Casey


Kawamoto


Raaker


Gundershaug

A special two-hour session Sunday afternoon brought first-timers up to date on the design of the LM2500, LM5000, LM6000, and LMS100 GE aero engines supported by the group, as well as the acronyms used in this sector of the electric power industry. Failure to "learn the language" can put attendees at a loss during the technical sessions starting Monday morning. The exhibit hall opened Sunday evening with live music to celebrate the special anniversary.

President Chuck Casey and the other officers and directors of WTUI rearranged the traditional Monday morning program to allow a tribute to Hinrichs by son Mike and a special presentation by Historian Mike Raaker of Raaker Services Inc who has been a Western Turbine organizer/member/officer/director since well before incorporation.

Casey, the utility generation manager for Riverside Public Utilities, opened the meeting promptly at 8 a.m., updating the group on changes in the WTUI leadership. New directors Howard Hoffmann of Ameren Missouri and Rick McPherson of NRG Energy (Walnut Creek Energy Park) were confirmed by the membership. Director Don Stahl of Black Hills Corp completed his three-year term on the board and was recognized for his service. Calpine Corp's Andrew Gundershaug, the LM6000 breakout chair, was appointed to fill the remaining year of Director Dan Arellano's term; a job change dictated his resignation.

Following brief comments by Casey on WTUI's value proposition, how to extract maximum value from the meeting, introductions, program comments, etc, the president invited Kawamoto to the podium to deliver the Treasurer's Report. Finances were in order and positive, and accepted by voice vote. The treasurer then reviewed plans for future meetings (details will be posted on the organization's website as they become available):

- March 20-23, 2016, Palm Springs, Calif, Renaissance Hotel/Palm Springs Convention Center.
- March 19-22, Las Vegas, Nev, venue to be announced.

Timeline

Twenty-five years may not seem long, but a lot certainly can happen in that period of time, as this section attests. The timeline compiled from many contributors is not complete by any means, but it offers a perspective on how much the electric generation sector of the electric power industry has changed since owner/operators of GE aero gas turbines first started meeting informally in 1982.


AGTSI
since 2004
All kinds of parts.
One kind of support.
COMPETITIVE
KNOWLEDGEABLE
RELIABLE
Aeroderivative Gas Turbine Support, Inc. (AGTSI) is a global supplier of gas turbine parts for:
• LM2500
• LM5000
• LM6000
• LMS100
• GG4/FT4
sales@agtsi.com
since 2004
Aeroderivative Gas Turbine Support, Inc.
1141 South Rogers Circle, Suite 11
Boca Raton, Florida 33487, USA
ISO 9001:2008
phone: +1 (561) 994-0000
fax: +1 (561) 994-3600
email: sales@agtsi.com
web: www.agtsi.com

Celebrating 25 years of service to the industry

A history of the Western Turbine Users Inc, the world's largest independent organization for gas-turbine owner/operators was published by CCJ and distributed at the organization's 25th anniversary meeting at the Long Beach Convention Center, March 15-18, 2015. You can access this special publication by scanning the QR codes below with your smartphone or tablet.

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

QR1 QR2 QR3 QR4 QR5

QR6 QR7 QR8 QR9 QR10

QR1: Before incorporation, *contributed by Mike Raaker*
QR2: After incorporation, *contributed by Sal DellaVilla*
QR3: Legislative drivers of GT technology, *contributed by Jason Makansi*
QR4: The LM engines, *contributed by Team GE*
QR5: A turbine salesman remembers, *contributed by Mark Axford*
QR6: WTUI's place in gas-turbine, power-industry history, *contributed by Wayne Kawamoto and Mike Raaker*
QR7: Aero engine portfolio, *contributed by Team GE*
QR 8: Profiles of ANZGT, TCT, IHI, MTU, *contributed by the depots*
QR 9: User remembrances, *compiled by the CCJ editorial team*
QR 10: Vendor remembrances, *compiled by the CCJ editorial team*

This mosaic blends snippets of information on the users who have given freely of their time to create and grow the WTUI into the world-class organization it is today, the laws affecting gas-turbine design and operation, LM engine engineering, noteworthy plants in the fleet, highlights of involvement by the OEM, depots, and exhibitors. We think you'll find a quick read illuminating.

1939 The first utility gas turbine to generate electricity, rated 4 MW and developed by Brown Boveri & Cie of Switzerland, is commissioned in the town of Neuchatel. The ASME Landmark is on display at the Alstom factory in Birr. Key to this engineering achievement was the successful demonstration of an efficient axial compressor. Its high power density made possible jet engines for aviation service—the forerunners of the GE LM engines supported by WTUI.

1945 IHI, one of the four depots supporting WTUI technical sessions, develops Japan's first jet engine. Fast forward to today, the company has shipped more than 560 gas turbines—including LM machines.

1967 IHI begins working in the areas of gas-turbine power generation equipment and cogeneration operations.

1969 GE launches the LM2500 engine; marine propulsion is the first application.

1971 First industrial use of an LM2500 is in the oil and gas industry.

1978 Passage of the Public Utility Regulatory Policies Act (Purpa) opens the generation market to non-utility entities, provided their facilities meet certain size, fuel, and efficiency criteria.

1979 LM2500 is first used in power generation service.

1981 Batch Air Inc begins life as an engine repair facility. It is located

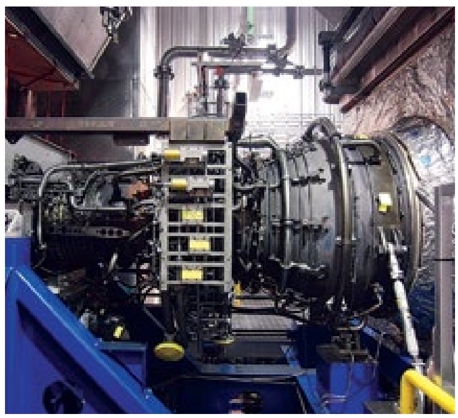
1. Wayne Kawamoto needs shades to protect his eyes from the reflection off the first LM2500 engine installed by Stewart & Stevenson in the US. The year is 1983, the place was Hawaiian Independent Refinery. Mark Axford remembers

2. GE's Jim McGlothlin presents plaque to Andy Anderson and Brian Brown of Procter & Gamble recognizing the LM2500 at the company's Oxnard (Calif) facility for being the first Model PC to achieve 100,000 operating hours. Year was 2002. The engine eventually would break the 250,000-hr barrier before being replaced with a PE model

TRANSCANADA TURBINES

Tel: 1.403.420.4200
Toll Free: 1-877-219-5800
Email: info@tcturbines.com

TransCanada Turbines (TCT) is an OEM-licensed global service provider for aeroderivative industrial gas turbines manufactured by GE and Rolls-Royce. TCT provides complete support for the Rolls-Royce Avon, RB211, RB211 DLE, GE LM2500, LM2500+ and LM6000 gas turbines under one roof.



TransCanada Turbines' test cell is located in Calgary, Alberta beside the Calgary International Airport. Operating for fourteen years, this test cell is capable of testing all marks of the Rolls-Royce Avon, RB211 and RB211 DLE, as well as the General Electric LM1500 and LM2500. TransCanada Turbines performs all tests with natural gas.

In 2013 TCT completed commissioning on a state of the art LM6000 testing facility, conveniently located adjacent to our existing test cell. It is fully capable of testing the LM6000 PA, PB, PC, PD and PF gas turbines'. Among other features and enhancements, the new test cell features a quick change design to allow for quick turnaround times when testing engines.

TransCanada Turbines Ltd.,
998 Hamilton Boulevard NE,
Airdrie, Alberta, Canada,
T4A 0K8

Tel: 1.403.420.4200
Toll Free: 1.877.219.5800
Email: info@tcturbines.com

TransCanada Turbines Ltd. is an ISO 9001:2008 and OHSAS 18001:2007 Certified Company.

3. Mike Raaker (at right in left photo) and Wayne Kawamoto (right photo) prove their long-term involvement with LM aero engines with these 1980s Polaroids taken at the Batch Air repair facility in the shadows of the Miami airport

at the Miami (Fla) airport and owned by George Batchelor.

Stewart & Stevenson receives its first LM2500 genset order from India, for an offshore platform.

1982 A handful of users responsible for O&M at several West Coast LM2500 generating facilities and the first LM5000 cogen plant at Simpson Paper Co (Shasta mill) in Anderson, Calif, begin meeting every couple of months in break rooms to discuss problems/solutions, best practices, lessons learned. This is the beginning of what would become WTUI. The host plant was responsible for coffee and lunch.

IHI's first LM5000 begins operating in the US.

Stewart & Stevenson receives its first US LM2500 genset order for the Hawaiian Independent Refinery Inc (Fig 1). It begins operating the following year under the watchful eye of HIRI's 20-something lead engineer, Wayne Kawamoto. He later is elected WTUI's first treasurer, a job Kawamoto still has today.

The first West Coast LM2500PC installed by GE's Turbine Business Operations Div (TBO) is commissioned at Procter & Gamble's Oxnard (Calif) manufacturing plant as a Purpa-qualified cogeneration package (Fig 2). Mike Raaker, former WTUI VP and board member and current historian/ambassador, was the technical engineer assigned to that project by P&G management in Cincinnati. He was involved from the beginning of work.

1983 Batch Air begins to overhaul LM engines for GE, to reduce the OEM's service backlog. Fig 3 is an "ancient" Polaroid of Mike Raaker (right) and Kevin Camfield in front of the Batch Air sign at the shop. Raaker was representing Procter & Gamble's Oxnard facility, Camfield P&G's Sacramento plant. As Raaker remembers, everyone visiting the plant was asked to sign in with a photo; that picture was circulated throughout the facility so everyone working on your engine could address you by name. How times change.

Hawaiian Independent Refinery starts up the first LM2500 packaged by Stewart & Stevenson for US service (Fig 4).

Simpson Paper Co's (Shasta mill) commissions the first LM5000 installed in the US. Steve Johnson, one of WTUI's early proactive users, has responsibility for the engine and quickly becomes expert in operating and maintaining the problematic GT model. He remains at the mill for more than 12 years. At the time of installation, the Shasta unit was the third LM5000 operating worldwide—if you count the two engines in Bangladesh which reportedly were not running well, if at all.

1985 The LM5000 at Simpson Paper Co (Shasta mill), which went commercial in May 1983, serves as the beta test site for the development of steam injection. Tests were successful and brisk sales of LM5000 STIG80 and STIG120 gas turbines followed.

1987 Batch Air is sold to Greenwich Air Inc, owned by Eugene Conese.

1988 Power Systems Engineering Inc builds the LM5000-powered Corona (Calif) Cogen Plant (Fig 5), today managed by WTUI Treasurer Kawamoto, and three LM2500-equipped generating facilities in Bakersfield, Calif.

TransCanada Turbines Ltd, perhaps best known as TCT, is established as a joint venture between Wood Group and TransCanada Corp.

Stewart & Stevenson provides Wheelabrator Technologies, Norwalk, Calif, its first LM2500 designed for high STIG injection. This technology is accepted and adopted by the South Coast Air Quality Management District in its NO_x reduction retrofit rule.

1989 Frank Oldread's focus on LM engines begins with his hiring by Power Systems Engineering Inc during construction of the LM5000-powered San Joaquin Cogeneration Facility in Lathrop, Calif. All of the LM5000 plants installed by PSE initially provided steam to an adjacent process plant (in this case, a glass factory). Some of the steam produced by the HRSGs installed in all PSE LM5000 plants was injected into the gas turbine to reduce NO_x emissions. San Joaquin's thermal host has since

4. Stewart & Stevenson's first LM2500 package was installed at the Hawaiian Independent Refinery in 1983. Photo was taken years later

5. Wayne Kawamoto's plant in Corona, Calif, provided steam and electricity to an adjacent cheese manufacturing plant

1>2

How one screw compressor gives you greater value than two reciprocating machines in fuel gas boosting for gas turbines

1. No Standby Required.

Still thinking about reciprocating or centrifugal compressors for fuel gas boosting? A Kobelco screw compressor is so reliable, you won't need to buy a spare. What's more, the screw design is inherently more economical to maintain. You'll get around six years of continuous operation between overhauls. Plus you'll have only one machine to maintain.

2. Save on Power.

Kobelco screw compressors feature an innovative slide valve that substantially reduces power consumption – without steps – to handle fluctuations in turbine load (turndown range: 100% to 20%) and suction pressures (up to 1,500 psig/100 barg). So you'll continue to conserve power and reduce costs every day.

Call Kobelco today to find out how one compressor can multiply your savings.

Ask Kobelco! The Best Solution for Any Gas Compression.

KOBELCO
KOBE STEEL GROUP

Kobe Steel, Ltd.
Tokyo +81-3-5739-6771
Munich +49-89-242-1842

Kobelco Compressors America, Inc.
Houston, Texas
+1-713-655-0015
sales@kobelco-kca.com

www.kobelcocompressors.com

gone out of business, but steam still is injected into the GT.

Power Systems Engineering Inc is purchased by Dow Chemical Co and the business is renamed Destec Energy Inc, which builds five more LM5000-powered generating facilities in Bakersfield, Calif.

1990 WTUI incorporates in the fall. Bylaws are developed. The directors elected after incorporation and their officer positions: John Tunks, president, until 1992; Kawamoto, assistant secretary, until 1994, and treasurer (he continues in this position); Bob Fields, secretary, until 1993; Ernie Soczka, chairman of the board, until 1993; Bill Caldwell, VP, until 1992; Leon Ballard, VP, until 1992.

1991 Strategic Power Systems Inc (SPS) begins collecting O&M data for GE, sharing this information with WTUI. The company also releases its first ORAP® report to participating aero users and GE summarizing operating data from 24 plants equipped with 19 LM2500s and 14 LM5000s. SPS has worked collaboratively with the WTUI leadership since incorporation.

The first LM6000PA, designed for NO_x control by use of water or steam injection, goes into service.

1992 Congress passes the National Energy Policy Act, allowing access to utility transmission lines by independent power producers. This complemented Purpa (1978), which opened up the generation segment of the electricity value chain to non-utilities.

John Tunks resigns as president of WTUI and Jim Hinrichs is elected to succeed him. Hinrichs serves in that position until 2008.

1993 Air New Zealand Gas Turbines' John Callesen attends his first WTUI meeting, returning every year since.

An Eastern Turbine Group is formed and holds its first meeting to reduce cost and time of travel for owner/operators in the East. But the allure of California is too great and the group cannot be sustained.

1994 The first LM6000PB, equipped with a dry low emissions combustion system (DLE), begins operation. It produces less than 25 ppm NO_x.

1995 Simpson Paper Co's LM5000/STIG80 in Anderson, Calif, reaches 100,000 operating hours under the maintenance contract offered by Energy Services Inc. Simpson owned three LM5000s; the other machines were in Pomona and Ripon, Calif. The Shasta mill went into bankruptcy and closed its doors in August 2001; however, the cogeneration plant continued to operate until May 2013.

1996 The first LM2500+ rolls off the production line.

1997 The first Model PC and PD

engines leave the GE factory.

Greenwich Air Inc is sold to GE, which closes the facility's doors in the early 2000s.

NGC Corp acquires Destec Energy and its plants in Bakersfield, San Joaquin, and Corona, Calif.

The first LM6000PC (SAC) and PD (DLE) models, more powerful than the earlier PAs and PBs, achieve commercial operation.

1998 LM6000 highlights include a variable-speed mechanical-drive option, commercial operation of the first dual-fuel DLE combustor, and first commercial operation of the Model PC Sprint™ (Spray Intercooled Turbine) system.

Stewart & Stevenson sells its gas-turbine business to GE.

1999 NGC Corp is rebranded Dynegy Inc.

2000 More than 200 LM6000s have entered commercial operation since the model was introduced in 1991. The high-time engine had logged more the 50,000 operating hours by this time; fleet operating hours were in excess of 3 million, reliability was 98.8%, and the 12-month rolling average engine availability was 96.8%.

More than 23,000 MW of GT capacity begins operating in this first year of what came to be known as the "gas-turbine bubble." From 2000 through 2004, a nominal 200,000 MW of GT capability is installed in the US. During the same period, WTUI attendance grows by nearly 30%.

The Dynegy generating plants are sold to El Paso Merchant Energy. Four years later El Paso sells its powerplants to Northern Star Generation LLC, illustrating the volatile nature of the independent power business.

2001 Base-load cogeneration contracts begin transitioning to cycling/peaking agreements.

TCT begins supporting technical sessions for the annual WTUI meetings. This effort continues today.

2002 GE offers to buy WTUI.

TCT's Dale Goehring leads the company's participation in WTUI technical sessions and continues in that capacity until passing the torch to Steve Willard in 2008.

GE pulls its support for WTUI.

2004 GE-authorized depots begin to provide WTUI technical support.

2006 First LMS100 engine, rated a nominal 100 MW and having an efficiency of 46% (LHV) in open-cycle operation, enters commercial service for owner/operator Basin Electric Power Co-op at the utility's Groton (SD) Generating Station.

2007 A new management team at GE reinstates the company's support of WTUI.

2008 Chuck Casey is elected secretary of WTUI, a position he retains until his election as president in 2013.

Jim Hinrichs and Jack Dow become the first WTUI officer/director retirees to earn lifetime membership in the organization.

Jon Kimble succeeds Jim Hinrichs as president of WTUI and serves in that capacity until his retirement in 2012.

WoodGroup Pratt & Whitney opens a shop in Florida to overhaul LM2500s and FT4s. The business is not sustainable long-term.

2009 Bob Nelson's battle with cancer ends at age 46. The former WTUI director was SMUD's superintendent of thermal projects. He was highly regarded by industry peers for his technical and management prowess, and well liked. One industry colleague said, "You always felt good being around him." Nelson's recipe for professional success: "No serial number ones."

Charlene Raaker is appointed conference coordinator; she continues in that position.

2010 IHI partners with Reed Services Inc in the Cheyenne Service Center equipped especially for supporting LM6000 owner/operators.

WTUI's 20th anniversary celebration is held aboard the USS Midway.

2011 CAMS and Air New Zealand collaborate to launch Air New Zealand Field Services LLC in Bakersfield, Calif. Frank Oldread is named general manager.

TCT opens its state-of-the-art 220,000-ft² repair and overhaul facility in Airdrie (near Calgary).

2012 Chuck Casey replaces Jon Kimble as president of WTUI; he continues in that position.

WoodGroup Pratt & Whitney withdraws from its LM2500 overhaul offering.

2013 IHI celebrates its 160th anniversary.

Jon Kimble is granted lifetime WTUI membership upon his retirement as the group's president. Chuck Casey is elected to replace Kimble.

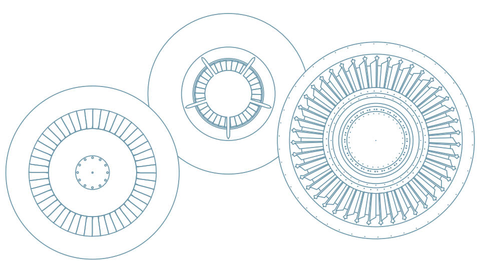
TCT expands its testing facility to better support the LM6000 PA, PB, PC, PD, and PF engines.

Wood Group and Siemens TurboCare form the joint-venture company EthosEnergy Group, specializing in the maintenance, repair, and overhaul of gas and steam turbines.

2014 Jim Hinrichs, past president and the face of WTUI for two decades, passes unexpectedly during a back operation.

2015 MTU closes in on 20 years of participation at WTUI.

WTUI celebrates its 25th anniversary.



The depots

The success of Western Turbine meetings is underpinned by the technical and financial support of the OEM and the four depots licensed by the GE to inspect and repair the four engines addressed by the group: Air New Zealand Gas Turbines (ANZGT), Auckland; IHI Corp, Tokyo; MTU Maintenance Berlin-Brandenburg GmbH, Ludwigsfelde, Germany; and TransCanada Turbines (TCT), Airdrie, Alta.

Representatives of the depots work closely with the WTUI leadership to prepare "lessons" for each of the breakout sessions. Deliverables include notebooks, given to participants, which review recent service bulletins and service letters issued by the OEM; a summarize depot findings since the last meeting; explain causes of performance loss and how to correct them; and provide the fundamentals of critical-parts life management.

The knowledge contained in the notebooks, and that shared by LM experts during the meeting, provide comprehensive, low-cost training for all those involved in the operation, inspection, and maintenance of aero engines. Electric power generators obviously agree with the value proposition offered by Western Turbine because each year first-timers comprise between one-third and one-half of the user attendees.

Each depot presented a summary of its WTUI activities over the years as part of the 25th anniversary celebration. Here are some of the highlights:

ANZGT. General Manager John Callesen said Air New Zealand has been involved in the WTUI since its incorporation. His first meeting was in

Waterside Power, Ripon, Terry Bundy, Rokeby claim Best Practices Awards

CCJ Editor Bob Schwieger presents Best Practices Awards to 2015 LM aero recipients at the Western Turbine meeting in Long Beach last March. At left is Brett Weber, O&M manager at Ripon Cogen; Tyson Chambers accepts for Lincoln Electric System's Terry Bundy and Rokeby Generating Stations (center); and Wayne Kawamoto, WTUI treasurer and Corona Cogen plant manager, accepts for CAMS colleague, Bill Jolly, the Waterside plant manager (right)

The four LM aero facilities among the nearly three-dozen plants selected by a panel of industry judges to receive the CCJ's 2015 Best Practices Awards were recognized by their peers at the Western Turbine Users Inc's 25th anniversary meeting. The presentations were made during the group's Tuesday awards luncheon, March 17, by Editor Bob Schwieger. Summaries of the plants' accomplishments follow:

Waterside Power, an emergency oil-fired peaking plant serving ISO-New England, received a Best of the Best award for its HMI upgrade, enabling automatic starts of three TM2500s and dramatically improving reliability. Automation of the fuel forwarding system was part of the improvement effort. Proven project results include the following:

- Staff reduced from five to three employees, including the plant manager.
- Time to go from notification to start to the desired dispatch point was reduced to 10 minutes.
- Between the time the HMI automation project was completed and the awards entry was prepared at the end of 2014, Waterside had responded to 29 fast-start emergency dispatches without a failure and made 40 successful starts without an operator error or a trip of any kind—both plant records. For details, go to article on p 26.

Ripon O&M personnel were challenged to keep their LM5000-powered cogeneration facility operating reliably given the unpredictable nature of plant's 25-yr-old WDPF control system. Multiple fail-safes were hard-coded into the DCS, so even small deviations in process variables—such as temperature fluctuations—could trip the unit. Re-starting of the gas turbine and critical subsystems—including the chiller and water treatment facilities—took about an hour.

A new contract with the California Independent System Operator focused on fast starts and flexible ramping. Reliability concerns, plus a lack of local support (repairs, maintenance) for the antiquated DCS, dictated the migration to a "non-proprietary" PLC-based control system with state-of-the-art functionality (Fig 1). Examples of the last include embedded time synchronization, rack-based historian, sequence-of-events capture, integrated condition monitoring, intelligent motor control, etc.

Project benefits include the following:

- Shutdowns and nuisance fail-safes are down nearly 90%. By eliminating unplanned shutdowns, the plant typically starts up only once daily now, keeping emissions well within permit limits.
- Other regulatory issues associated with unpredictable performance—the plant operates under permits from a dozen different regulatory bodies—have been mitigated by the new automatic start capability and ability to monitor operating conditions in real time.
- Re-start time has been reduced by 15 minutes.
- The transition to a non-proprietary network simplifies hiring. New personnel do not require specialized expertise to operate the plant and troubleshoot controls issues.

Lincoln Electric System's Terry Bundy Generating Station is equipped with three LM6000s, two incorporated in a combined cycle; the third is a simple-cycle peaker. The plant's main source of water is treated effluent from one of the Nebraska city's wastewater treatment facilities two miles away. Chemistry in the 3-million-gal storage tank at Bundy requires round-the-clock monitoring and periodic adjustment given the cycling nature of the 2 × 1 power block. The wet cooling tower is the largest water consumer onsite.

The original process for controlling biological contamination in the storage tank had its limitations. Chlorine addition was by carrying containers of the biocide to the top of the tank and

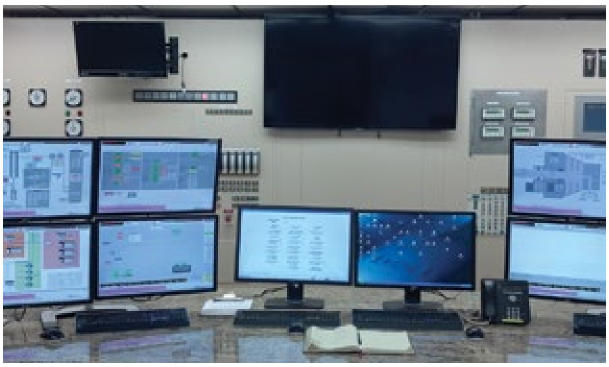
1993 and it proved to be the catalyst for Callesen's transfer from the company's aviation activities to its marine and industrial section.

One of the most significant developments for ANZGT and its ability to contribute to the WTUI conference in a major way came in 2003, he said, when the board of directors asked the four depots to coordinate and facilitate the technical breakout sessions.

Inviting four fiercely competitive companies to collaborate on content development could have been a recipe for disaster, Callesen recalled; however, the opposite occurred. The desire of each of the depots' leaders and teams to do what was right for WTUI by jointly sharing their technical knowledge and experience was agreed to unanimously and continues today.

ANZGT's involvement in the overhaul and maintenance of land-based and marine aero engines has grown in lock-step with WTUI throughout the organization's 25-yr history. One recent example is the company's partnership with Consolidated Asset Management Services (CAMS), Bakersfield, Calif, in 2011 to better serve the heavy concentration of LM users in the US—with specific focus on LM5000 owner/operators. GM of the US operation is Frank Oldread. Both he and his Bakersfield colleague, Jimmie Wooten, are well known to WTUI members, both having served the group as directors in their user days.

IHI's involvement with GE aero engines predates WTUI. The company developed the IM5000 gas turbine, comprised of an IHI power turbine and the LM5000 gas generator, and delivered its first unit to a Japanese customer in 1978. This engine was offered to US



1. Ripon Cogen migrated from an early WDPF control system to a non-proprietary PLC-based control system with state-of-the-art functionality (left)

2. Suppression system is designed to mitigate the impact of an ammonia release, considered unlikely (right)

pouring it through a hatch. This was not in keeping with today's safety culture; plus, mixing of the chemical with tank inventory was not thorough and the release of chlorine gas in the upper reaches of the tank contributed to the corrosion of roof structural supports.

Terry Bundy personnel resolved all three issues by replacing the original 2-in.-diam recirculation line between the storage tank and the cooling-tower sump with a 6-in. pipe equipped with chemical injection ports and arranged for automated delivery of chlorine to the system. In addition, the new recirc line was designed with a flow-distribution nozzle to enhance tank circulation and mixing.

Lincoln Electric's Rokeby Generating Station has three chiller-equipped simple-cycle gas turbines. The air-inlet chillers are supplied by two thermal-energy storage systems (total of 4 million gal) equipped with 2030 tons of ammonia-system ice-making equipment.

During the site's last risk-management program review, the potential for a catastrophic ammonia release was identified as a major concern. Reason: Plant was in a rural setting when it was built a decade ago; today there are residential developments on three sides.

Plant installed and demonstrated the effectiveness of detection and suppression systems to mitigate the impact of an unlikely ammonia release. The suppression system, designed to NFPA 15, consists of multiple spray nozzles configured on water distribution lines surrounding the 2800-gal ammonia receiver and condenser—considered the most vulnerable system components (Fig 2). Spray density is 0.25 gpm/ft^2. The site's fire protection system provides spray water at the pressure and flow required.

Detectors are installed both in the immediate vicinity of ammonia-system equipment and at the plant perimeter. The latter are solar-powered and have wireless CIP-compliant communication links to the detection system controller. Sensors can output alarms for multiple concentrations of ammonia. Thought is being given to automatic actuation of the spray system based on multiple sensor indications of a leak because the site is not manned 24/7.

power producers beginning in the early 1980s. Design of LM2500 and LM6000 packages were next. IHI's first involvement in the WTUI technical program came in 2000 when an IM5000 package session was launched.

Today, the company operates two LM-series Level 4 maintenance facilities in Japan, at its Mizuho and Kure Works—the only such GE-authorized shops in Asia.

IHI's aero management team reviewed the capabilities of these facilities, and the company's new M&D center, on the first morning of the meeting. They stressed it is now possible for owner/operators to monitor all tests and hold points during engine overhauls without traveling to Japan.

IHI is a 162-yr-old company that continues to grow. In 2008, it expanded its operations in the US, offering its aero maintenance services to more customers and prospects. Two years later, it formed a partnership with Reed Services Inc and a branch office and shop were opened in Wyoming. The Cheyenne Service Center is equipped with a comprehensive customer support system—including maintenance tooling for all LM6000 models, an LM6000PC lease engine, and an experienced field-service team.

MTU Maintenance representatives discussed the company's package, upgrade, and engine relocation services at WTUI. MTU, an authorized service provider for all types of LM2500, LM5000, and LM6000 gas turbines, has a global repair and service network that includes shops in Germany, Kuala Lumpur, US, Thailand, Brazil, and Australia. LM overhauls over the years number about 1000. Company specialists are on call 24/7/365.

The Ludwigsfelde shops south of Berlin are the company's center of excellence for industrial gas turbine repairs. The test cell at these facilities was remodeled relatively recently to accommodate testing a broader spectrum of industrial gas turbines, such as the LM6000PF and the LM2500+G4. Among the improvements are an enhanced monitoring database and data acquisition system, a six-valve fuel skid, and Mark VIe control system. The MTU speakers encouraged attendees to visit Ludwigsfelde and take some personal time to enjoy Berlin.

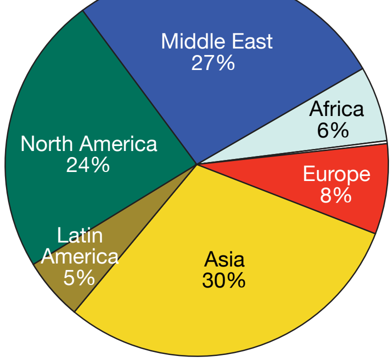
TCT's association with WTUI dates back almost to the time of its formation in 1998 as a joint venture between Wood Group Gas Turbines and TransCanada PipeLines Ltd. Dale Goehring led the way for TCT at Western Turbine, presenting for the first time in 2002 on what the authorized services providers were seeing in the fleet and what operators could do to address/prevent those issues. Five years later, he began transitioning the company's technical presentations to Steve Willard and a year later the latter got full responsibility for that ongoing effort.

TCT's management team stresses the health and safety aspects of its business at every meeting. The company is one of Canada's safest, having gone more than five years without a lost-time incident. OHSAS 18001:2007 certification was earned in 2010. Management takes particular pride in TCT's HandSafe program.

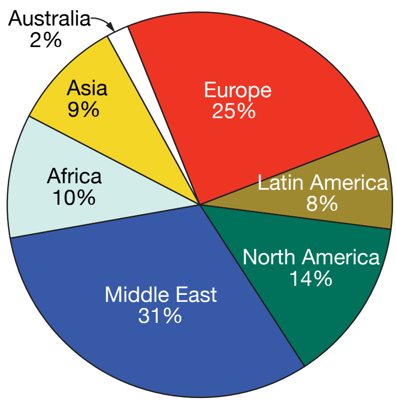
Another point of pride is the state-of-the-art, 220,000-ft^2 custom depot in Airdrie, which was opened in 2011. It enables faster turn times. To better serve owner/operators, TCT also has invested significantly in a large pool of assets for rotable exchange—including engines and a variety of modules.

The Axford Report

Mark Axford, the Houston-based consultant considered by many to be the leading independent expert on gas-



6. Orders for gas turbines worldwide in 2014 totaled slightly less than 52 GW, down 15% from the capacity booked in 2013. The highest percentage of business came from Asia, which has been the norm for the last several years. Two points made by Axford in his address before the Western Turbine Users: The US "fraction of the action" was 20% of world orders, the most since 2002; 93% of "Europe" orders came from the former USSR



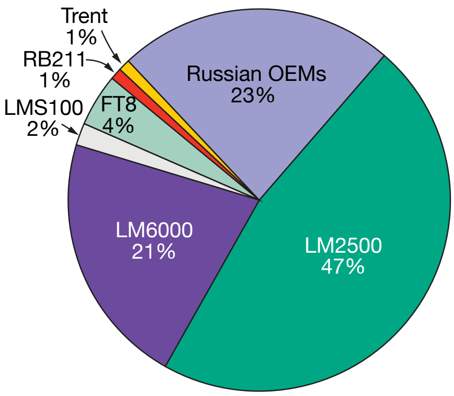
7. Aero GT orders worldwide totaled nearly 6800 MW in 2014, down 15% from the aero capacity booked globally the previous year. Note that 84% of "Europe" orders came from Russia and that engines ordered by Egypt (14 LM6000s and 20 trailer-mounted LM2500s) dominated in the Middle East

turbine (GT) markets, predicted US orders for GTs would drop by 10% in 2015 from the slightly more than 10 GW purchased in 2014. Worldwide, he expects orders will be up 10% from the nearly 52 GW booked last year. The Eurozone's lingering recession is a significant factor in the downward pressure on international orders (less than 200 MW in 2014).

The Axford Report presented at each WTUI meeting is highly regarded by conference attendees and always attracts a large audience. Axford's perspective and data help guide business decisions made by the 200 equipment and services providers that regularly participate in the world's largest meeting dedicated to GE aero engines in land and marine applications.

The market analyst began by comparing his 2014 predictions to actuals. His *Ax*Spectations were US orders would be up by 15% over 2013, worldwide down by 5%. The market surge he predicted for 2013 showed up in 2014 with orders from America up by 75% year over year; however, GT orders globally were down by 15%. "I got the direction right but the magnitude wrong. . .this is never easy," Axford said. The US "fraction of the action" was 20% of world orders, the most since 2002 when it was 26%.

Geographically, 30% of 2014 orders were from Asia, 27% from the Middle East, and 24% from North America (Fig 6). No surprise with Asia and the Middle East leading the purchasing activity, even with a nearly 5 GW drop in orders from China to 3000 MW in 2014. Africa, which finished third in 2013 sales with a 20% market share, dropped back to fifth place last year with slightly more than 6% of the order book. Recall that Algeria purchased lion's share of Africa's GT capacity in 2013, ordering 9800 MW. Last year,



8. LM6000s and LM2500s (including trailer-mounted TM2500s) dominated aero orders outside North America in 2014, as they have for several years, with GE compiling a 70% market share of the more than 5800 MW sold. Rolls-Royce's aero-engine business, recently purchased by Siemens AG, had 2% of the orders on a capacity basis (RB211 and Trent in the pie chart). Pratt & Whitney Power Systems' FT8 product line, now owned by Mitsubishi Heavy Industries Ltd, recorded 4%. Russian OEMs fared well in 2014, capturing 23% of the aero capacity ordered outside North America

it bought 1745 MW.

OEM market share. Globally in 2014, 78% of the units larger than 10 MW were ordered from GE and Siemens, with the split in round numbers at 49/29 favoring the former. GE's share was its best competitive performance since 2002. Mitsubishi-Hitachi was third with a 12% market share.

Axford breaks out the aero stats for WTUI attendees. In North America, 2014 orders totaled 938 MW, he told the group, with 91% of the order book going to GE. More than half of the total was purchased by the oil and gas industry (horsepower of mechanical-drive units was converted to megawatts for the purposes of this analysis). Worldwide, aero orders in 2014 totaled nearly 6800 MW, down from 8000 MW a year earlier (Fig 7). GE garnered 72% of the total aero business globally.

Fig 8 illustrates that aero orders outside North America were dominated by sales of LM2500 and LM6000 engines. Those models also were favored by North American customers. Global sales of the popular LM6000 totaled 35 engines in 2014; four will be installed in North America. Egypt led all customers with 14 orders; it also ordered 20 TM2500s. More than 1000 LM6000s have been ordered since 1990; peak year was 2000, when nearly 175 were bought.

Sales of the LMS100 dropped to two units in 2014—one for service in America, the other in Argentina. Fleet now totals 64 machines (45 in the US) on order, being installed, or operating. Base rating for this model is now 110 MW, was 100 MW. Industry sources have told the editors that the premium price for the LMS100 might make it unattractive to at least some international prospects.

Aeros versus frames. Fig 9 shows that the split between aeros and frames has remained relatively constant for the last several years, with the latter capturing 84% to 88% of the business. But aeros are the clear choice among users for gas turbines rated between 18 and 65 MW, which includes all the LM engines supported by WTUI (Fig 10).

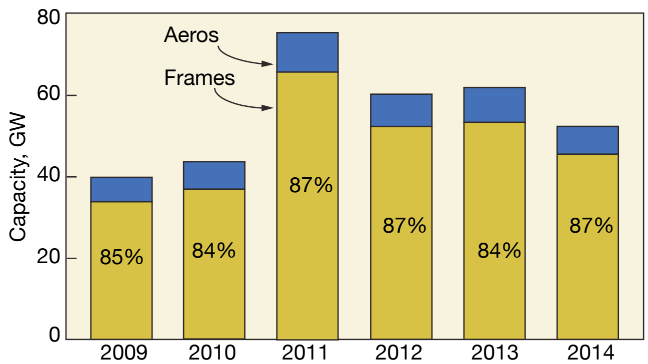
In North America, frame orders totaled more than 11,000 MW, split about 800 MW each for Canada and Mexico and balance US. GE booked 55% of the business, Mitsubishi-Hitachi 23%, and Siemens 19%. Nearly 80% of the orders are for GTs larger than 175 MW installed in combined cycles.

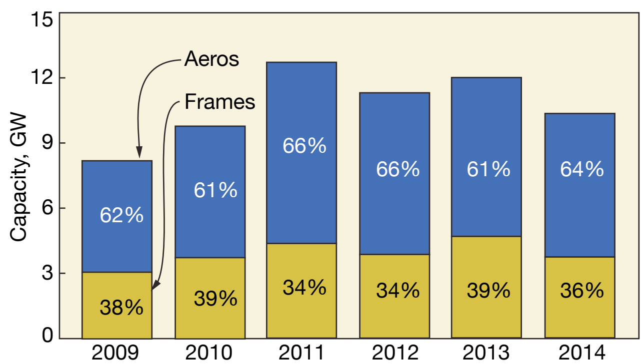
Simple cycle versus combined cycle. More than three-quarters of the gas turbines ordered last year for US service will serve in combined cycles, the balance in simple-cycle applications. This is significantly higher than the 64% averaged over the last six years, based on Axford's numbers.

Going back further in time, the market split was closer to 50/50, the consultant said. Perhaps the ability of the latest combined cycles to start faster because of equipment design improvements and better startup procedures make owner/operators more inclined to cycle these units and compete against simple-cycle engines for some business that in the past was almost exclusively theirs.

Economic climate, observations. Axford closes his annual presentations with a look at economic and market trends. Here are some takeaways from the 2015 Western Turbine meeting:

- Euro was $1.38 during the 2014 WTUI meeting, $1.05 this year. A falling Euro boosts the US economy in general but hurts exports of machinery—like LM6000s.
- Oil prices fell 60% in the nine months before the 25th anniversary conference. Axford quoted a news source as saying wells are being drilled but not completed; also, reserves remain very significant. He doesn't expect to see US crude prices above about $60/bbl in 2015.
- Europe still is in recession. Power demand is soft and orders for GTs will reflect that in 2015. Germany is retiring nuclear generating stations and adding low-cost coal-fired units—go figure.
- Canada is being clobbered by falling oil prices, and currency valued at 78 US cents per Canadian dollar (March 2015).
- In Mexico, energy reforms are working but the pace of change has slowed with the decline in oil and gas prices. The peso is off by about 15% with respect to the US dollar since July 2014.
- In Asia, LNG prices, linked to crude are down sharply: $19 million Btu in 2014, about $11 today. This will stimulate GT orders.
- In Africa, Nigeria has huge potential if the independent power movement is successful.
- US exports of LNG are expected to raise the prices of domestic gas





9, 10. Market share of aeros versus frames, worldwide, for all gas turbines larger than 10 MW is at left. For GTs rated between 18 and 65 MW, worldwide, aeros traditionally hold a 2:1 advantage in aggregate capacity (right) supply by 15-25 cents/million Btu.

- If the Siberian pipeline to China happens, it will require the equivalent of 4 GW of GT additions for compression service. While the selling price of the gas has not been announced, most experts predict about $10/million Btu.

Special technical presentations

HEPA filters may double time between aero-engine overhauls

QR11

Alliance Pipeline's evaluation of hydrophobic high-efficiency particulate air filters, now in its fifth year (QR11), continues to support the company's confidence in the W L Gore & Associates' product. The integrated Canadian/US high-pressure natural-gas transmission system had more than 500,000 hours of Gore HEPA experience at the time of the 2015 meeting.

Alliance Pipeline's Rob McMahon and his company have generously shared the results of the long-term evaluation program with Western Turbine Users and CCJ readers annually. Coverage began in 2011, a year after HEPA filters were installed on the LM2500+G4 serving the Windfall pumping station at the start of the Alliance system and a midstream LM2500 at Kerrobert in west-central Saskatchewan. In 2012, the company equipped its entire fleet with Gore filters.

McMahon was scheduled to update users on the last year's results but had to cancel at the last moment. Coauthor Ryder Pingry of Gore handled the assignment. The first half of the presentation, discussing the HEPA value proposition and the pipeline's early experience with the Gore filters, is summarized in articles published previously (QR12).

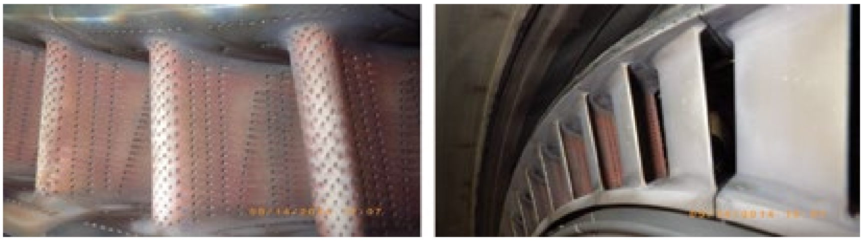
QR12

Highlights, recent history. The filters installed on the Windfall G4 in April 2010 were changed out in November 2013—as a precaution. Some delta-p spiking had occurred and not having first-hand experience on how HEPA filters fail, Alliance erred on the side of caution going into the winter peak run season. Interestingly, this was the only engine in the fleet using HEPA filters without coalescer wraps and the only one reported as experiencing delta-p spiking. The replacement filters have coalescer wraps. Pingry said the original Kerrobert filters would be replaced in 2015.

The last third of the McMahon/Pingry presentation focused on a hot-section maintenance-extension experiment involving Alliance Pipeline's Unit 671059 and included a summary of the company's HEPA experience to date. This well-traveled LM2500 began its career at the Manchester compressor station near the delivery end of the pipeline.

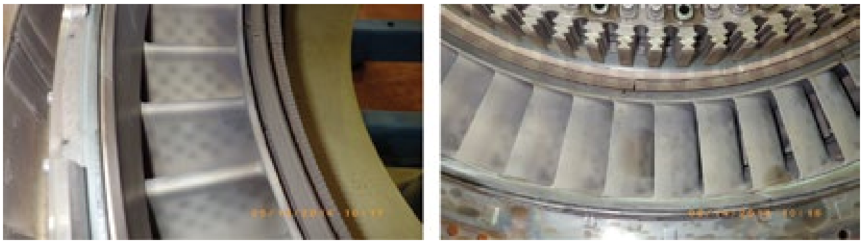
The engine was removed from Manchester when its No. 4 bearing failed. After repairs, the unit was installed at Fairmount, three compressor stations upstream. It operated there until the second-stage high-pressure-compressor blade issue that affected the fleet dictated its removal. At this point the LM2500 had operated for 25,000 hours with standard filters.

Important to note is that the hot section was inspected during both shop visits for repairs, but never touched. The unit was reinstalled at Olivia, one station downstream from Fairmount, in 2012 but with the HEPA filters being deployed fleet-wide. The goal was to see if extending the maintenance interval beyond 25,000 hours would have any adverse effects on the



11. LM2500 first-stage nozzles have operated for 43,000 hours; the last 18,000 hours the engine was protected by hydrophobic HEPA filters. Cooling ports in the leading edge (left) are clear and there are no burn marks on the airfoils. Trailing edges at right are clean and exhibit no erosion, cracking, or platform deformation

12. First-stage rotating blades show some heat erosion, but tip caps still are in good condition. Experts recommend a shop visit when heat erosion gets close to, or into, the cooling holes



13. Second-stage nozzles look almost new—leading edges at left, trailing edges at right

14. Looking at the tip and tip cap of this second-stage rotating blade you might think it new, certainly not an airfoil with 43,000 hours of service

unit and its performance.

Engine 671059 was sent to a depot in May 2014 for its 25,000-hr overhaul—at 43,000 hours. The very positive results are evident in Figs 11-14. First question many experienced users likely would ask: If the engine ran 25,000 hours without HEPA filters, where did the fouling and/or water-wash residue from that period go? The assumption is that it burned off during the last 18,000 hours; no more fouling was added during this period because of the HEPA filters.

Engine experts agreed that the hardware from this hot section (43,000 hours) looks similar to that for an engine after 25,000 service hours. The takeaway for owner is obvious: There doesn't seem to be a reason why the typical hot-section exchange at 25,000 hours couldn't be extended to 50,000 hours—as long as Alliance Pipeline's operational profile remains the same.

Payback. McMahon's slides indicated the short-term benefits of HEPA filters include virtually no degradation in compressor efficiency and shaft power over the run period, and better heat rate. The use of hydrophobic HEPA filters saves Alliance Pipeline considerable resources. The environment surrounding these compressor drivers dictated water washing each spring, summer, and fall pre-HEPA. Annually, engine washing took more than 1000 man-hours and consumed more than 2250 gal of demineralized water and more than 20 gal of soap, which required disposal in an environmentally acceptable manner.

Long term, HEPA filters save big bucks for Alliance. McMahon figures the ability to operate its engines for six years between overhauls reduces expenses in the neighborhood of eight figures. Hot parts last longer because they run cooler.

HRSG coverage increases as LM cogen, combined-cycle facilities multiply

Over the last three Western Turbine meetings, HRST Inc's Ned Congdon, PE, has built an enviable following among aero owner/operators with heat-recovery steam generators. At the 2015 conference, he and colleague Jack Odlum presented on HRSG economizers.

Congdon, a dyed-in-the-wool boiler guy with decades of experience, never repeats subject matter from meeting to meeting. That's probably why his session is always full. Attend for five or six consecutive years and you might qualify for a degree. In case you missed his presentation in 2014, the focus was on reducing the startup time of aero combined cycles; in 2013, he provided solutions to HRSG inlet-duct challenges.

Congdon and Odlum began this year's presentation with a review of the two principal economizer designs for HRSGs: panel type and return bend. Flow patterns characteristic of each design, and the importance of vents and drains, were included in the subject matter. To access the basics, read "In the boiler business this is front-page news" (QR13).

QR13

Thermal shock. This CCJ article also describes how thermal shock occurs in panel-type economizers and how HRST's ShockMaster® avoids it. Simply put, ShockMaster is a special type of economizer where water flows up in all panels, enabling it to resist tube cracking and other issues caused by the thermal gradients experienced in some conventional economizers where water flows both up and down in each panel.

Buoyancy instability was the next topic addressed by the speakers. Like thermal shock, it is a cycling issue—one that causes flow stagnation (sometimes even reverse flow) in downflow tubes in panel-type economizers. When stagnant (and reverse flow) tubes become hotter than neighboring tubes because heat transfer is compromised, tubes are severely stressed and fatigue failures can result because it's possible to have hundreds of thermal cycles daily. The risk of buoyancy instability is greatest at low loads.

Congdon suggested users have three solutions at their disposal to mitigate buoyancy instability in panel-type economizers. They are:

- Recognize that certain operating loads are damaging and avoid them.
- Increase water velocity in economizer tubes with a recirculation circuit.
- Modify the flow circuitry of pressure parts.

In return-bend economizers with low design velocities, buoyancy causes water in some circuits to flow very slowly (almost stagnant), and others to flow quickly. If the gas temperature is above the saturation temperature, stagnant tubes will vapor lock—that is a steam bubble is trapped in the return bend. The bubble will remain there until the load increases enough to clear it. However, the speakers said this might never happen. Operations personnel know when a vapor lock clears; the banging and clanging of water hammer is distinctive.

An interesting point made was that different tubes may become stagnant from one startup to the next. Also, it is difficult to modify existing systems to correct the problem. If a return bend fails in service, consider replacing it with one having a thicker wall.

Congdon and Odlum closed out their presentation with highlights of their thinking on drain cracking, corrosion under insulation, freeze damage, and performance thieves.

How to maintain SCR catalyst at peak effectiveness

The testing, cleaning, maintenance, and replacement of SCR and oxidation catalysts is a popular topic at gas-turbine user-group meetings—WTUI in particular—for a very simple reason: You can't operate your generating units if they don't meet the permitted emissions levels for NO_x and CO. The Western Turbine leadership assures ongoing coverage of emissions control systems at its annual meetings. At the Long Beach conference, Cormetech's Elizabeth Govey and Karolyn Hagan updated attendees on SCR catalyst technology.

Team Cormetech packed four hours of information into a one-hour presentation, using 57 slides to cover the science of emissions control, performance monitoring, maintenance, and catalyst replacement. Recall that the SCR process is relatively simple: Nitrogen oxides present in the gas-turbine exhaust stream are contacted by ammonia sprayed into the flow path—ideally from both sides of the SCR—in the presence of a catalyst; the ensuing chemical reaction produces nitrogen (an inert gas) and water vapor, which are vented to the atmosphere.

Good distribution of ammonia across the entire exhaust stream is critical to system performance the speakers told the group. The quality of aqueous ammonia is important, too; it should be prepared using deionized water. Require that a chemical analysis certification accompany every shipment to your plant.

Inspect the SCR regularly, during planned outages. Check the condition of the perforated plate; also the condition of seals within the SCR modules and between the modules and reactor frame. Make repairs as necessary. Keep in mind that some seal loss is acceptable, but repacking is needed periodically. In cases where catalyst elements have shifted, it may be necessary to remove SCR modules to reposition properly. Consider installing retention plates as a mechanical barrier to hold seal packing in place.

Inspect lances, vaporizers, the piping network, air blowers, etc—and the catalyst, of course (QR14). Regarding the last, pay attention to catalyst appearance, particularly any discoloration and the uniformity of that discoloration. Check for fouling of the catalyst bed by insulation or particulate matter and clean as required. Important: Keep the catalyst dry when the SCR is out of service. Every other year, pull catalyst samples from the unit for testing.

QR14

SCR catalyst deactivates over time, but the process is slower for gas-fired plants than for coal-fired ones. Remaining activity is determined in the laboratory. There also may be a change in the physical structure of the catalyst, but it may not be visible to the untrained eye; lab tests will provide a proper assessment. When catalyst testing reveals a significant loss of performance, and ammonia use has increased, replacement generally is recommended by a rigorous economic evaluation (QR15). Regeneration, common in coal applications, is not suggested for gas plants. The deactivation mechanisms differ with the fuel.

QR15

Team Cormetech advised that the typical lead time for replacement catalyst is nine to 12 months and installation time ranges from three to five days depending on whether one or two shifts are used.

Other recent presentations at WTUI on emissions control and catalyst testing, care, and performance, etc:

- 2014, Dan Ott, Ted Heron, and Joe Otto, Environex Inc (QR16).
- 2013, Nathan White, *Haldor Topsoe Inc* (QR17).
- 2012, L J Muzio, T D Martz, and R A Smith, *Fossil Energy Research Corp* (QR18).

QR16 QR17 QR18

A CliffsNotes-type of maintenance guide for the LM6000PC

Dale Reed (Reed Services Inc, Calgary, Alta, and Reed Services of Wyoming Inc, Cheyenne) is a frequent presenter at Western Turbine meetings and respected for his knowledge of the LM6000. At the 2015 meeting his topic was "LM6000PC Maintenance Requirements (commonly overlooked)."

The basis for Reed's presentation was the content in Volume 1/Chapter 12 of GEK 105059, updated in 2014 by the OEM, which focuses on preventive maintenance and servicing checks. He walked attendees through the document, pointing out the value of reading the introductory material to get an understanding of important terminology, such as serviceable and repairable limits.

Serviceable limits define the maximum departure from the OEM's established new equipment standards that will not materially reduce the usability of a part, or will have no significant bearing on effective use or operation of equipment between scheduled maintenance intervals.

Repairable limit defines the extent of repair that can be performed on a part to return it to a serviceable condition. As you read through the tables in Chapter 12, if there is no entry in this column it does not mean the part cannot be repaired, but rather that no repair procedure has yet been developed. Obviously, if the notation "not repairable" appears it means you should not even *attempt* a repair.

Reed's presentation, encompassing more than five-dozen slides, walked users through each maintenance item highlighted in the three summary tables presented in Chapter 12—one slide per item. This is a valuable resource for plant personnel. Think of a deck of flash cards with all the information you need for each maintenance item on a single card, with room for your own notes if you print out the deck accessible to Western Turbine user members on the organization's website at www.wtui.com.

By way of example, at the first entry in Table 12-1, "Recommended Preventive Maintenance and Servicing Checks," is "Borescope Inspection." Reed's flash card gives the following information:

- First line: Borescope Inspection, 4015 00. (The number is the GE procedure number.)
- Second line: Maintenance interval. For virtually all items, the interval is 4000 operating hours, 450 starts, or annual (whichever comes first).
- Third line: Special notes identified in the table. Table 12-1 has six notes; the listing for Borescope Inspections indicates that Note 5 applies. It reads, "Inspections shall be made as required per troubleshooting procedure."
- Fourth and additional lines (as required) identify references users should have available to fulfill requirements. In this case, Service Bulletin (SB) LM6000-IND-062 R0 and Service Letters (SL) LM6000-IND-04-001 R2 and 08-002 R0. Note that the titles of the supporting documents are provided on the flash card.

Reed took a few minutes to explain the value of the first and third supporting documents. The service bulletin, which dates back to 1994, has to do with safety cables for borescope-inspection plugs. The speaker stressed that safety cables can save your bacon should a plug back-out during operation (they sometimes do). The second service letter recommends torque levels to mitigate the possibility of back-out.

The enclosure inspection slide listed nine supporting documents. There's a lot to check in the package, including the crane and trolley. A photo of a trolley that failed, showing the engine on the ground half in/half out of the package, was an exclamation point on Reed's message regarding the importance of inspection. You should be looking at your engine all the time, he said.

Understanding the lingo of LM engine component dispositions

MT R&O LLC's Rick Kowalski, PE, opened his presentation, "Maintaining an Ageing Fleet through Parts Repairs," by saying that repair and overhaul (R&O) are key components in serviceability strategies used throughout the four aero fleets served by the Western Turbine Users. Component salvage options are available for the proportionate extension of part serviceability, he continued, with material-add constituting the largest portion of component R&O—through standard joining, plating, thermal spray, coating, and custom mods.

The speaker learned through discussions with LM owner/operators the following influences on repair decisions:

- OEM guidelines and recommendations can drive decisions for replacement versus repair for serviceability.
- Access to inventory is controlled and can be limited.
- There is finite availability for replacement parts in the market.
- There is an expressed need for salvage options with existing engine components.

Kowalski reviewed the attributes of the repair technologies identified in the opening paragraph for extending part serviceability and offered a couple of examples—including bearing journal restoration by use of thermal spray, and replacement of the wear strip on the No. 3 bearing stationary seal with an improved component.

The need for evaluation and disposition follows every aspect of engine and component review and processing, he continued—including visual and borescope inspection, engine teardown reviews, component reviews, and standard R&O in-process.

The portion of Kowalski's presentation concerning dispositions and how to use them was particularly instructive, in the editor's opinion. He began by identifying five functionally available

dispositions cited in military standards:

- Accept/use as is.
- Rework.
- Repair.
- Reject.
- Scrap.

The speaker said the primary purposes of the corrective action and disposition system, as spelled out in MIL-STD-1520, are to identify and correct causes of nonconformances (including those identified in engine-run hardware), prevent the recurrence of wasteful practices, reduce the cost of manufacturing, and foster quality and productivity improvement.

Accept/use as is, despite one or more minor nonconformaces, is a decision that should be made by an individual qualified to evaluate the usability of a part for its intended purpose in its existing condition. Kowalski stressed that the decision-maker must understand how the part impacts the system and know that the as-found condition is benign to any system effects in its "as-is" state.

Rework is a disposition applied to a nonconformance that will eliminate it and result in a characteristic that conforms completely to the drawings, specifications, or contractual requirements.

Repair reduces but does not completely eliminate a nonconformance but has been reviewed and concurred by an owner or its authorizing agent. Repair is distinguished from rework in that the characteristic after repair still does not completely conform to the applicable specs, drawings, or contractual requirements.

Reject is a *temporary* disposition allowing the part condition to be accepted or corrected at a later date or by way of alternative repair development.

Scrap is a permanent disposition and requires part destruction to prevent its further availability for engine duty. This disposition only can be made by the hardware owner, unless the owner formally authorizes a representative to act on its behalf.

Kowalski closed out his presentation with a series of case histories illustrating the various dispositions. They included a nick on a bearing journal that was disposed as a reject; pitting of components in the low-pressure compressor (LPC); and cracks, nits and scratches, and dents in the LPC case.

Electronic logbooks and the 10 commandments of healthy communication

The last of the six Special Technical Presentations at the Long Beach meeting, while not technical, might have been of greatest interest to the majority of attendees. eLogger Inc of Cloquet, Minn, and Schick Corporate Learning presented an eBoot Camp that encouraged attendees to transition to an electronic logbook because of its ability to meet the specific information needs of various disciplines in an organization virtually instantly.

The presentation was delivered by Ted Schick, a corporate trainer/consultant based in Esko, Minn, a retired naval officer who rose up from the enlisted ranks. Many attendees could relate to that accomplishment given the large percentage of Western Turbine members who also started their careers in the US Navy.

With a greying shore-side powerplant workforce transitioning to retirement, Schick's "10 Commandments of Healthy Communication" offered sage advice for very capable technicians stepping up into supervisory positions. In the majority of cases, they did not have to be "sold" on the value of electronic data capture but they might not have been aware of all the benefits offered by an electronic logbook. Here's a snapshot of what Schick had to say minus the screen shots he used to illustrate various points:

Commandment 1: Be aware of your non-verbals—60% of the message is in your body language, 30%

in your voice/tone. People will recall only about 10% of what you say.

2: Listen. Good leaders really listen. This is listening to understand, Schick said, not just respond. Active listening is a practiced art, he added.

3: Be approachable, visible, accessible. Good leaders get out from behind their desks. People should feel comfortable coming to you with issues and concerns, Schick continued. When they do, they feel you care and can help; when they do not, you are no longer their leader.

Operational information in an electronic logbook is always legible and easily accessible, and it promotes healthy communication.

4: Use the chain-of-command. Too many people do not really understand what the chain-of-command is

WTUI golf tournament brings users, vendors together

The Western Turbine Users' 25th anniversary golf tournament drew 128 players to the El Dorado Golf Course in Long Beach, Calif, Sunday, March 15. The popular social function, held annually before the conference officially begins, was organized this year by Charlene Raaker, Wayne Feragen, Julie Heck, Wayne Kawamoto, and Jim Bloomquist.

Sponsors of the golf awards were: AGTSI, GE, Braden Manufacturing LLC, Turbine Technics Inc, Caldwell Energy, GE Power & Water, HPI LLC, Maximum Turbine Support Inc, SSS Clutch Co, The Timken Company, Parker Hannifin Corp, AAF International (chipping contest), and WTUI.

Individual achievements

Men's long drive: Rich Mears, *Component Repair Technologies Inc*

Closest to the line: Gary Werth, *Duct Balloon/G R Werth & Associates*

Closest to the pin (hole 3): Troy Scott, *Coolidge Power LLC*

Closest to the pin (hole 9): Tim Perrott, *Nyco America LLC*

Closest to the pin (hole 12): Tony Dunkle, *Sulzer Turbo Services*

Closest to the pin (hole 17): Joe Lamberty, *GE Power & Water*

Chipping contest: Ariel Alviz, *Calpine Corp*

Team achievements

Two teams tied with scores of 61 (11 under par). First place was decided by a "card-off" tiebreaker.

First-place team: Brian Mallory, Orange Cogeneration LP; Stephane Daviault, *GasTOPS Ltd;* Glenn Knight, *GE Distributed Power*; Kevin Kane, *Olympus.*

Second-place team: Christopher Melka, *EthosEnergy Group;* Tim Perrott, *Nyco America LLC;* Jay Dunkelman, *Emerson Process Management Power & Water Solutions.*

Third-place team: Richard Trent, *Hy-Pro Filtration;* Don Lonsert, *US Water Services;* Dennis Schendel, *Weir Specialty Pumps;* Larry Kostrzewa, *Rockwell Automation.*

Fourth-place team: Marc Rose, *GE Power & Water;* Olivia Woodlee, *Strategic Power Systems Inc;* Phillip Gehring, *Royal Caribbean Cruise Line;* Michael Hein, *GE Distributed Power.*

Fifth-place team: Gary Werth, *Duct Balloon/G R Werth & Associates;* Tom Frisch, *Chromalloy;* Chris Wylder, *Compression Source Inc;* Rick Vogler, *Star West Generation LLC.*

used for, the ex-naval officer said. He pointed out that it is not just a military thing. Properly used, problems within the organization are handled at the lowest level possible, freeing those at the upper levels of the organization to think about what they should be focused on.

Use of security, mandatory entry fields, and automated emails incorporated into a proper electronic logbook allows everyone from the lowest to the upper levels of the organization to be informed on the specific issues they need to be aware of.

5: Be succinct and to the point. People are busy and appreciate those who speak with purpose and brevity. Schick urged attendees to say what they need to say, say it, and stop talking.

Customizable templates offered with eLogger allow you to capture the data essential to your plant via a user-friendly interface with the majority of the entries point and click.

6: Connect frequently. See for yourself what is going on by visiting with your team members on a routine basis.

Entry acknowledgements, conditional emails, and notifications allow you to deliver important information immediately to those who need to know.

7: Keep your promises. Your reputation as a leader depends on keeping the promises made to your team. Schick said he would remember what you told him you would do—but would you?

Required entries in electronic logbooks remind individuals to perform specific tasks as frequently as once per minute or as infrequently as annually.

8: Provide feedback. If we are doing our jobs right as leaders, the speaker stressed, we are constantly giving feedback—from easy to hard conversations. Formal or informal, don't shy away from connecting with your employees.

Appended entries allow those with security rights to provide feedback on existing entries while maintaining the integrity of the initial entry.

9: Keep people informed. This is respect, Schick said. When people do not know what is going on in an organization, he cautioned, they make stuff up—and it almost always is *wrong.*

The primary function of an electronic logbook is to keep people informed with tools such as shift turnover reports, saved searches, and custom data-entry screens—all with your plant's specific information.

10: Have a vision and strategy. We all need to know where we are going and this need is not reserved for the pinnacle of the organization, but for all levels. Create, execute, and communicate direction and the way to get there, and then keep people informed. CCJ

Metallurgical aspects of joining Stellite 12 to Type 316L stainless steel

By Oscar Quintero, M&M Engineering Associates Inc

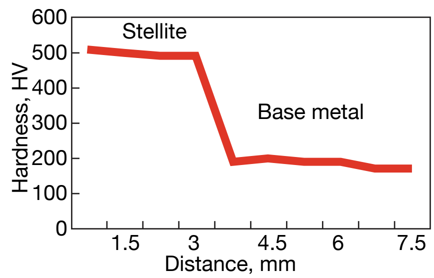
Applying a corrosion-resistant Stellite overlay to a stainless steel can be a daunting task, causing various problems if the welding is not done properly. Problems such as cracking along the weld line, hydrogen-induced cracking, and porosity, among others, have been reported. This article addresses issues such as lack of fusion and porosity encountered when welding Stellite 12 and Type 316L stainless steel, and offers some mitigation strategies.

Fusion/dilution issues

A microhardness profile between the base material and the Stellite overlay can give very helpful information at the dilution area. The step function on the profile graph in Fig 1 indicates that the diffusion/dilution between both materials is very poor.

Microhardness measurements at the overlay would indicate very high hardness values (usually in the Rockwell C scale) while the base material would have readings in the Rockwell B scale. The step function also indicates a lack of dilution that is usually harmful to the mechanical properties, such as tensile strength and fracture toughness, of the component.

The dilution between both materials is very important. Dilution is defined as the change in chemical composition of a welding filler metal (in this case Stellite) caused by the mixture of the base metal—or previous welds if several weld passes were made—in the weld bead.



1. Microhardness profile of a Stellite overlay in a Type-316L stainless-steel component

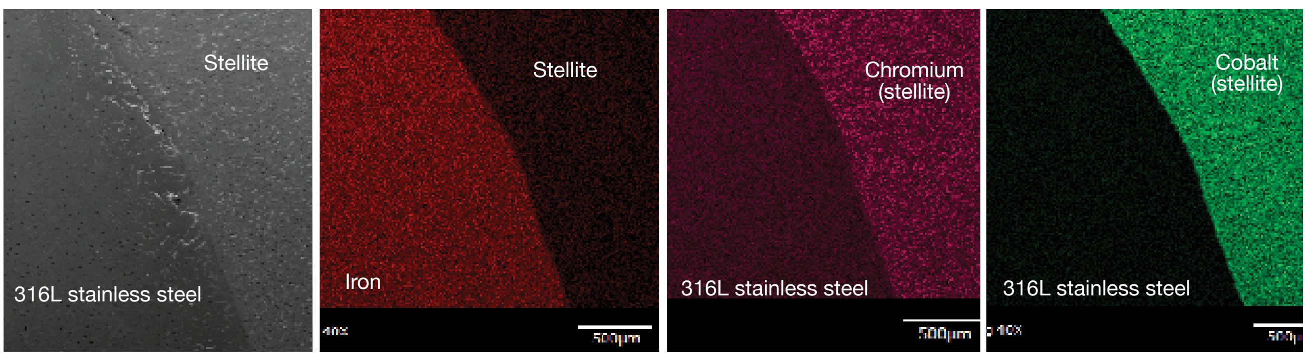
Too little dilution could cause a stress riser at the fusion line that can potentially fail. The lack of fusion (dilution) or too little dilution can cause a hardness (or microhardness gap) creating stress risers—areas in which localized stresses are highly concentrated. If these stresses exceed the material's strength, a crack may result and potential failure may occur. Too much dilution could reduce the wear-resistance properties associated with the hardfaced surface at the fusion area.

The example below shows the results of microhardness testing and a map of the elemental composition of the fusion area using energy dispersive x-ray spectroscopy (EDS) between Stellite 12 and 316L stainless. Fig 1 shows the microhardness testing results of the fusion area. A steep microhardness drop is noted between the base metal and the hardened surface in a distance of approximately 0.30 in. (7.5 mm). The hardness drop was close to 300 points in the Vickers scale, which converts to approximately 30.0 Rockwell C (HRC).

In addition, the dilution between the filler metal (Stellite 12) and the base metal is almost non-existent, as shown in the EDS map of the fusion line (Fig 2). This suggests that in this particular case, there was an issue in the welding process which led to this low dilution—such as an incorrect temperature causing not enough base metal and hardface layer to mix.

Gas porosity

Porosity, or holes within the weld metal, usually occurs because of the absorption of gases and a chemical reaction. This happens when a metal susceptible to porosity dissolves large amounts of gas contaminants to the molten weld pool which are then



2. Elemental map showing the lack of dilution between the Stellite and Type 316L stainless steel entrapped when solidifying.

Contaminants can include moisture, oil, paints, and rust, as well as oxygen and nitrogen in the air. Heat from the welding arc can also decompose such contaminants into hydrogen and other gases.

Another contributor is cooling rate. When cooling rates are fast, the level of porosity is low because the gases are suppressed and no bubbles are formed. At very slow cooling rates, porosity is also minimal because the bubbles have time to coalesce and escape from the weld pool. When the weld cooling rates are intermediate, porosity can become a problem because conditions become optimum for both formation and entrapment of the gases.

Porosity also can be associated with lack of workmanship. If the parts to be welded and the consumables are not cleaned and dried, the risk of porosity increases.

Shrinkage porosity

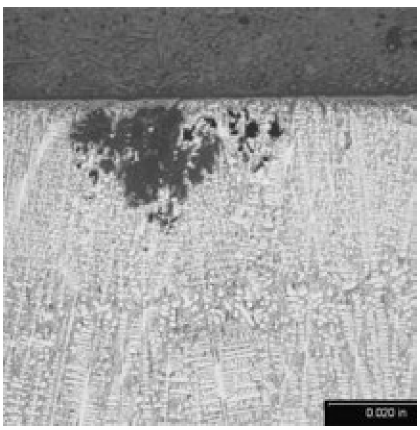
Shrinkage porosity is caused by sections of the hardface layer that solidify faster than the material around it and insufficient metal flow for a complete fill (Fig 3). This generally happens when the weld area is too hot relative to the surrounding area. From another perspective, when the part is not preheated enough, the heat is quenched too fast and may also cause shrinkage porosity. Unsuitable material composition, incorrect temperatures, or a combination of these factors also can cause shrinkage porosity.

Mitigation strategies

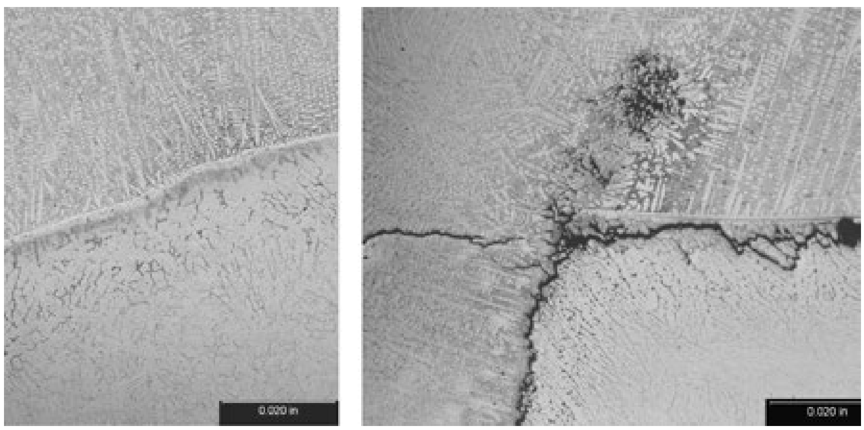
Preheat. Applying heat to the base metal immediately before welding will improve the quality of the weld/overlay. Preheating affects these four factors:

1. *Slows down the cooling rate.* A slow cooling rate helps minimize porosity since the bubbles have time to coalesce and escape from the weld pool.
2. *Reduc*es shrinkage stresses and distortion. When a drastic temperature change occurs, the material suffers shrinkage stresses and distortion. Shrinkage stresses and distortions will not go away but they can be minimized. By preheating, such stresses and distortions are minimized.
3. *Promotes fusion.* This raises the material's initial temperature to ensure good weld fusion from the start. There are instances when a material with a high thermal conductivity (such as copper or aluminum) is welded onto another material. For comparison purposes, the thermal conductivity in SI units of watts per meter kelvin(W/m•K) for copper is 385; for 316L, 14-15.9; and for Stellite 12, 14.6. Since the thermal conductivity is very low for both Stellite 12 and 316L stainless steel, the deposited layer chills and cools down slowly without any fusion onto the parent material.
4. *Removes moisture.* Usually, it is not necessary to preheat austenitic stainless steels, unless there is condensation. If condensation is present, usually a gentle and uniform heat should remove it. Preheats higher than 212F in stainless steels can cause negative effects, such as rise to carbon pickup or metallurgical instabilities. In martensitic stainless steels, a high preheat temperature is recommended and cooling must be controlled. Ferritic stainless steels rarely are preheated.

Post-weld heat treatment (PWHT) typically is applied to increase resistance to brittle fracture and reduce residual stresses. PWHT also can reduce the hardness gradient between the base material and the weld, and enhance the material's properties—such as ductility



3. Shrinkage porosity at the surface of the Stellite overlay



4. Porosity and cracking at the fusion line between the Stellite overlay and 316L stainless steel

and tensile strength.

Typically, there is no need in austenitic stainless steels (Type 316L is one of these) for PWHT. However, PWHT after applying the overlay most likely will enhance mechanical properties—such as fracture toughness and ductility. PWHT can also reduce residual stresses and may also reduce the hardness.

By either annealing or stress relieving the component, the hardness gradient between the overlay and substrate will be reduced. A higher hardness gradient usually causes higher stress concentrations along the weld line and higher cracking potential.

Additionally, the weld and heat-affected zone (HAZ) will be prone to hydrogen-induced cracking (HIC) if any hydrogen was entrapped during the original overlaying process. Three main factors are required for HIC: stress, a sensitive microstructure, and hydrogen.

The stress source is caused by the residual stresses along the weld line. Austenitic stainless steels have a sensitive microstructure. If the fusion line becomes sensitized, it loses strength from the diffusion of hydrogen into its grain boundaries and becomes brittle (Fig 4).

The PWHT should be performed outside the range 806F to1652F. Any PWHT performed in this temperature range will cause the chromium carbides to precipitate within the grain boundaries (sensitization) and will reduce the corrosion resistance of the alloy. In addition to reducing the hardness gradient, PWHT will stress relieve the weld line and HAZ. This also will result in an increase in fracture toughness. CCJ

Grid-scale storage advocates prepare for a 'flood' of business

The days of May 27-29, 2015 may not have been the best time to use the word "flood" in Dallas as an analogy for business opportunities. Amidst daily rainstorms, roaring creeks, flood-ravaged neighborhoods, and nightly lightning shows seen from upper-floor hotel windows rivaling a Pink Floyd concert, the storage industry gathered at the Energy Storage Assn's (ESA) 25th Conference and Expo to assess the state of the market, technologies, and policies.

Those who build, own, and operate gas-turbine and combined-cycle assets need not worry that grid-scale storage is going to "eat their lunch" anytime soon. But, clearly, it is time to pay close attention; the tipping point, courtesy of government policy, may be near.

Indeed, the mismatch between storage-system supply and storage-system demand, at least for the technology (photo) that currently prevails in the market, was one takeaway. Many have read about Tesla's plans for storage and the company's 35,000-MWh lithium-ion (Li-ion) "giga-factory" in Nevada (nicely subsidized by $1.5-billion in state taxpayer funds, with the parent company receiving billions more in federal and other subsidies).

Another company, Alevo, reported at the meeting that it has built a factory in North Carolina with a maximum annual supply potential of 16,000 "GridBanks," 2 MW/1MWh Li-ion storage systems. That's 16,000 MWh.

Other storage companies, like SAFT America Inc, already have built large factories in the US and others plan to. This is in addition to current global supply in Asia and Europe.

On the demand side, Oncor Electric Delivery Co LLC, a Texas "wires" company and the state's largest regulated utility, has offered up a plan to install 5000 MW of storage systems dotting ERCOT. The company has recently built 1000 miles of transmission lines under the state's Competitive Renewable Energy Zone (CREZ) program mandated by the government.

Li-ion battery storage facility is installed in Portland General Electric Co's 5-MW Salem Smart Power Center. The technology currently prevails for new grid-scale storage opportunities

The irony of a transmission system "mandate" for an "open market" in electricity should not go unnoticed. Clearly, Oncor is seeking a similar policy framework for its storage plan.

But Oncor's VP of transmission operations, Wes Speed, stated in the keynote session that the company "is waiting on the 'flood' of storage opportunities." Later, the company's Michael Quinn, VP and chief technology officer, acknowledged that Oncor's ambitious storage program requires a "legislative push" to monetize the reliability benefits of storage on the "regulated" side and the ancillary services benefits on the "market" side. The Texas Legislature meets every other year.

In a pre-conference workshop, Michael Berlinski of Customized Energy Solutions noted that ERCOT is redesigning its ancillary services market, with implementation expected in the 2018-2019 timeframe; the total megawatt need is expected to be modest. That suggests that Oncor is betting far heavier on the regulated side than the market side of ERCOT.

ERCOT is not subject to FERC Order 755, which essentially broke open the frequency regulation market as a singular "ancillary service." Berlinski went on to quantify the size of the frequency regulation market by ISO around the country. The numbers add up to around 2000 MW. Frequency regulation, with PJM in the lead, is currently driving the grid-scale storage market, he added.

How, you might ask, does the storage industry square a 2000-MW present opportunity (plus isolated other opportunities around the country) with giga-size manufacturing facilities? To even attempt it, you have to understand three fundamental tenets of the electricity industry. The first is historical—the industry has always driven by policy and regulation. The second is modern: The industry is being driven more by the *value* of "clean air" and less by the *cost* of megawatts. This means growing intermittent renewables and declining base-load fossil and nuclear generation. Somehow, nuclear can't seem to get credit for being a carbon-free source of megawatts.

The third is less apparent, but

think of it this way: The traders have won. Electricity markets continue to evolve towards real-time or competitive market pricing for a variety of services (capacity, energy, frequency regulation, and other ancillaries). From a trader's perspective, storage provides inventory and, finally, a halt to the grid as the largest and most complex "just in time" inventory system in the world. Electricity markets will function more like the market for financial instruments, where intermediaries buy, hold, and sell, as well as "warehouse" inventory to manipulate the market.

Energy insights from SECNAV address on energy

Let's face it, government officials who get prime-time speaking slots at power-industry events usually aren't invited for their groundbreaking assessments and insights. At the 25th Annual Energy Storage Association (ESA) Conference and Expo in Dallas, May 27-29, 2015, Secretary of the Navy Ray Mabus' address was a refreshing exception.

One point Mabus made should be particularly poignant for this industry. He drew an historical trend line on energy sources for naval vessels. We started with sail (wind), Mabus noted, and progressively went through eras dominated by coal, oil, and nuclear. Now, the Navy's goal is to achieve 50% renewable sources by 2020 for both its seafaring vessels and naval bases around the world. Part of that effort involves hybrid ships (he likened them to the concept behind a Prius), all-electric ships, and microgrids on bases.

"The limiting factor today is storage," he said, referring to challenges in achieving the Navy's ambitious goals. In the meantime, the renewables goals are being met by displacing fossil fuels with biofuels—including algae, bio wastes like cooking oil, and municipal waste—and making use of solar, wind, geothermal, and hydro at land facilities.

He said the military is building 50% of the microgrids today. "Energy is being used as a weapon around the world, and that's a national security issue," he stressed, referring to the need to be as self-sufficient as possible. "Our SEAL teams are getting close to being net zero in energy and water consumption." He also said the Navy would get to the goal of 50% alternative energy use on-shore by next year.

The Navy's energy appetite is massive and keeps growing, he observed, and cutting fossil-fuel consumption saves huge amounts of money. The US Dept of Defense is the world's largest user of fossil fuel.

The US military's "rebalance" to the Pacific is real. "The Navy is 'presence' around the world," Mabus added. Up to 60% of the fleet ultimately will be stationed in the Pacific.

With perhaps some intra-Defense competitive bravado, Mabus noted proudly that the Navy has "always led in technological innovation." If so, then the stationary power industry can expect to leverage much of that innovation.

Thirty years ago, ex-nuclear Navy specialists began entering the power industry in big numbers and today, an impressive percentage of powerplant managers, operators, and specialists are ex-Navy. Perhaps in a decade or two, those specialists will be permanently stationed shoreside to run all the microgrids some anticipate will be responsible for a significant percentage of the nation's new generating capacity.

Already, where wind penetration is highest, electricity markets have become like "casinos" (turn to p 30). Grid functions like frequency regulation require "a trader's mentality, a different skill set," said a representative from American Electric Power, an early leader in energy storage technology demonstration.

Coincidentally, perhaps as a reflection of the growing political influence of storage advocates in Washington, two US Senators introduced the Energy Storage and Deployment Act of 2015 to the Senate Energy Committee May 27. They seek to create by 2021 a national storage mandate of up to 1% of the peak demand of retail utilities. This would amount to about 10,000 MW. The bill mirrors California's AB2514, the storage "mandate," which requires (with important caveats) the state's three investor-owned utilities to install 1300+ MW of storage by 2024.

The Senate bill has no chance of passage as standalone legislation, but that's not the point. Once this provision gets tucked into a broader energy bill, the storage business is off to the races, much like renewable energy when the production tax credit (PTC) was instituted.

Other states are seeking to incentivize storage, among them New York and Massachusetts. Judith Judson, when with Beacon Power (a commercial flywheel storage company), was arguably the private sector representative most responsible for crafting and moving Order 755 through FERC. She's now the incoming commissioner of the Massachusetts Dept of Energy Resources. Judson said at the meeting that the state "is taking steps to incent storage," such as through grid modernization studies required of utilities and $10-million from the Alternative Compliance Payment program to do storage projects.

Although one representative from Con Edison stated that "storage is "mostly past the technology barriers," there are other high hurdles. Much of the ESA meeting was devoted to codes and standards for safety (for example, fire protection and storage energy management in commercial buildings in areas like NYC), grid protection, and avoidance of catastrophic events—something which must be confronted with all leading storage technologies.

Codes and standards are an area of current DOE-led industry activity. EPRI is heading up a relatively new Storage Integration Council to ensure that the principal subsystems—storage medium, power conditioning system (PCS), grid interconnection, and the multiple control, automation, communication, and protection systems—are properly engineered as a complete utility-grade system.

Skepticism of investors was reflected in a keynote speech delivered by Jigar Shah, now with Generate Capital, well known at his former employer, SunEdison, for his work in solar PV. Shah provoked the audience with questions, such as: What does it mean to be in the storage business anyway? Who gives the system warranty? Who is in charge of figuring out servicing over the long haul? Does storage carry the PV project or does storage sink the PV project?

He then offered needling observations. Example: The frequency market in PJM is already saturated, and no one (storage company) is going to be good at all the grid functions. He complained that there is still not a monetization path for the solar PV/storage option.

Although this writer/analyst did not hear every presentation, it seemed clear from the agenda that operating experience with existing projects is a key gap, and that there is a dearth of new project announcements.

In sum, it appears there's a disturbing supply and demand gap with grid-scale storage based on the currently prevailing technology, Li-ion, but all it would take to change that is a few strokes of policy pens. **CCJ**

KNECHTIONREPAIR®

"connection repair"

A uniquely designed tool that will repair your cross threaded industrial Swaged type compression fittings in seconds!

KnechtionRepair tools are designed to make thread repairs to both the internal/female and external/male threads of industrial standard two ferrule Swaged type compression tube fittings. With its uniquely designed holder and hollow bore tap, damaged threads are easily repaired.

Available now tap and die repair kits for 1/4", 3/8", 1/2", 5/8" and 3/4" tube fittings. Coming soon repair tools for your Hydraulic JIC , Aircraft AN fittings and turbine T/C fittings. KnechtionRepair also takes special orders for your problem connections.

KnechtionRepair tools are 100% manufactured in the USA. Order your tools today and save on fitting replacement , down time and money! To view a video demonstration of the thread repair process and watch a live pressure test visit us at www.knechtionrepair.com

For more information and to place an order email info@knechtionrepair.com or phone (907)688-5051
www.knechtionrepair.com

Rigorous protection scheme, proper maintenance help prevent over-fluxing

By Dr Isidor Kerszenbaum, PE, IzzyTech LLC

Although the duration of an over-fluxing condition may last only a few seconds, the consequences can be extremely damaging to the machine—including expensive repairs, several months of forced outage, and loss of production. One of the most problematic aspects of an over-fluxing incident is the difficulty in assessing the condition of the generator after the event has occurred. Thus it is critical to avoid creating the conditions that could lead to such an incident.

The physics of over-fluxing

A large turbine-driven generator (turbogenerator) is an electromagnetic-mechanical device; it converts mechanical energy delivered by the turbine to the generator via the shaft, into electrical energy flowing out of the generator via its terminals and into the grid. As most readers are aware, to convert mechanical energy to electrical energy, the rotor of the generator creates a magnetic flux that links the rotor to the stator through the air (gas) gap. This induces a voltage in the stator winding that drives the electrical output of the machine.

The magnetic flux has two sources: the first, internal to the generator, is the DC current carried by the rotor winding, also called the "field current" and "field winding." The second is the current flowing in the stator winding. When the machine is not synchronized to the grid (generator breaker open), the only source of magnetizing flux is the rotor winding and the field current flowing in it. By changing the magnitude of the field current, the voltage in the terminals of the machine is controlled.

An expression to remember is:

$$B \propto \frac{V_T}{f} \equiv \frac{Volts}{Hz}$$

where B is the flux density, V_T is the voltage at the terminals, and f is the frequency. The ratio is commonly known as "volts per hertz."

In a typical turbogenerator, the flux density (B) is between 1.5 and 2 tesla, depending on the part of the core in question. The region of highest flux density is the tooth. Fig 1 shows the typical magnetic flux distribution inside a generator. A key characteristic of the flux, under normal operating conditions, is that in the stator, it is confined to the core material because of the high permeability of its constituent laminations.

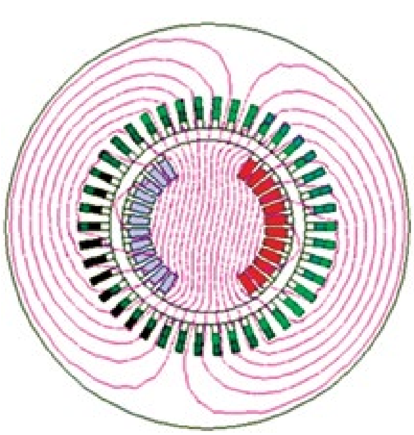
However, increasing the flux density beyond a certain value (the "knee" region of the saturation curve of the core steel) reduces the permeability of the iron, allowing some of the flux to escape beyond the core boundaries. This gives rise to two serious conditions:

- Large voltages and currents induced in the keybars and other structural members of the stator; Degradation of the stator inter-laminar insulation with subsequent hotspots in the core. This condition is known as "over-fluxing" or "over-excitation." But the latter, which happens when the field current is raised beyond its normal limits, does not necessarily lead to over-fluxing; hence, in this article over-fluxing is the term used.

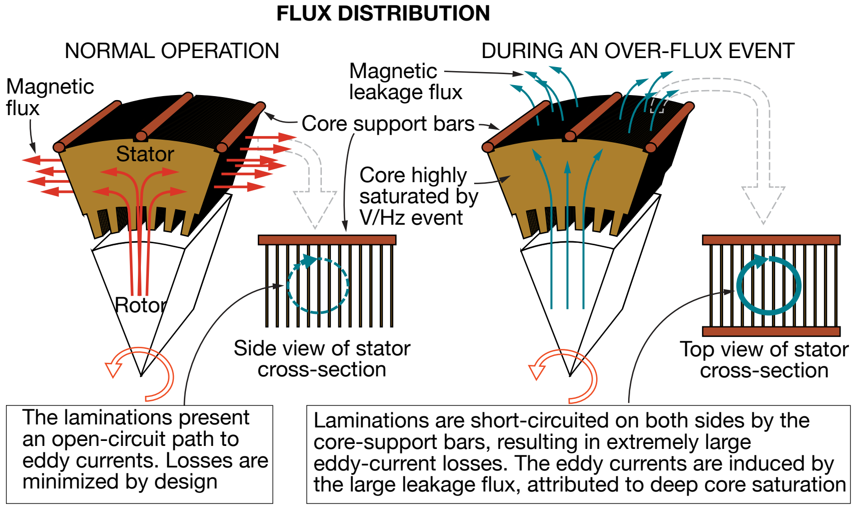
Fig 2 shows the normal flux distribution inside a section of the core, and shows the flux distribution when the machine is over-fluxed.

What is interesting with over-fluxing events (and also a source of big headaches to those trying to ascertain the condition of the machine) is that once the over-fluxing ends, there is practically no way to tell if the core has been damaged and if it is advisable to resume operations. It can be very difficult to find signs that major rework is needed.

Perhaps the only way to effectively assess core condition is to remove the rotor and perform a loop flux test. There are serious doubts that an EL-CID test (with the rotor in or out) will be able to identify core insulation damage immediately after over-fluxing, and EL-CID certainly will not detect damage to the keybars,



1. Typical magnetic flux density inside the machine during operation. Figure shows the stator magnetic flux is contained within the core



2. Normal magnetic flux distribution in the stator core is at the left. A saturated core during an over-fluxing event (right), results in the flow of large currents in the keybars and has the potential to damage core interlaminar insulation

keybar insulation, or other structural members.

Hence, the best practice is to avoid—at all cost—experiencing an over-fluxing event. Damage to a core caused by over-fluxing can happen in a few seconds, if the flux density is high enough. This is more likely if the core inter-laminar insulation is aged or otherwise degraded.

Fig 3 shows the result of an over-fluxing event; portions of the core have melted. The unit was over-fluxed. Twelve hours later the machine tripped because of a winding ground fault and an examination revealed the damage.

Missteps conducive to over-fluxing

Almost without exception, over-fluxing occurs when the field is applied, but before the machine is synchronized to the grid. Reason: Once the breaker is closed, increasing field current mainly increases VAr loading, while mildly increasing the terminal voltage.

There are two key protection functions that are supposed to detect an over-flux event, then alarm and trip the unit. One is the volts-per-hertz relay (also known by its device number, 24, as specified in ANSI/IEEE Standard C37.2). The second is the over-excitation limiter in the excitation system. Unfortunately in some cases, the over-excitation limiter is not set properly, and the No. 24 relay malfunctions, leading to a major failure—such as that shown in Fig 3.

Example 1: 500-MVA coal-fired unit. A maintenance error during a routine outage allowed the potential transformer circuit, feeding both the automatic voltage regulator (AVR) and the volts/hertz relays, to remain open. When the unit was energized, the AVR didn't receive a signal indicating the terminal voltage was going up and the field current had increased beyond normal conditions. The over-excitation function was not set, or not set properly, and the No. 24 volts/hertz relay also had no voltage input.

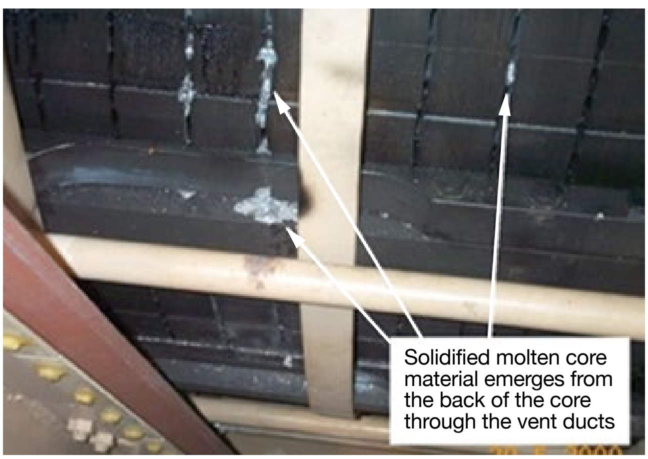
The voltage increased to about 135% of nominal, and the condition lasted for about 16 seconds, until the unit was tripped. A cursory inspection of the machine did not reveal any obvious problems, so it was returned to service. The result was a partially melted core requiring a complete stator rewind, major core re-staking, the replacement of one retaining ring, and several months of lost production.

Example 2: A 180-MVA GT generator. The unit was returned to operation after some work was done on the iso-phase bus. During the work, the leads to the potential transformers feeding the AVR and other protection systems were left unterminated.

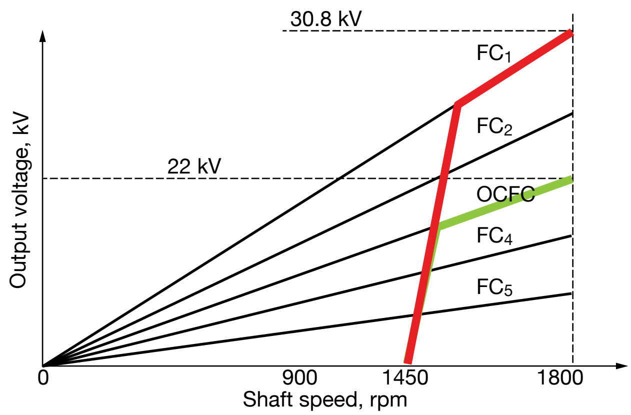
As with the previous case, this oversight put the generator in jeopardy, with the potential for a catastrophic failure and long forced outage. But unlike the previous case, the machine was tripped in a few seconds by a timer in the excitation system, without discernible damage to the core. Nevertheless, degradation to the inter-laminar insulation might have occurred, reducing the expected core life.

Example 3: 1300-MVA, 4-pole nuclear unit. While being returned to service after an outage, the AVR malfunctioned, "going ceiling" and increasing the excitation current well beyond normal limits—thereby creating an over-fluxing situation. The volts/hertz relays were arranged many years ago with a very permissive setting, and there was little doubt that if the unit was not tripped by serendipity (an auxiliary transformer protective relay), it might have led to serious core failure.

In the case of large units, the main transformer oftentimes is at the generator side of the main breaker, meaning that a large over-fluxing event of the generator may also result in over-fluxing of the main and auxiliary



3. Over-flux event caused core melting



4. Green trace shows the typical trajectory of the field current during normal energization of a generator. The red trace is the trajectory following a failure of the AVR transformers.

Fig 4 shows how the over-fluxing incident happened. The field voltage is routinely applied to this machine at about 1450 rpm, as it is accelerated to its rated 1800 rpm. When all goes as it should, the field current follows the green line and settles on the open-circuit field current value (OCFC). When the AVR malfunctioned, the field current followed the red trace, creating both an over-flux and over-voltage condition—that is, the stator was inadvertently "high-potted."

The common thread through the foregoing examples is an absence of diligence in designing the protection scheme (be it hardware configurations or relay settings) coupled with easily avoidable maintenance blunders.

Takeaways

- Over-fluxing events are very serious, and in some cases can lead to major equipment damage and loss of production.
- Over-fluxing events overwhelmingly tend to happen during energization of the generator and prior to synchronizing to the grid.
- Damage to the core and/or other stator components is very difficult to identify, and may require a full loop test to uncover.
- Degradation leading to catastrophic failure may occur in over-fluxing events even though they only last several seconds. The actual failure of a component and trip (typically a stator-winding ground fault) may happen several hours, days, or months after the over-fluxing event.
- Routine electrical tests such as megger and hipot or other dielectric tests will yield no information about damage to the inter-laminar insulation or other structural damage caused by over-fluxing.
- It is extremely important to properly set the volts/hertz protection and over-excitation limits.
- If possible, the potential transformer feeding the AVR should be different from the one feeding the volts/hertz relay. This can be accomplished in most large units, but may not be possible in the case of small machines.
- After a serious over-fluxing accident, it is strongly recommended plant operators ascertain, as judiciously as possible, whether the generator is healthy enough for a return to reliable it to operation. This may require consultation with the OEM and/or other informed parties. CCJ

Your direct connection to CCJ's Online Buyers Guide

at www.ccj-online.com/bg

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

AAF International

Global leader in the field of air filtration, meeting the most demanding conditions and the toughest environmental challenges. The company's filtration, noise abatement, and other turbine products are effective, durable, and crucial to greater efficiency and performance.

ABB

Leading power and automation technologies that enable utility and industry customers to improve performance while lowering environmental impact. Turbine-automation control systems are based on ABB's field-proven control platforms that deliver safe and reliable control.

Advanced Filtration Concepts

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

Advanced Turbine Support

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

Aeroderivative Gas Turbine Support

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

AGTServices

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

Allied Power Group

Earned a reputation for high-quality repairs of IGT and steam turbine components. APG specializes in hot-gas-path and combustion components from GE, Siemens/Westinghouse, and other leading OEMs. Shop staff includes engineers and expert technicians who work together to determine the best method of repair.

American Chemical Technologies

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

AmertechTowerServices

Single source supplier of cooling towers, cooling tower spare parts, repair, and maintenance services; offering competitive prices with expert technicians to oversee the installation, restoration, and preservation of your towers.

ARNOLD Group

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

BASF Corp

Committed to providing customers with cost-effective solutions to the most complex emissions control problems; company is constantly developing new catalyst technologies to meet ever-more stringent emissions requirements.

Braden Manufacturing

Braden designs and manufacturers air filtration systems and filters, inlet cooling/heating, silencing, exhaust and inlet ductwork, diverter dampers, simple cycle SCRs, expansion joints, bypass stacks, and diffusers and plenums.

ABOUT QR CODES

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

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

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

Available on the Android App Store

Available on the App Store

Bremco

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

C C Jensen Oil Maintenance

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

Caldwell Energy

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

Camfil Farr Power Systems

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

Chanute Manufacturing

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

CLARCOR Industrial Air

Formerly GE Power & Water's Air Filtration business, CLARCOR helps customers achieve air quality and plant performance goals with products and solutions for gas turbine inlet filtration, industrial filtration, and membrane technologies. Company is committed to improving plant performance and enabling users to realize their operating goals.

Cleaver-Brooks

Complete boiler-room solutions provider that helps businesses run better every day. It develops hot-water and steam generation products aimed at integrating and optimizing the total boiler, burner, controls system to maximize energy efficiency and reliability while minimizing emissions.

CMI Energy

Known globally for HRSGs and aftermarket solutions that are engineered to tackle the most stringent power industry demands, company serves its customers with experienced teams, advanced designs, and reliable operation. Count on CMI for proven technologies, expert project execution, and top-quality support for the life of every job.

Conval

Designs and manufactures high-performance valves for the world's most demanding applications, including power generation. Company has a series of power generation case studies that demonstrate the unique features and benefits of forged valves.

Cormetech

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

COVERFLEX Manufacturing

Offers superior removable insulation systems for an array of gas and steam turbines. Based on OEM turbine designs and feedback from plant managers, insulation systems are custom-designed to provide comprehensive thermal protection.

Creative Power Solutions

CPS is a group of engineering companies in the power generation and energy utilization sector. Its mission is to provide advanced, efficient, and customized technology solutions to clients ranging from OEMs to plant operators and energy consumers.

CSE Engineering

Specializes in gas, steam, and hydro turbine control system upgrades, <ITC>® HMI replacement for GE Speedtronic™ MK IV and V, gas and steam turbine field services, Woodward parts and repairs. CSE is a *Woodward Recognized Turbine Retrofit Partner.*

Cust-O-Fab Specialty Services

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

Cutsforth

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

DEKOMTE de Temple

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

Donaldson Company

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

Dry Ice Blasting of Atlanta

Offers professional dry-ice contract cleaning services performed at your facility. Company provides a full range of dry ice blasting machines and capabilities to accommodate any size job by its team of trained, certified, and experienced operators.

EagleBurgmann Expansion Joint Solutions

Leading global organization in the development of expansion-joint technology; working to meet the challenges of today's ever-changing environmental, quality, and productivity demands. Company's flexible products are installed on equipment where reliability and safety are key factors for operating success.

ECT

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

Emerson Process Management

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

Eta Technologies

Consulting services for all types of GTs, especially in the areas of component manufacture, repair, RCA, component remaining life assessment and metallurgical evaluations, with extensive and unique experience on Siemens V engines. Eta also provides replacement aftermarket parts for V engines.

EthosEnergy

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

Falcon Crest Aviation

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

Frenzelit North America

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

Fuel Tech

Leading technology company engaged in the worldwide development, commercialization, and application of state-of-the-art proprietary technologies for multi-pollutant control of air emissions, plant process optimization, and advanced engineering services.

Fulmer Company

Provider of brush holders, machined components, and assemblies for the OEM, power-generation, and industrial markets. Fulmer is the largest North American manufacturer of brush-holder assemblies, offering single- and multiple-brush units for power generation OEMs and aftermarket customers.

Gas Turbine Controls

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

Gas Turbine Efficiency

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

GEA Heat Exchangers

From design to construction, replacement towers to spare parts, GEA has built, repaired, replaced and upgraded field-erected cooling towers for over 40 years for the power and process industries.

Graver Technologies

Designs, develops and manufactures a variety of technologies and products that enable and enhance the separation and removal of trace contaminants. Strengths include, but are not limited to, both ion exchange and filtration for condensate polishing and other power generation applications.

Groome Industrial Service Group

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

GTC Services

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

Gulf Coast Filters & Supply

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

Haldor Topsoe

Our air pollution technology includes a series of unique catalysts for Selective Catalytic Reduction (SCR) systems for the control of nitrogen oxides (NO_X), and the reduction of carbon monoxide (CO) and volatile organic compounds (VOCs), from stationary and mobile sources.

Hilliard

The HILCO® Division cost-effectively brings fluid-contamination problems under control and engineers a full-range of filters, cartridges, vessels, vent mist eliminators, transfer valves, reclaimers, coolant recyclers and systems, and membrane filtration systems.

HPI

A leading provider of OEM alternatives for engineered turbine solutions. Founded in 2002, the company offers EPC services for turnkey powerplants; maintenance, repair, overhaul, and mechanical field services in addition to custom controls. Company also is a qualified provider of turbine refurbishment solutions for the nuclear and marine markets.

Hydro

Engineered solutions enable combined-cycle plants to achieve pump reliability and reduced O&M costs. As the largest independent pump rebuilder, Hydro works hand-in-hand with pump users to optimize the performance and reliability of their pumping systems.

Hy-Pro Filtration

Provides innovative products, support, and solutions to solve hydraulic, lubrication, and diesel contamination problems. Company's global distribution and technical-support networks enable customers to get the most out of their diesel, hydraulic, and lube-oil assets. ISO 9001 certified.

HYTORC Industrial Bolting Systems

Takes gas turbine, steam turbine, and HRSG assembly and disassembly to the next level with tremendous improvements in safety, speed, and accuracy on all bolting jobs. From boiler feed pumps and control valves to the entire turbine casing bolting, HYTORC has the tools and fasteners to make sure the job is done right the first time.

Indeck Keystone Energy

Designs and manufactures packaged boilers "A", "O", "D" Type, Modular "D" type packaged and field-erected boilers, International Lamont line of high temperature hot water generators, and auxiliary equipment. Indeck has over 5,000 successful boiler installations in 45 countries.

JASC

Engineers and manufactures actuators and fluid-control components for power generation, aerospace, defense, and research applications to improve operational capability and performance.

KnechtionRepair Tools

Manufactures tools designed to make thread repairs to both the female and male ends of cross-threaded compression fittings. In most cases, the repair will be accomplished without removing the tube from the system. This saves the O&M tech time and avoids additional downtime.

Kobelco Compressors America

Provides robust, high-efficiency fuel-gas compressors for use with all major types of gas turbines—including GE, Mitsubishi, Alstom, Siemens, Rolls-Royce, and Solar. Over 300 of the company's screw-type compressors have been supplied for gas turbines.

Liburdi Turbine Services

Advanced repairs employ the latest technologies and are proven to extend the life of components for all engine types. Company specializes in high-reliability component repairs and upgrades for blades, vanes, nozzles, shrouds, combustors, and transitions.

M & M Engineering

Provides failure analyses and related services to industrial and insurance-company clients. M&M's expertise includes corrosion in boilers, steam turbines, generators, combustion turbines, deaerators, feedwater heaters, and water and steam piping.

Mechanical Dynamics & Analysis

One of the largest turbine/generator engineering and outage-services companies in the US. MD&A provides complete project management, overhaul, and reconditioning of heavy rotating equipment worldwide.

Mee Industries Inc

Pioneered gas-turbine inlet fogging technology more than 20 years ago. Ever since, MeeFog™ systems have set the standard for cost-effective power augmentation. MeeFog has been used by, or approved by, every major GT manufacturer in the world.

Membrana, a Polypore company

Market-leading producer of microporous membranes and membrane devices used in healthcare and industrial degassing applications. The Industrial & Specialty Filtration Group manufactures Liqui-Flux® ultrafiltration and microfiltration modules as well as Liqui-Cel® membrane contactors.

Moran Iron Works

Global fabrication company committed to providing efficient processes, flexibility, and adaptability to ensure projects are completed on schedule. Moran specializes in one-of-a-kind fabrication and replacement of critical turbine components.

NAES

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

National Electric Coil

Leading independent manufacturer of high-voltage generator stator windings with expertise in design and manufacturing of stator windings for any size, make, or type of generator. This includes diamond coils, Roebel bars—including direct cooled, inner-gas, and inner-liquid cooled bars—and wave windings.

NEM Energy

A leading engineering company operating globally in the field of steam generating equipment. NEM supplies custom-made solutions regarding industrial, utility, and heat-recovery steam generators for power generation and industrial plant applications.

Nooter/Eriksen

World's leading independent supplier of natural circulation HRSGs behind gas turbines and a single-source supplier of custom-designed heat-recovery systems. NE's annual sales volume includes HRSGs for combined-cycle powerplants whose output exceeds 8 MW.

NRG Energy Services

Backed by the strength and reach of the America's largest independent power generation company, NRG Energy. Company provides plant maintenance solutions to minimize downtime, increase asset availability, reduce ownership costs, and boost profits. Company delivers custom-tailored O&M solutions to meet any generation need, on any scale.

Pneumafil

Major air-inlet filter-house supplier to all major turbine manufacturers for over 45 years. Company manufactures certified, high-efficiency filtration products for all brands, pulse style or static style inlet housings, to ensure maximum turbine output and efficiency.

PowerFlow Engineering

Specializes in servicing variable speed fluid drives for boiler feed pumps with focus on the Voith®, Howden, American Standard, and American Blower brands. Services have recently expanded to include repair and maintenance of turbine start-up couplings.

Powergenics

Leading supplier of industrial electronic circuit-card and power-supply repairs to industrial and power generation customers. Company provides a very high-quality repair at a substantial cost savings from the OEM and other competitors while maintaining a warranty service second to none.

Praxair Surface Technologies

Leading global supplier of surface-enhancing processes and materials, as well as an innovator in thermal spray, composite electroplating, diffusion, and high-performance slurry coatings processes. Company produces and applies metallic and ceramic coatings that protect critical metal components such as in gas turbines.

Precision Iceblast

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

Proco Products

Supplies rubber expansion joints to the power industry in sizes ranging from 1 to 120 in. ID. Proco keeps joints up to 72 in. ID in stock at its Stockton (CA) warehouse and works through an agent/distributor network to supply products to combined-cycle plants.

PSM—an Alstom company

Full-service provider to gas-turbine equipped generating plants, offering technologically advanced aftermarket turbine components and performance upgrades, parts reconditioning, field services, and flexible Long Term Agreements (LTAs) to the worldwide power generation industry.

PW Power Systems

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

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.

ROBLICORP

Serves the industrial gas-turbine aftermarket by supplying an extensive range of renewal items—including ancillary, auxiliary, accessory, and control room spare parts and material. Supplier of new gas turbine spare parts, accessories, components, hardware, filtration, and consumables for LM5000/LM6000, FR5/7/9 HD, GG3/GG4/GG4C/FT4/GG8/FT8/ST6 IGT aftermarket.

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.

Sentry Equipment

Engineers, manufactures, and services components for collecting representative samples of steam, water, gas, liquid, slurry, and bulk solids. This enables analytical and operational professionals to gain samples safely and simply, and with repeatable results.

Siemens Energy

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

Sound Technologies

Provides engineered silencers and systems for new and replacement gas-turbine applications—including turbine inlet silencing, turbine enclosures, bypass systems, and HRSG inlet shrouds and stack and vent silencers.

South-Tek Sytems

Designs and manufactures nitrogen generators to purities ranging from 95% up to 99.9995% for powerplant applications including wet and dry HRSG layup, nitrogen blankets for ammonia storage tanks, and natural gas line purging.

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.

Stellar Energy

Leading provider of energy plant systems, including turbine inlet-air chilling and TIAC with thermal-energy storage, district cooling, modular utility plants, and CHP. Steller offers a complete range of in-house analysis, design, fabrication, installation, start-up and commissioning, and maintenance.

Strategic Power Systems

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

Sulzer

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

TEC-The Energy Corp

Our skills and experience assist GT owners with front-end engineering, procurement of major equipment, and management of engineering, construction, and commissioning of new facilities. From due diligence to detailed design, TEC covers all phases of complex power projects.

TEi Services

Offers a full range of heat-transfer products and services and fully trained, certified maintenance personnel. Provides world-class emergency repair services, underpinned by a 75-yr history in the design and manufacture of condensers, feedwater heaters, and heat exchangers.

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 Controls & Excitation

TC&E is an engineering consultation firm focused on turbine and generator controls services. Services include emergency troubleshooting, maintenance support, and equipment upgrades on GE MK I-VIe controls, exciters, and LCIs.

Turbine Generator Maintenance

Provides turnkey field service maintenance for all turbine/generator components. TGM services the turbine, generator, exciter, control systems, and auxiliaries either individually or in any combination. Its service area includes the US, Caribbean, and South America.

Universal AET

Global engineer and manufacturer of acoustic, emission, and filtration systems. Systems portfolio includes a vast complement of silencers, catalysts, and filters for blowers, vacuum pumps, vents, diesel/gas engines, gas turbines, and compressors.

Universal Plant Services

Specializes in the maintenance, repair, and overhaul of gas and steam turbines, centrifugal and reciprocating compressors, as well as all rotating equipment, with qualified millwright and field machining specialists.

Victory Energy

Offers all types of industrial boilers: watertube, HRSG, firetube, and solar-powered units. Company provides unprecedented support with its rental boilers, spare parts, field service, and auxiliary equipment—including water-level devices, economizers, stacks, expansion joints, and ductwork.

Vogt Power International

Supplies custom-designed HRSGs for GTs from 25 to 375 MW and has extensive experience in supplementary-fired units. Scope of supply includes SCR and CO systems, stack dampers, silencers, shrouds, and exhaust bypass systems.

Young & Franklin

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

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.

New interests outweigh DCS at PowID keynote

The annual conference of the ISA Power Industry Div (PowID) has a small but loyal following of plant I&C and automation professionals (sidebar) and the audience normally is stacked with traditional distributed control system (DCS) types. But at this year's keynote and industry issues session and panel discussion (June 7, 2015 in Kansas City) it seemed that industry leaders and audience wanted to talk about everything but traditional powerplants and control systems.

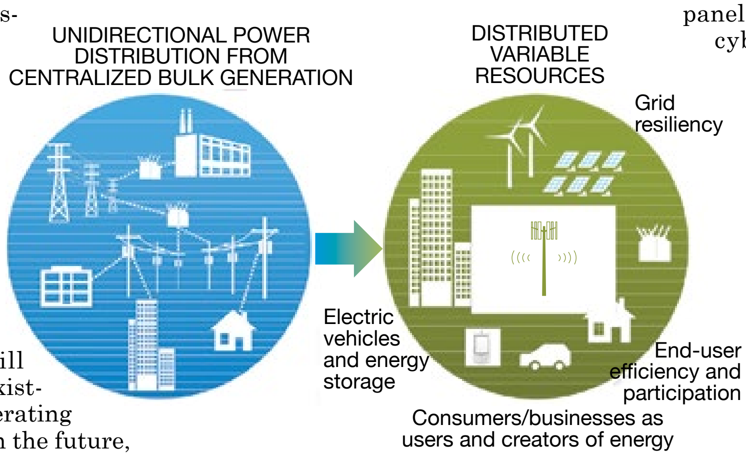
The two broad discernable trends percolating through were (1) "big data" solutions will be central to how the existing "big iron" power generating assets will be managed in the future, and (2) the movement towards distributed power and customer onsite solutions and systems appears inexorable.

Here are the highlights:

It's about the agility, stupid. Scott Stallard, VP, Asset Management Services, Black & Veatch, said the industry is moving from command-and-control to a distributed and *participatory* network (figure). Paying for the agility necessary to keep the grid stable under these new conditions is difficult for stakeholders to grasp. Existing assets have to operate in ways not ever intended in their original design. Stallard believes all this is an opportunity, not a nightmare, because of "the convergence of advanced technology, advanced control, and multi-objective optimization."

New microgrid in town. B&V recently brought online its own microgrid serving the company's innovation pavilion building at the headquarters complex in Overland Park, Kans. The microgrid includes a lithium-ion storage unit, two gas-fired microturbines, geothermal heat management, rooftop solar, and electric vehicle charging stations.

Predictive analytics. Pengju Kang, GE Global Research, Electrical Technologies & Systems, forecasted that by 2025, billions of data points from thousands of machines (gas turbines, wind turbines, etc) will be crunched by the company's Predix servers to provide operational trends and analytics. The analytics will be "built into" the machine controllers at the plant.



The distributed participatory electric system is emerging; it offers opportunities for combining advanced technology, control schemes, and functional optimization

Embedded advanced sensors. Robert Romanosky, deputy director, NETL/DOE Office of Coal and Power, discussed (1) new sensors for turbine blades and other components which will be embedded in the metal and powered by thermoelectric-device heat recovery, and (2) new "lick and stick" sensors powered by machine vibration energy. Both can communicate wirelessly to the larger control and information platform. They will help reduce the design margin required. "Sensors are cheap relative to physical power systems," he said.

Intrigue with energy storage. The audience was intrigued by the control requirements around energy storage. Not only do the subsystems have to communicate with each other (battery unit, power conditioning system, grid interface) but the overall system has to operate according to the instantaneous needs of the grid and price signals from the marketplace.

Noise level with storage grows. During the meet-and-greet following the panel, a director-level representative of a small Midwest utility noted that company executives recently had been visited by representatives from Tesla, keenly interested in selling grid-scale storage to utilities. This followed a press report that Tesla had just signed an agreement with Southern Company to investigate storage; plus, the introduction of a bill in Congress the week before to impose a (very modest) storage mandate on utilities. Storage, it seems, is now part of every discussion about the future of the electricity industry.

The cavalry isn't being trained. One topic which came up in the panel and after was that, with cybersecurity, disruptive changes to centralized command-and-control electricity paradigm, multi-directional relationships among utilities or utility-like entities and customers, cybersecurity, and ever-greater proliferation of wireless, personal devices, and software applications, etc, the role of control, automation, and communication grows exponentially. Yet, according to one professional, new engineers are not entering the workforce in near the numbers required. "Why aren't there 500 people in this room, and half of them half my age?" one participant asked, rhetorically.

Overall, it was difficult to square the topics which drove the industry issues conversation with the rest of the program, focused on fossil, nuclear, and hydroelectric control systems; cybersecurity; and advanced technologies for power generation. CCJ

ISA: one acronym, several names over the years

ISA's name has changed over the years. The organization, founded in 1945, began as the Instrument Society of America, and many in the industry still call it that. In 2000, the name was changed to the Instrumentation, Systems, and Automation Society, reflecting ISA's expansion into areas other than instrumentation. The group's current name—International Society of Automation—was adopted in 2008. Today ISA has more than 28.000 members in nearly 100 countries.

PROFESSIONAL SERVICES

Plus new/used equipment, tools, parts

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

Inspection guidelines for air-cooled condensers help identify, characterize issues

One goal of the ACC Users Group, established in 2009, is to offer critical and timely information to owner/operators of air-cooled condensers (ACCs), thereby enhancing both performance and reliability of personnel, equipment, and plant. Such information includes mechanical component discussions at annual meetings (sidebar) and via the organization's online forum at www.acc-usersgroup.org, field-service program results, control options for efficiency, as well as critical water/steam chemistry issues and best operating practices.

ACC impact is recognized as a key measurement parameter within the complex interactions of all powerplant systems and equipment, making inspection of this equipment a significant part of each plant's O&M program.

By consolidating ACC information on its website, the user group becomes a critical companion to those who operate the equipment, as well as those who take responsibility for ACCs and their impacts. The all-volunteer organization, chaired by Dr Andrew Howell of Xcel Energy, keeps pace with the growing number of units, and perhaps more importantly, tracks operating equipment over time, including state-of-art technology developments. This helps users:

- Anticipate issues experienced by others.
- Reduce elements of surprise.
- Learn new details on perhaps unfamiliar elements of powerplant science.
- Tap the minds of a growing and increasingly experienced ACC workforce.
- Recognize and apply related skills—such as safety and personal risk.

Guidance documents are developed periodically to reinforce and add hands-on depth to the issues identified and discussed. Below is a content summary of one such document available on the group's website, "Guidelines for Internal Inspection of Air-Cooled Condensers," issued May 12, 2015. Although concentrating on corrosion, it also addresses equipment and plant interaction, inspection frequency, and safety.

Offline inspection

The use of air-cooled condensers in fossil-fueled powerplants has increased dramatically during the past two decades. These condensers normally are massive structures because a large amount of cooling surface is required to compensate for the poor heat capacity of air (relative to water).

Corrosion of steam-side surfaces within an air-cooled condenser can be a significant operating problem. In particular, iron-oxide transport can introduce a large quantity of contaminants to the condensate/boiler feedwater circuit. Plus, corrosion can eat through the thin walls of cooling tubes, allowing ingress of air, which adversely impacts condenser (and plant) performance.

Carefully planned internal inspections of ACCs during unit outages have become increasingly important and beneficial.

See, for example, Fig 1. This tube entry area within an ACC shows serious corrosion, marked by extensive areas of black deposition adjacent to bare metal. When compared with the relatively good condition shown in Fig 2, this signals a major concern within the upper section of the condenser.

Even more serious is the condition shown in Fig 3. This tube entry evidence indicates widespread holes in the tubing and welding, and would receive the highest severity rating of 5 in the index discussed below.

Seventh Annual Conference
Sept 21-24, 2015

Air Cooled Condenser Users Group

Windham Gettysburg (Pa)
Agenda at www.acc-usersgroup.org

Steering committee
Chairman: Dr Andrew G Howell, *Xcel Energy*
Gary Bishop, *GWF Energy*
Dr R Barry Dooley, *Structural Integrity Associates*
Hoc Phung, *PG&E*
David Rettke, *NV Energy*
Rene Villafuerte, *Falcon Group—Comego*

1. Tube entry DHACI rating 4

2. Tube entry DHACI rating 1

Dooley Howell Index

The Dooley Howell ACC Corrosion Index (DHACI) evaluates and defines these and other ACC characteristics and concerns. The index combines alpha and numeric values applied during inspection of the upper and lower sections, as described below:

- Upper section, including upper duct/header and cooling-tube entries—rated 1 through 5.
- Lower section, including turbine exhaust, lower distribution duct, and risers—rated A through C.

A lower-duct rating of B is shown in Fig 4, revealing minor bare-metal areas on generally grey ducts. Some "tiger striping" may also appear with darker grey/black areas indicating flow-accelerated corrosion (FAC), and an overall assessment of minor but noteworthy damage.

Fig 5 would receive a higher rating of C for severe local damage. This photographic evidence clearly shows multiple, widespread areas of bare metal in the turbine exhaust and at abrupt changes in flow direction (where steam flow enters a vertical riser from the lower distribution duct). Bare metal areas (white) clearly indicate metal loss.

The DHACI provides a number (1 to 5) and letter (A to C) to describe and rate the ACC's condition. A rating of 3C would indicate moderate corrosion at tube entries, but extensive corrosion in the lower ducts. Such information is valuable for tracking changes that occur in a particular ACC resulting from changes in steam-cycle chemistry; or, it can be used to compare the status of several ACCs.

3. Tube entry DHACI rating 5

4. Lower duct DHACI rating B

Register today for the seventh annual ACC Users Group meeting

Perhaps the most important industry service provided by the ACC Users Group (www.acc-usersgroup.org) is the organization's annual meeting, typically held in early fall. The group's library of past presentations, online forum, and technical guidance documents are other valuable contributions to the collective knowledge.

The 2015 meeting, the group's seventh, features a compelling technical conference at the Wyndham Gettysburg (Pa), September 22-23, sandwiched between meaningful tours and social events. On "optional Monday," September 21, Evapco, one of a dozen sponsors (see logos) has invited attendees to participate in a morning bus tour of Gettysburg National Park. In the afternoon, Evapco is hosting a tour of its Dry Cooling R&D Facility. A welcome reception from 6 pm to 7:30 closes the day. "Optional Thursday" features a morning tour of NRG Energy's ACC-equipped Hunterstown Generating Station. The meeting concludes at the end of the tour.

Chairman Andy Howell told the editors the steering committee had a fine technical agenda shaping up with plenty of time for discussion/interaction. Presentations accepted as June came to a close are listed below. Follow www.acc-usersgroup.org for up-to-the-minute details.

Design and performance, organized and chaired by Hoc Phung and Gary Bishop.

- Wind shields for Mystic Generating Station (Unit 8), *John Ayvazian, Exelon Generation Co.*
- Wind shields for Caithness Long Island, *John Maulbetsch, Maulbetsch Consulting.*
- Wind loads on fan blades and blade dynamics, Nicola Romano, Cofimco Srl.
- ACC performance improvement project, *Huub Hubregtse, ACC-Team Technologies.*
- Aluminum-clad steel (FERAN® process) for direct ACCs, Hans-Juergen Gauger, Wickeder Westfalenstahl GmbH.

Operation and maintenance, organized and chaired by Dave Rettke and Rene Villafuerte.

- Fin cleaning of ACCs, *Fabian Noack, JNW Cleaning Solutions GmbH.*
- Fan blade failures, *Robert Mozzoni, Goreway Power Station*.
- How to diagnose/troubleshoot air ingress, *Martin Cyr, SPX Cooling.*
- Venting systems in ACC applications, *John Aglitz, Nitech Engineered Vacuum Systems.*
- General ACC improvement considerations, *Rene Villafuerte, Falcon Group—Comego.*

Chemistry and corrosion, organized and chaired by Barry Dooley and Andy Howell.

- Particle measurement for iron transport and iron analysis, *Ken Kuric, Hach Company.*
- Case studies of various facilities using polyamine filming inhibitor technology, *Paul Sehl, GE.*
- ACC01: Internal Inspection Guidelines, *Andy Howell, Xcel Energy.*

5. Lower duct DHACI rating C

Inspection regions

Tube inlet. It is important to inspect the tube inlet region carefully (Fig 6). Bare metal is commonly found here because of the effects of two-phase flow, a turbulent 90-deg turn into the tubes, and (often) a weld lip that increases local turbulence. Note that this is the only region where through-wall penetrations caused by FAC have occurred; the wall thickness of ACC tubes typically is 0.059 in.

The first few inches into certain tubes are commonly found to have patches of black deposit alternating with either bare metal or flash-rusted metal. In some cases, entries closer to the duct inlet are more severely corroded than those further downstream.

In some ACC designs, the trough between tubesheets retains standing water as indicated in Fig 6, demonstrating that offline rusting contributes iron oxide to condensate. Cross-beams above the tubesheets frequently exhibit bare metal on the side facing steam flow, and often tube entries with the most corrosion are located beneath these cross-bars, where turbulence is greatest.

Turbine exhaust. Steam exiting the LP turbine may impinge directly on baffles or ducts; therefore, the area is susceptible to significant FAC. Metal loss and black iron oxide at this location appear similar to that at the turbine exhaust in a water-cooled condenser (Fig 7).

Upper distribution duct and entry baffle. This duct may have redder oxide than other ducts in the ACC. The baffles and entry region may show FAC attributed to turbulent flow.

Ductwork from LP turbine to lower distribution duct. A very-large-diameter section of duct typically extends from the turbine exhaust to the lower distribution duct. High-energy steam/drain returns into this duct may show bare metal where duct walls are impacted. Structural supports in the steam path are susceptible to impingement. Flow disruption by protruding weld seams may result in FAC at or immediately downstream of these welds.

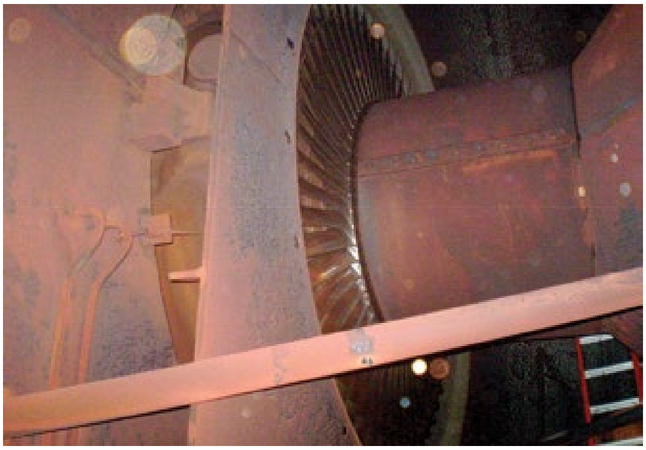
Lower distribution duct and entries to riser ducts. The diameter of the lower distribution duct typically decreases with distance from the turbine exhaust duct. The entry into risers is a turbulent location that should be examined for bare metal.

Inspection frequency

If possible, thorough inspection during the ACC construction and installation process is recommended. Excess weld flux and construction debris have caused difficulties with initial startup, including failure to achieve steam-cycle purity requirements.

Once in operation, the rate of wall loss caused by steam-cycle corrosion typically is not rapid. Through-wall leaks in thin-walled tubes may take

6. Tube inlets upper duct DHACI 1



7. LP turbine exhaust

8. Permanent ladder access to upper duct, with permanent platforms at manways

9. Upper duct with difficult access to manway at top side a decade or more to develop. Iron transport, on the other hand, will occur virtually from the time of initial unit operation. To establish a baseline and document corrosion-susceptible areas, a newly commissioned ACC should be inspected within the first few months, if possible.

Subsequently, an annual inspection should be adequate, unless specific concerns exist that would require more frequent examination. If the first three or four annual inspections show little change in corrosion location or extent, and there are no significant changes in operating patterns or chemistry control, biannual inspections may be deemed adequate thereafter.

Role of good photography

Photographic documentation of cooling-tube entry points and duct surfaces is essential for characterizing internal corrosion. Although any areas that appear abnormal must be recorded, it is important to document the appearance of "normal" areas as well.

Items of particular interest include deposit color, areas where color changes, regions that appear to be bare metal, positions of flow disruptions that may have led to flow-accelerated metal loss, and regions showing heavy deposition or significant depth of metal loss.

Safety awareness

Serious hazards exist for persons inspecting ACCs, and careful planning is critical. One potential hazard is falling (Fig 8). The fan decks of ACCs typically are 80 to 100 ft above ground, generally reached by a lengthy climb on a permanent staircase if elevators are not available. Protective rails are ordinarily well placed to minimize risk.

Reaching the upper distribution duct, however, may be more challenging (Fig 9). While some units are constructed with permanent ladders and platforms for easy access to a manway on the side of the duct, others may require scaffolding or a temporary ladder, followed by a difficult climb on handrails to the top to reach a manway. Fall protection is required.

Once on location, ductwork generally is defined as a "confined space," and breathing air of acceptable quality should be verified before entering a duct; continue to monitor air quality while personnel are inside the duct. Lighting may be poor, with flashlights perhaps the only light source. Temporary LED lighting may be a better alternative.

Certain areas of ductwork offer a slipping hazard when walking on curved surfaces, particularly in wet areas. Sharp edges may be present on support structures, or may develop because of flow-accelerated metal loss. Covers over drain ports may be displaced, resulting in tripping danger; large open drain piping in the lower duct can constitute a fall hazard.

Personnel may move a considerable distance from entry ports during inspection, and the upper ducts in particular have cross-braces that could obstruct personnel removal in an emergency situation. A specific confined-space rescue plan should be in place.

Further guidance

As noted earlier, the complete technical guidance document is available at www.acc-usersgroup.org. It includes additional photographs, configuration and operation discussions, an inspection worksheet for recording DHACI ratings, and a list of authoritative references. CCJ

Closing the disconnect between business and education

The pending retirements of generating-plant personnel, discussed at virtually every industry meeting for at least the last five years, are finally happening. Look at the participants in the next user group meeting you attend. You'll see that the sea of white hair of the recent past is now speckled with black, brown, and blonde, and the overwhelmingly American white male audience is transitioning to one that includes meaningful participation by women, other races, and many nationalities. In effect, your industry is becoming melting pot for talented engineers and technicians from around the globe.

No doubt that the loss of experienced deck-plates personnel has left a significant void in O&M knowledge at some locations. Despite the warnings and endless rhetoric, little was done by most owner/operators to capture the know-how of veterans before they walked out the door. And with the military shrinking, the seemingly bottomless pool of talented US Navy vets is rapidly evaporating.

Immediate need

What to do to fill the manpower gap depends on your particular situation and how much time is available to implement a solution—temporary or "permanent." To begin, assume an immediate need. If an operations person is required, you know the plant/engine/controls/HMI experience/familiarity you want the successful candidate to have.

If your strategy is to run some advertising to identify candidates, it could take six months or more to bring someone onboard. Making calls through your personal network probably is more efficient because you can prequalify individuals and not have to wade through hundreds of resumes from wannabees. You know the value of having a network; that's why you go to user group conferences and meet with other plant managers in your area a couple of times a year over lunch.

What seems to be happening with greater frequency these days is the "raiding" of a nearby plant. Makes sense because no home move is involved and, if terms can be agreed to quickly, you can have someone onboard within a few weeks. But this can be expensive. Expect to pay a signing bonus and a salary increase, provide healthcare and 401K plan, five weeks of vacation, etc. If a move is required, you likely will be asked by your new hire to also purchase his home and pay moving expenses. These are table stakes today.

All this might equate to a "good deal" if you can immediately bring onboard the person you think you want. However, some things to consider: You will not be viewed kindly by your new hire's former employer. If a non-union hire is offered a salary above what you're paying other operators, prepare to increase the pay of those in similar positions. And that of the plant manager: Having lead CROs making more than the person in charge generally is not embraced as a successful management strategy.

Fail to take action. . .then prepare to lose people in the salary war you started. If anyone walks, you're back in the same predicament. And the stakes keep getting higher. In case you haven't given it much thought, you can't manage a plant successfully with a staff of mercenaries; you need team.

There are other solutions of course. You might bring back a recent retiree on an interim basis, or engage a third-party operator, which might have a flexible labor pool. The latter may be a necessary action by the owner if you don't meet staffing expectations.

Maintenance positions at plants with separate operations and maintenance staffs may be easier to fill than operator positions. Many industries employ mechanics, I&C techs, and electricians with skills suitable for generating plants, so the local labor pool may be bigger. If you have no luck in hiring immediately, there are many capable third-party contractors and OEMs generally available to do the work required.

Where you can get squeezed is during a scheduled outage requiring turbine and generator work. Overhauls generally are contracted out, but you need experienced plant staff to monitor contractor performance. In such cases,

1. Power Plant Technology Advisory Board and OSU Power Plant Technology Instructors gather for a photo op. From left, back row: Terry McGee, American Electric Power Co (AEP)/Public Service Co of Oklahoma (PSO); Rick Shackelford, NAES Corp/J-Power USA Generation LP; Mark Barton, AEP/PSO; Ed Going, Tenaska Inc; Ken Egnor, Grand River Dam Authority (GRDA); Stacy Johnson, GRDA; Steve Crary, OGE Energy Corp (OGE); Roy Achemire, Oklahoma State University Institute of Technology (OSUIT). Front row: Terry Hanzel, OSUIT; Elsie Milkowski, OGE; Andrea Simmons, Oklahoma Municipal Power Authority (OMPA); Bob Pope, OSUIT; Mike Pierce, OSUIT. Cameral shy: Chad Chester, EthosEnergy Power Plant Services LLC; Mitch Hurt, Siemens Energy Inc; Mandi Wilson, Western Farmers Electric Co-op; Abul Hasan, OSUIT you might consider hiring an owner's representative, or two, with the necessary skillsets to protect your specific interests. Networking can identify these qualified professionals quickly.

Intermediate need

If you're a capable hands-on manager and relatively sure one or more of your employees will retire in the next year or two, consider bringing in at ground level a recent graduate from one of the several specialty powerplant technician and engineering programs that have been established nationwide in recent years. Colleges offering associate, and higher, degrees, you might want to learn more about include Fort Myers (Fla) Technical College (ad p 120), Oklahoma State University Institute of Technology (OSUIT, ad p 101), and Idaho State University's Energy Systems Technology & Education Center (ESTEC).

Grads from these institutions have a good foundation in power-generation technology and are anxious to prove themselves and earn a paycheck that your plant can afford. If you have the year or so required to mold a graduate into a productive team member, you'll likely have a loyal employee for the long term.

The new schools

The objective of this section is to introduce you to a few of the new schools preparing capable high-school graduates for entry-level positions in industry—electric power, in particular. Add them to your existing list of maritime colleges, Bismarck State College, etc, for recruiting purposes.

But don't stop here. Make a few calls to technical schools and colleges in your area to see if they offer courses of study that are compatible with your employment needs. If not, ask if there would be interest in starting such a program in cooperation with industry. The obvious goal is to build a labor pool in your geographic area, which is what the three institutions profiled below— and several others—have done successfully.

Fort Myers Institute of Technology, recently renamed Fort Myers Technical College, is an accredited public post-secondary career and technical education center operating under the Florida Dept of Education's Division of Workforce Development and the Lee County School District.

Development of the institution's "Turbine Generator Maintenance, Inspection, and Repair" curriculum was a collaborative effort between FMTC Director Bill McCormick and David Branton and his team at nearby TGM-Turbine Generator Maintenance Inc. Program details, shop/equipment facilities, interviews with students, etc, were published in **CCJ** 2Q/2014, p 36. If you can't find a copy of that issue, access "Forget the 'labor pool,' developing employee skills is management's responsibility" using the search function at www.ccj-online.com.

OSUIT launched its two-year Power Plant Technology Program in 2007 and is now considering the addition of a four-year program that would lead to a bachelor's degree in technology. Instructor Terry Hanzel, who has powerplant and oil-and-gas industry experience, told the editors that about 15 students are accepted into the program annually; typically a dozen will graduate with an Associate of Applied Science Degree.

2. OSUIT students benefit from field instruction by Green Country Energy Lead Technicians Derek Hale and Daniel Barbee

Motivation for the program was provided by American Electric Power (AEP) which believed a technical vacuum would be created by looming retirements. It approached OSUIT with the idea of developing a collaborative program between industry and academia to address the coming need for quality technicians.

AEP and OSUIT sought out other power producers in the area to work with the institute's instructors and administrators to ensure the curriculum, training methods, and equipment remained current and were properly aligned with the latest technologies and methods used in powerplants.

A Power Plant Technology Advisory Board was formed, comprised mostly of Oklahoma plant managers, training directors, and HR professionals (Fig 1). Today, virtually all of the large utility and IPP generating plants in the state are represented on the advisory committee, chaired by Rick Shackelford, plant manager of Green Country Energy (owned by J-Power USA and operated by NAES Corp), a 3 × 1 F-class combined cycle. He is a proactive participant in user-group meetings and currently serves on the CTOTF™ leadership committee as vice chair of the organization's combined-cycle roundtable.

"We have industry directly participating in the program with curriculum development," Shackelford continued, "donating equipment for training purposes, hosting new-student open houses at powerplants, serving as guest speakers and instructors, and offering paid internships." Hanzel said that the product/services providers sharing their know-how include DRB Industries, Braden Manufacturing, Parker, Kansas City Deaerator, and ChemTreat.

The plant manager described the OSUIT curriculum as "combining the science and technology of power production with realistic assignments, hands-on instruction in state-of-the-art lab spaces, and internships at powerplants prior to graduation." What makes OSUIT different than most technician development programs, he explained, is its formal degree program coupled with real-world field experience.

There are 10 powerplants within about an hour's drive of the school and they are visited regularly to reinforce classroom lessons (Fig 2). Plus, each student participates in a 15-week plant internship after successfully completing the first year of study.

"The internship experience is where students take what they've learned in the classroom and labs to a higher level and apply it to real-world situations," Shackelford said. "It's also where they learn if powerplant technology is where they want to build their careers." Hanzel added, "The transformation seen in the students after their internship is amazing. They return to the classroom with the realization that what they are learning will be used on the job, confident that the education they are receiving will help them land a meaningful job at a good salary in a secure job market."

Parker Minor graduated from OSUIT in 2013 and interned at Green Country, where he is now an operator. Minor admits he knew nothing about how a powerplant worked when he enrolled in the program at the suggestion of a family friend. "You develop a solid foundation at OSUIT," he said, "but the internship is what made me want this career."

Brandon Sorum is another OSUIT student who didn't know much about powerplants until he enrolled at OSUIT, and after interning at Green Country during the summer of 2014, he couldn't wait to start his career in the industry. His work assignments involved maintenance, operations, and instrumentation. Operations Manager Danny Parish said the internship program gives plant personnel the opportunity to help students; the plant's reward is the work the interns do.

Reflecting, Minor said everyone he graduated with from OSUIT has a job. That helped to convince his brother to enroll in the program. Sorum said he had a friend with a four-year degree who couldn't find a job; he sent out three resumes, got two responses, two interviews, and two offers.

At the conclusion of the internships, the OSUIT instructors ask plant managers and supervisory personnel for feedback on what aspects of the curriculum should be improved. Shackelford said this information exchange is vital to the success of the program given demands for technology advancement, the impact of regulatory oversight, etc. The instructors also maintain an open communications network with graduates to get their thoughts and ideas from the workplace. In sum, it's a process of continual improvement to ensure win (industry), win (university), win (student).

ISU's ESTEC. Executive Director/Chair Lawrence Beaty has a long-term association with powerplant equipment and training. With Beaty as the driving force, Idaho State University joined with Idaho National Laboratory, the nation's leading center for nuclear R&D, to train plant operators: The lab's experiment with hiring engineers for this purpose had failed.

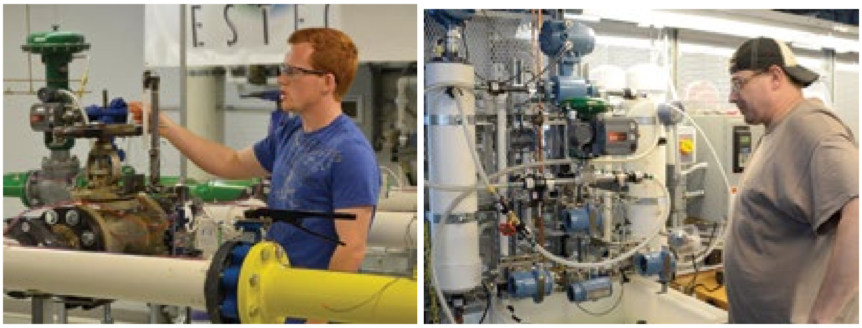
ISU partnered with Idaho Power, PacifiCorp, and others, received funding from the Dept of Labor, and ISU provided a building to launch a two-year program that would award Associate of Applied Science Degrees to successful students. The goal was to design a course of study to train students to operate all types of plants, not one dedicated to a specific type—nuclear, for example. The first class graduated in 2007; today, nearly 150 students are enrolled in the program at any one time.

Beaty explained to the editors how the ESTEC program fits in the total scheme of operator training in the modern world. He looked back to powerplant I&C shops in the mid-70s/80s when there might have been a dozen technicians on staff; today there's about one-third that many, all with excellent skills learned incrementally over careers spanning decades.

However, informal on-the-job training is no longer a viable way to learn. Technology has gotten too complex and changes are occurring too rapidly, and there aren't enough people on staff to train you. Even if there were, it takes a very long time—if ever—to acquire the required foundational principles in an informal setting.

On the flip side, formal engineering education has migrated to virtually theory-only at many institutions. Reason is simple: Lab facilities are expensive; theory is inexpensive (relatively) to teach. A result of the changing paradigm is electrical engineers who can't read one-line diagrams, maintenance engineers who can't pack valves, and mechanical engineers who don't know what P&IDs are let alone know how to read them.

ESTEC fits between on-the-job and formal engineering programs. At ISU, it's all about application engineering—that is, the application of fundamental engineering principles to solve problems, not design equipment. You need system knowledge in today's world, Beaty says, not specific equipment knowledge. This is why students in his program do cross-discipline work.



3. Lab facilities are what make ISU's powerplant training program special

Look at Fig 3 and you quickly get a sense of the ESTEC program. Students learn safe work practices and take basic theory and basic math, but not to solve for “x,” rather to calculate the flow through a valve, across an orifice, etc. The program is laboratory-intensive—three hours daily, five days a week. That the labs are equipped with real-world equipment should be obvious from the photos.

Many aspects of the ESTEC and OSUIT programs are similar with regard to internships, continual improvement of the curriculum, etc. ISU has created a four-year Bachelor of Applied Science program designed for experienced people who want to move from the technical world to the business world.

STEM, CTE

Beaty is the perfect segue to the work being done by Dr Robert Mayfield, chairman of the Combined Cycle Users Group and vice chair of the Virginia Career Education Foundation, to develop and promote STEM (science, technology, engineering, and math) and CTE (career and technical education) programs in his home state. Beaty stressed how critical a solid foundation in mathematics was to success in the ESTEC program. Applicants are required to have appropriate math skills before enrollment is possible. For those who don't, ISU offers a remedial program, complete with math workshops and tutors, made possible by STEM grants.

For its program, ISU wants applicants with passing grades in advanced algebra, Lego League experience, etc, who enjoy using their hands and are enthusiastic about learning. Building on this enthusiasm is what ESTEC is all about: To make students aware of the many opportunities open to them. The vast majority of jobs in the power world today do not require engineering degrees.

In effect, Dr Mayfield's work, and that of others like him, is critical to the ready availability of human capital for workforce development. Without a strong foundation in math, science, engineering, and technology, acceptance into programs such as those offered by FMTC, OSUIT, and ISU ESTEC to create a skilled labor pool for the industry is not possible. It behooves industry to get involved proactively.

To learn more about what you and your company can do to help put middle- and high-school students on a path to a financially and prefessionally rewarding career, access “Building a 21st century workforce begins with education,” and other articles written by Dr Mayfield via the search function at www.ccj-online.com.

In-plant training

Having discussed the fallacy of relying on on-the-job training to develop the world-class O&M team required today to assure financial success in the generation business, recognize too that formal education in an institution of higher learning is not a panacea. There is need for periodic training in-plant to address deficiencies, “connect” a team having undergone recent personnel changes, stay abreast of technology changes, etc.

It's easy to stand in front of a group and tell them what you think they should know—that's talking. Training takes skill: At the end of the day you want personnel to leave the plant conference room having learned something to improve facility operations.

A true training professional can create a custom program to improve plant reliability and efficiency by enhancing management and operator technical understanding and plant-specific knowledge. Human performance improvement, a powerful tool to proactively prevent forced outages triggered by human error, is part of this. Technical Training Associates recently shared its formula for success with the editors.

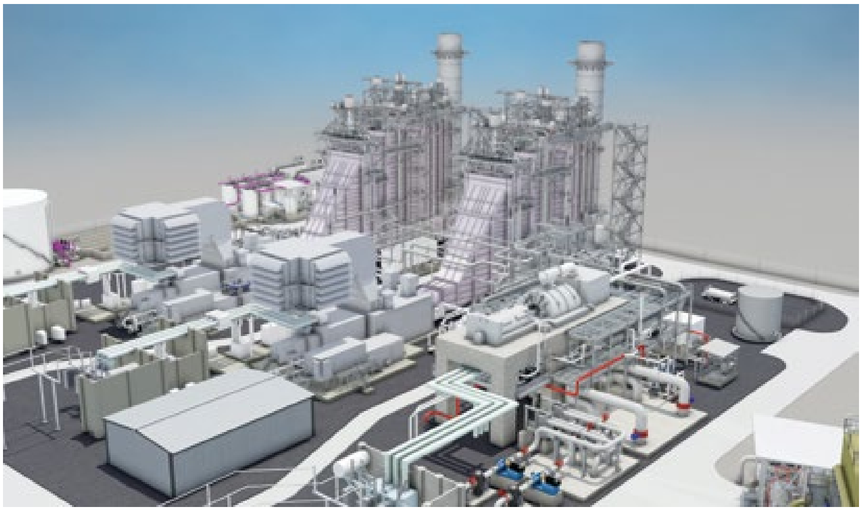
The firm's lead instructor is Jose Femenia, PE, (jose.femenia@yahoo.com) former engineering chairman at the State University of NY Maritime College (Fort Schuyler) and department head at the US Merchant Marine Academy (Kings Point).

Finally, every training program needs training aids, another technology that has changed dramatically in recent years. To learn more, turn the page and read the next article. CCJ

It's a visual world: Training aids go 3D

Three-dimensional (3D) modeling is a standard tool in today's engineering—used for everything from the design of advanced concepts to equipment fabrication. Taken one step further these models, coupled with advanced computers and software, give training providers the ability to create detailed 3D content showing information previously available only in the 2D world of books, brochures, outage photos, and artist renderings.

Additionally, use of plant design/construction models provides site-specific content critical to any successful training effort, say Tony Wiseman, training manager, Calpine Corp, and Fred Foster, president/CEO, Technical Training Professionals. Wiseman has more than three decades of experience in technical training with the US Navy and at electric-utility and independent power producers.



1. Access to site engineering models is the first step in creating the training content required for success in the millennial era

Millennials, the new workforce. The retirement of workers from the post-war baby boom is one of the most important demographic shifts facing industrial America today, the Calpine manager continued. Companies have spent years addressing this issue, he said, resurrecting training and qualification programs for the first time in decades, preparing for the workers who will replace the boomers.

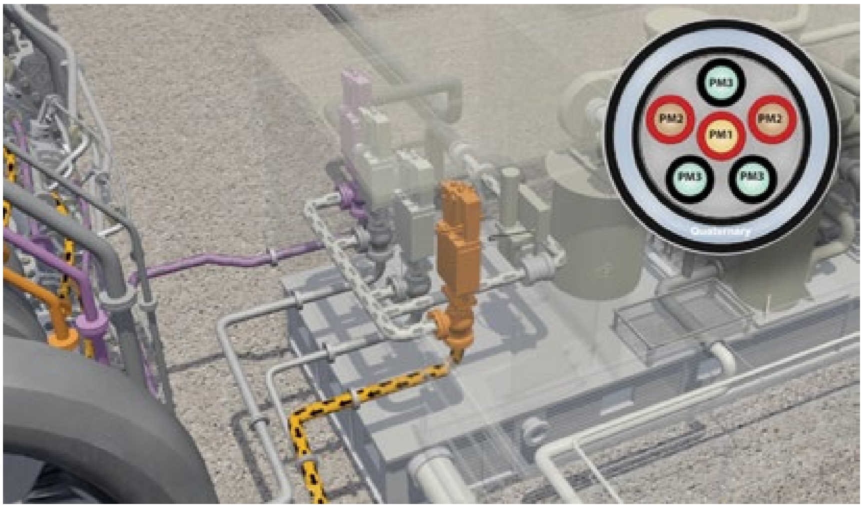
Members of the millennial workforce, the 18- to 25-year-olds currently seeking employment, are accustomed to multimedia content that quickly explains everything from Sudoku games to interstellar travel. Much of this content is instructional and can quickly show how things work or how tasks are accomplished. Add the immersive gaming experiences of this generation, and it's no surprise that the same techniques are seeing strong success in the power industry.

Leveraging site engineering models (Fig 1), along with the ability to draw and create realistic equipment internals, is the first step in creating the training content required for success in the millennial era. Once accomplished, it becomes possible to create intuitive 3D videos with highly illustrative cutaway graphics. Layered, interactive equipment graphics can be exported in common file formats, such as portable document files (PDFs). These 21st-century graphics enhance e-learning solutions, as well as the more traditional training manuals and books.

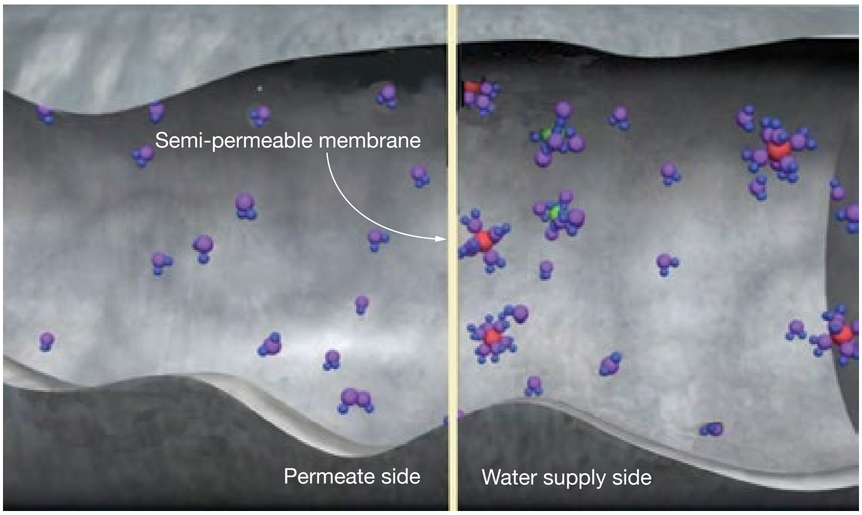
One of the challenges faced in creat-

2. Arrangement of a triple-pressure HRSG is much easier for a new employee to understand in 3D than in a 2D drawing

3. Arc-flash hazards are one aspect of safety training benefitting from animation



4. GT firing modes graphic demonstrates how walls, structural steel, etc, can be made translucent or invisible, enabling trainers to focus attention on gas control valves, gas supply headers, burner internals, etc



5. Here's how 3D graphics illustrate the rejection of hydrated chloride and sodium ions by reverse osmosis because of their large size, while water molecules pass through the RO membrane

ing the development of modern training materials is finding people with the capability to take highly technical engineering content and turn it into a 3D virtual world. Look to the gaming industry, Foster said.

Already trained in creating graphic-intense virtual-reality worlds, these talented people are able to transition their considerable skills to the power-generation world. Gamers, 3D modelers, videographers, and artists from the nation's art schools already are collaborating with power-industry subject-matter experts to develop compelling visual content.

21st century content. Whether explaining stress corrosion cracking, reverse osmosis, or flow through a heat-recovery steam generator (Fig 2), it has been proven time and again that most people are visual learners. Visual presentation allows trainees to easily grasp technical material. Then, empowered by their new-found abilities they embrace the challenge of even more complex subjects. This has been the experience of Calpine and others in the training of operations, maintenance, and engineering support personnel.

In addition, safety training of topics ranging from arc flash (Fig 3) to forklift operation to site hazards is far more engaging when presented with detailed 3D models and live video. Wiseman and Foster agreed that perhaps the most important aspect of these training solutions is they graphically illustrate a company's commitment to employee development.

Whether an employee is transitioning from a coal plant to a gas-fired plant, or just starting work in the power industry, the ability to see step-by-step explanations is extremely valuable. Following flow paths and design in 3D with related control-screen depictions provides the needed training in a more understandable manner.

One example of what can be demonstrated is the firing modes of a gas turbine (GT). Fig 4 demonstrates how walls, structural steel, and other items can be made translucent or invisible, enabling trainers to clearly show gas control valves, gas supply headers, burner internals, etc.

Chemistry control is critical to overall plant health, but the underlying processes can be challenging for plant personnel to master. Reverse osmosis (RO) is a good example. Fig 5 reflects how 3D graphics illustrate the rejection of hydrated chloride and sodium ions because of their large size, while water molecules pass through the RO membrane.

Once they see this simplified concept, trainees understand the membrane basically is a molecular filter. From this point, it is easier to understand why certain gases—such as non-ionized gases that do not hydrate in water, easily pass through the membrane while ionized gases are rejected.

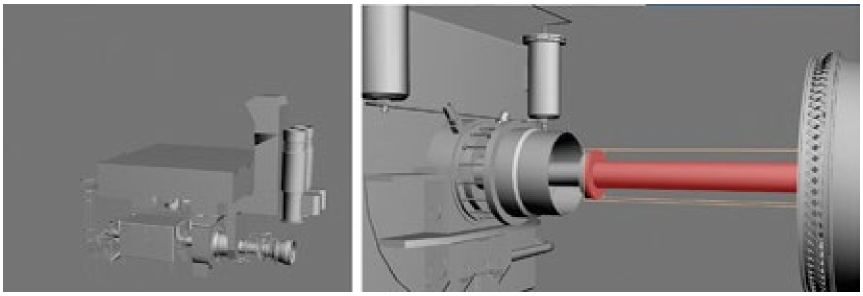
3D visualization also can be helpful in explaining things electrical—including ground-fault protection relays, power factor, and other concepts that plant personnel sometimes struggle to understand. This is accomplished by showing the actual current transformers, breakers, etc, while "flying through" buildings and transformers. For example, the graphics can clearly illustrate what causes a relay to activate. Memory retention is better when trainees "see" the devices than when they are just shown out-of-sync sine waves and other 2D representations.

Visual procedures. Training on maintenance procedures probably is one of the largest growth areas for this technology, Wiseman and Foster told the editors. Maintenance personnel welcome step-by-step, detailed 3D procedures on topics such as rebuilding valve actuators, they said, and find extremely helpful the ability to go quickly to any step in a procedure and be able to access linked complementary information from vendor manuals, rebuild photos, notes from co-workers, parts numbers, etc.

Access Video 1 by scanning the QR code with your smartphone or tablet and experience the power of 3D in transferring labor-saving information quickly and efficiently; here the disassembly of a main steam stop valve serves as an example.

Video 1

Safety. Another application for 3D visualization is site orientation. The use of a canned video followed by talk-through of a site's general arrangement drawing is obsolete. 3D site



6. Layering helps trainees focus on what's pertinent to a particular aspect of the "lesson." An LM6000 is used in this example (left). A couple of "layers" removed reveals the GT-to-generator shaft connection being discussed by the trainer

fly-through videos provide an overview of the facility, summarize the functions of its major components, and identify the location of personnel hazards in an engaging, memorable manner (access Video 2).

Video 2

Video 3

These videos can be leveraged for contractor and new-employee orientation, site safety instruction, and to explain the plant's design and function to the public. Regarding the last point, an easily understood explanation that the cooling-tower plume is steam, not smoke, can be very helpful in gaining public acceptance of a new facility. Video 3 is a typical safety clip, this one concerning the ammonia storage tank.

Enhanced classroom experience. Animation is only part of the 3D visualization value proposition. 3D PDF files derived from previously created models are used by trainers to remove equipment "layers." Each layer can illustrate selected systems or even identify specific components (for example, valves, instrumentation, etc). Fig 6 illustrates "layering" as applied to an LM6000. Such 3D PDF files are particularly useful to control-room operators—to identify the location of a valve or other flow element in support of the lock-out/tag-out (LOTO) process, for example.

Plus, an operator can click on a control-screen depiction of a component—such as a valve, breaker, controller, temperature indicator, or other device—and request to see its physical location. Then he or she can choose to see the full system supported by the component—for example, feedwater supply to the HP drum from from the boiler feed pump. This eliminates the need for operators to search vendor manuals, paper files, and other references, saving both time and money.

Another tool available to plant personnel, Foster said, is a series of learning-management-system/collaboration sites that allows access by a smart device to 3D content and related reference data for a particular piece of equipment. Example: A technician preparing to work on the GT can synchronize all related 3D training, vendor manuals, most recent P&IDs and electrical schematics, thermographic data, walk-down sheets, previous inspection reports, and other relevant materials.

When the technician returns to the control room, he or she can re-sync the smart device with the server, thereby updating training records, inspection reports, etc.

As this content is created, a multi-plant owner can make it available across the enterprise and provide specifics for each site. If the same power-block major equipment is used at multiple facilities, high-quality, site-specific training featuring 3D content can be created at reasonable cost, assures Foster.

Collaboration. Calpine recently used detailed 3D models, and animation of those models, at two combined-cycle projects in California—its new Russell City Energy Center and the repowered Los Esteros Critical Energy Facility. In both cases, Wiseman said, 3D site models created for engineering functions were repurposed for training.

Some manufacturers were willing to partner with Technical Training Professionals to provide detailed 3D equipment models in return for access to content created from the models—a win for all parties. Nooter Eriksen, for example, provided the engineering model for the Russell City HRSGs. For its participation, NE received copies of the courses developed for the HRSGs and will receive the coming chemistry courses in which its boiler is featured.

Calpine has leveraged the animations beyond employee training, Wiseman added. One significant example is in the investigation of plant events. Employees and contractors involved in one investigation were better able to visualize equipment issues, resulting in more detailed and comprehensive investigation findings. The animations also have been used during job briefings as part of complex construction and outage work. CCJ

IAPWS releases best operating practices for water chemistry at annual meeting

Readers should be somewhat familiar with the work being done by the International Assn for the Properties of Water and Steam (IAPWS) to help powerplant owner/operators upgrade cycle chemistry at their facilities, given CCJ's coverage in the last year (4Q/2014, p 90 and 2Q/2014, p 26; if you can't locate those issues, simply access www.ccj-online.com and type IAPWS into the search function on the home page).

Dr R Barry Dooley of Structural Integrity Associates Inc, a member of CCJ's Editorial Advisory Board and Executive Secretary of IAPWS (bdooley@structint.com), called the CCJ offices shortly after the organization's 2015 meeting concluded in Stockholm, July 3.

Recall that the primary purpose of this annual conference is to connect researchers and scientists with the engineers who use their information. The exchange provides researchers guidance on industry problems while engineers receive the latest research results. The meeting in Sweden attracted 88 scientists and engineers from 21 countries.

IAPWS also documents certified research needs that represent the opinion of experts who believe research on particular subjects (in their fields of expertise, of course) is greatly needed to fill gaps in knowledge. All of this information is accessible, at no cost, at www.iapws.org.

In the Stockholm meetings of the IAPWS Power Cycle Chemistry (PCC) working group, amendments to Technical Guidance Documents (TGD) were finalized for (1) instrumentation, and for (2) for volatile treatment and (3) phosphate/caustic treatment at cycling and fast-start plants. Amendments to all three TGDs are ready for immediate release. Access these documents on the organization's website.

Additional discussion and work were undertaken to begin the preparation of three new TGDs with a completion goal consistent with their release at the 2016 meeting. Guidance will be provided on (1) the use of film-forming amines in water/steam cycles; (2) tube sampling and deposit analysis for HRSG HP evaporator bundles; and (3) the integrity of high-purity demineralized makeup. CCJ will report on developments as information becomes available.

Sulzer acquires Precision Gas Turbine

Sulzer acquired the business of Precision Gas Turbine Inc of Plantation, Fla, on June 3, 2015. Precision, founded in 1997, offered a wide variety of gas-turbine services both inside and outside the US. Work on V machines was one of the company's specialties.

Peter Alexander, president of Sulzer's Rotating Equipment Services Div, told the editors, "Precision Gas Turbine greatly enhances our gas-turbine service competencies, primarily in the US, but also worldwide. The acquisition will allow us to offer rotating services to the benefit of existing and new customers in the power market. In addition, we expect sales synergies from insourcing workshop repairs to our existing Houston location."

Full integration of Precision into Sulzer's North American service operation is to begin immediately after closing.

Emera Energy selects GE to upgrade Tiverton

Halifax-based Emera Energy has selected GE to upgrade its COD 2000 Tiverton Power 1 × 1 7FA.03-powered combined cycle to increase efficiency, generating capability, and availability—all while reducing operating costs and environmental impacts. Emera acquired the plant, which dispatches to ISO-New England, from Calpine Corp in 2013.

Tiverton would be the first North American combined cycle to incorporate three FlexEfficiency™ upgrades from the OEM: a new Dot-04 compressor, DLN 2.6+ combustion system, and GE's Advanced Gas Path technology solution. Expectations are that Tiverton Power would save about $1 million annually in fuel, extract an additional 22 MW from the 265-MW combined cycle, and reduce heat rate by 3.4% at ISO conditions.

The three upgrades are scheduled for implementation during a planned maintenance outage in April 2016 and expected to be commissioned about a month later.

Company news

NAES Corp, Issaquah, Wash, enters into preferred-vendor agreements with C C Jensen, an industry leader in oil filtration systems and related products, and Buckman, an industry leader in water-treatment technologies, increasing to more than 40 the number of such agreements in force. In related news, NAES has purchased Greenberry Industrial, a nationally recognized industrial contractor, fabricator, and mechanical installation provider.

Universal AET, Stoughton, Wis, receives a state grant to enhance the skills and credentials of unemployed, underemployed, and incumbent workers at the company's facilities. In related news, the company receives a Wisconsin Manufacturer of the Year Special Award in the Employee Development & Commitment category.

Indeck Keystone, Erie, Pa, celebrates 175 years of providing engineered steam solutions to industry. The company began as Presque Isle Foundry in Erie in 1840, later changing its name to Erie City Iron Works. After purchase by Zurn Industries Inc in the 1960s it was renamed Zurn Energy Division. Following acquisitions in 1997 by Aalborg Industries and in 2002 by Erie Power Technologies it became Keystone Energy Inc. Indeck acquired the company in 2004.

Ballistic Fire Barrier LLC, Manasquan, NJ, completes construction of an innovative transformer ballistic fire barrier at a utility substation. The highly engineered series of nine barriers from 20 to more than 51 ft long and 32 ft high meet NFPA 851 line-of-sight standards to protect critical equipment from ballistic fire from an adjacent hillside. The barriers also are tested to shield from transformer fires and blast.

Olympus, Waltham, Mass, introduces the Series C videoscope designed for cost-effective inspections of manufactured parts, structures, and areas with limited direct visual access. The portable, compact instrument is said to have a high level of maneuverability.

Conval, Somers, Conn, offers a wide range of automated globe, gate, and ball valve packages in 0.5 through 4 in. sizes that assure precise closing, allow for integrated remote monitoring and control, and other features. The high-performance Clampseal and Camseal forged valves are repairable inline, with no welds to remove and replace.

In related news, Conval releases its updated 900-page engineering binder containing technical information on the company's full line of high-pressure/high-temperature forged valves and accessories for the world's most demanding applications. It is available to qualified specifiers in hard copy or online (www.conval.com).

Emerson Process Management Power & Water Solutions develops a comprehensive portfolio of cybersecurity services designed to help Ovation ™ users secure their cyber assets and meet compliance regulations. The expanded services portfolio complements the company's existing cybersecurity products and service solutions.

COMBINED CYCLE Journal 1Q/2015

Index to advertisers

501F Users Group....96
7EA Users Group....116
7F Users Group....117
AAF....11
ACC Users Group....32
ACC China....113
Advanced Filtration Concepts Inc....59
Advanced Turbine Support LLC....25
Aeroderivative Gas Turbine Support Inc....69
AGTServices Inc....109
American Chemical Technology....31
Babcock Power/Vogt Power International....19
Bremco Inc....6
Camfil....62
CAMS....109
CCJ Buyers Guide....102
C C Jensen....21
CCUG-Combined Cycle Users Group....53
Chanute Manufacturing....13
CMI Energy LLC....60
Conval Inc....9
Coverflex Manufacturing Inc....61
CTOTF....67
Cust-O-Fab Specialty Services LLC....64
Cutsforth Inc....23
Donaldson Company Inc....86
DRB Industries....52
Duct Balloon....95
ep³....85
Esco Tool....95
EthosEnergy Group....124
Fort Myers Technical College....120
Fulmer Co....63
Generator Technical Forum....115
Generator Users Group....99
Graver Technologies....93
Groome Industrial Services Group....17
Haldor Topsoe Inc....37
Harco Laboratories Inc....80
Hilliard Corp....81
HPI....83
HRST Inc....65
Hydro Inc....4-5
Hy-Pro Filtration....88
IAGT....90
IHI....75
IST-Innovative Steam Technologies....33
IPG-Industrial Project Group SpA....57
JASC....27
Kobelco/Kobe Steel Ltd....73
KnechtionRepair....97
Maximum Turbine Support....55
Mitsubishi Hitachi Power Systems....35
Mechanical Dynamics & Analysis Ltd....87
Mistras Group Inc....49
MTU....77
NAES Corp....47
National Electric Coil....14
Natole Turbine Enterprises Inc....109
NEM Energy....89
NRG Energy Services....51
Oklahoma State Univ Institute of Technology....101
Platts....121
Praxair Surface Technologies....66
Precision Iceblast Corp....39
Rentech Boiler Systems Inc....2
Roblicorp....92
Siemens....41
STUG-Steam Turbine Users Group....53
Sulzer....123
Technical Training Professionals....92
Thermal Chemistry....101
TransCanada Turbines....71
TRS Services....43
Universal A&ET....93
Veracity....109
Victory Energy....28-29
Western Turbine Users Inc....42, 57, 76, 90
Young & Franklin Inc....15
Zeeco Inc....45