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CCJ COMBINED CYCLE Journal

POWER USERS Mega Event

2023 Conference and Vendor Fair

Omni Atlanta Hotel at CNN Center • August 28 – 31

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POWER PLANT CONTROLS USERS GROUP

Best Practices Awards (p 87)

Amman East Power Plant (Jordan) • Broad River Energy Center
H O Clarke, Topaz, and Braes Bayou • Exira Station
River Road Generating Plant • Ventanilla Combined Cycle (Perú)





Other content

Miscellany

INDEPENDENT VOICE OF THE GAS-TURBINE-BASED GENERATION SECTOR

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

Amman East Power Plant
Owned by AES Corp, Mitsui, and Nebaras Power
Operated by AES Corp

Broad River Energy Center
Onward Energy

H O Clarke, Topaz, and Braes Bayou
Owned by WattBridge
Operated by ProEnergy

Exira Station
Owned by Western Minnesota Municipal Power Agency
Operated by Missouri River Energy Services

River Road Generating Plant
Owned by Clark Public Utilities
Operated by General Electric Gas Power

Ventanilla Combined Cycle
ENEL Generacíon Perú

AES Alamitos Energy and AES Huntington Beach Energy
Owned by AES Southland
Operated by AES Corp

AES Levant Peaker Power Plant
Owned by AES Corp, Mitsui, and Neberas Power
Operated by AES Corp

Athens Generating Plant
Owned by Kelson Energy
Operated by NAES

Cape Canaveral Next Generation Clean Energy Center
Florida Power & Light

CC NORTE III
Owned by Abeinsa
Operated by NAES

CPV Towantic Energy Center
Owned by Competitive Power Ventures
Operated by NAES

CPV Valley Energy Center
Owned by Competitive Power Ventures and Diamond Generating Corp
Operated by DGC Operations LLC

Energía Del Valle de México II
Owned by Energia del Valle de Mexico Generador SAPI de CV
Operated by NAES

Essential Power Newington LLC
Owned by Essential Power Investments LLC
Operated by Cogentrix Energy Power Mgt

Fairview Energy Center
Owned by Osaka Gas USA, DLE, and Competitive Power Ventures
Operated by NAES

Faribault Energy Park
Owned by Minnesota Municipal Power Agency
Operated by NAES

Hunterstown Generating Station
Owned by Platinum Equity LLC
Managed by Competitive Power Ventures
Operated by NAES Corp

Jackson Generation
Owned by J-Power USA
Operated by NAES

Kings Mountain Energy Center
Owned by Carolina Power Partners LLC
Managed by CAMS
Operated by NAES

Kleen Energy Systems LLC
Owned by EIF Kleen, LLC
Operated by NAES

Lawrence County Generation Station
Owned by Hoosier Energy, REM, and Wabash Valley Power Assn
Operated by NAES

Lee County Generating Station
Owned by Rockland Capital
Operated by NAES

Linden Cogen
Owned by JERA Co, EGCO Group, Development Bank of Japan, and GS-Platform
Operated by NAES

Mariposa Energy Project
Owned by Diamond Generating Corp
Operated by DGC Operations LLC

Milford Power
Owned by Starwood Energy Group Global and JERA Co
Operated by NAES

Plant Wansley Combined Cycle
Southern Company

Quail Run Energy Center
Owned by Starwood Energy Group Global
Operated by NAES

REO Cogeneration Plant
Lansing Board of Water & Light

Rolling Hills Generating
Owned by LS Power
Operated by PIC Group

St. Charles Energy Center
Owned by Competitive Power Ventures
Operated by CAMS

Sentinel Energy Center
Owned by Diamond Generating Corp, Partners Group, and Voltage Finance LLC
Operated by DGC Operations LLC

Plant Wansley Combined Cycle
Southern Company

Wildflower Indigo Generation LLC
Owned by indirect affiliates of Diamond Generating LLC
Operated by DGC Operations LLC
Managed by DGC Asset Management LLC

Wildflower Larkspur Energy LLC
Owned by indirect affiliates of Diamond Generating LLC
Operated by DGC Operations LLC
Managed by DGC Asset Management LLC

Worthington Generation Station
Owned by Hoosier Energy
Operated by NAES

COMBINED CYCLE Journal

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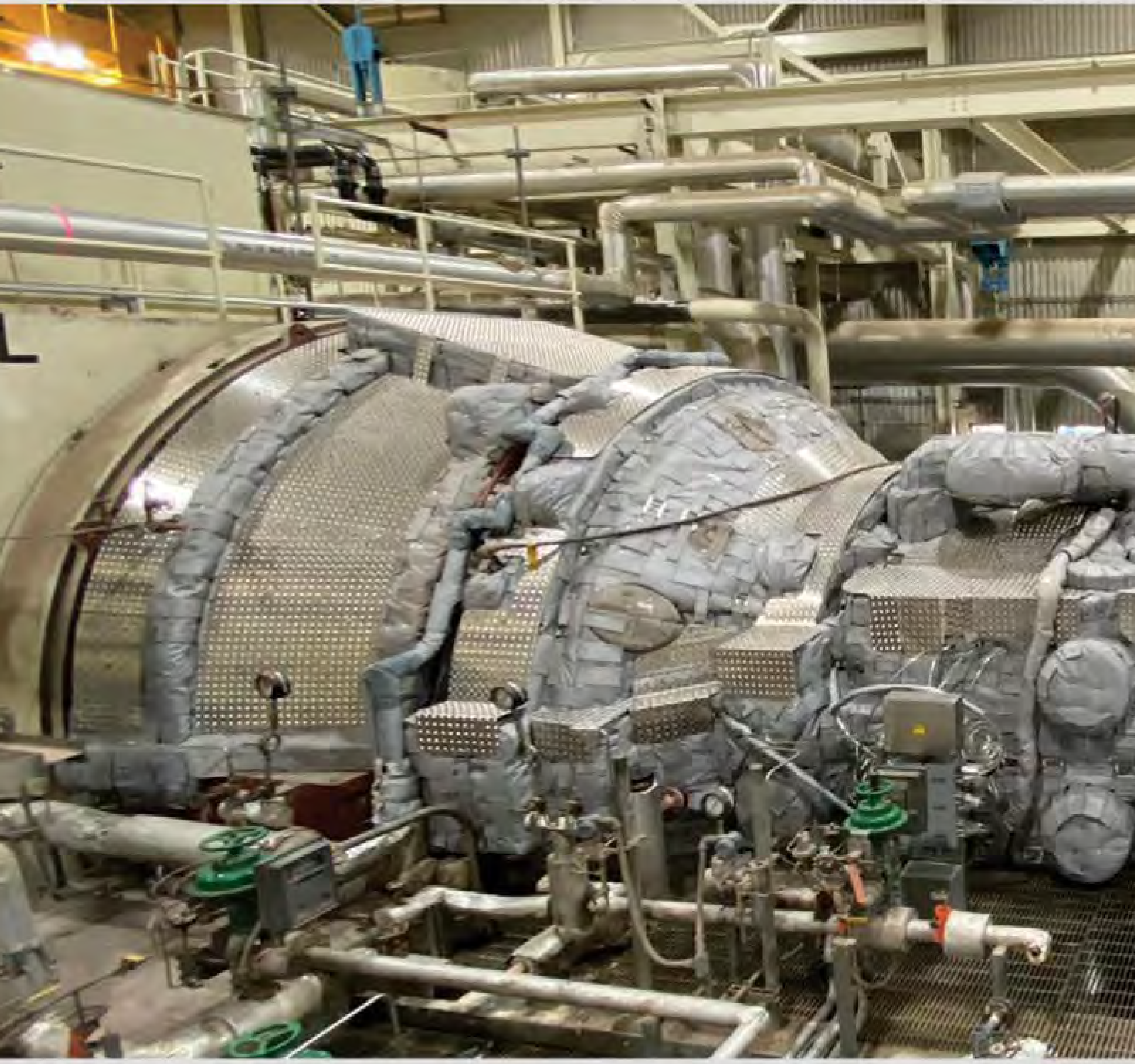
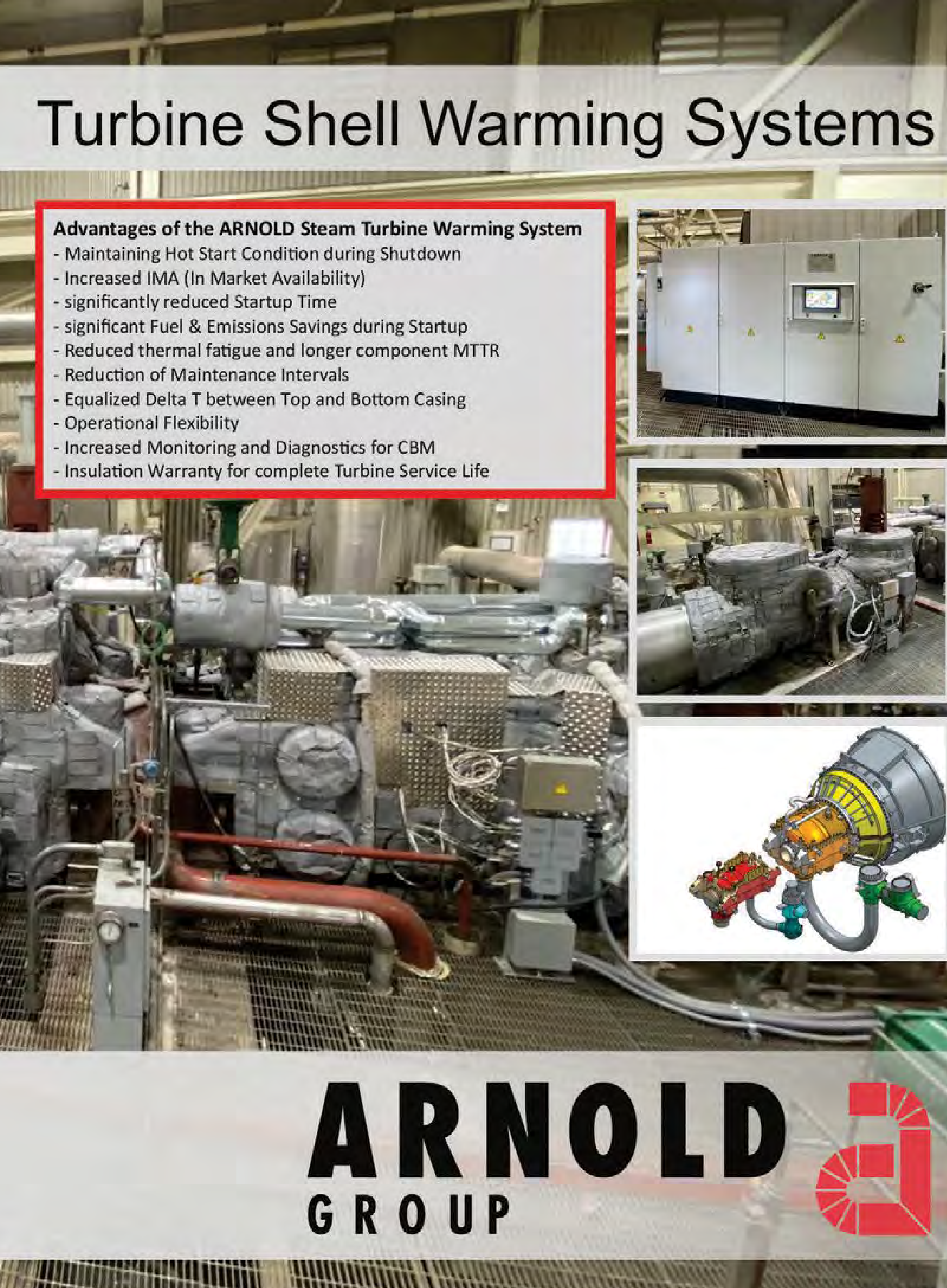
Advanced Single Layer Steam




Turbine Shell Warming Systems
Advantages of the ARNOLD Steam Turbine Warming System
- Maintaining Hot Start Condition during Shutdown
- Increased IMA (In Market Availability)
- significantly reduced Startup Time
- significant Fuel & Emissions Savings during Startup
- Reduced thermal fatigue and longer component MTTR
- Reduction of Maintenance Intervals
- Equalized Delta T between Top and Bottom Casing
- Operational Flexibility
- Increased Monitoring and Diagnostics for CBM
- Insulation Warranty for complete Turbine Service Life
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POWER USERS

2023 Annual Conferences

Omni Atlanta Hotel at CNN Center
August 28 – 31

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Low Carbon Peer Group

STUG STEAM TURBINE USERS GROUP

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Chevron

EthosEnergy

Filter-Doc Corporation · Memphis, TN
Filter-Doc
Combustion Turbine Inlet Services

K Machine Industrial Services
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Process Innovations
Process Plugins®

SIEMENS energy

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Sulzer Turbo Services

TTS Power

TAYLOR'S Industrial Coatings

STAR™
DEFENDING THE DESIGN CLEARANCE

Viking Turbine Services

BRONZE

CUTSFORTH
THE POWER OF INNOVATION™

PSM
a Hanwha company

GROOME
Industrial Service Group

IC Spares
Instrumentation & Control Spares

National Electric Coil

EMERSON.

PSG Power Services Group
Your Turbine Experts

Pioneer Motor Bearing

TOSHIBA

Technical Program at a glance

DAYS	CCUG	GUG	STUG
Monday, August 28	AM: Workshop on desuperheating and attemperation PM: User + vendor presentations, open discussion	AM: Workshop on endwinding support systems (GE, NEC, and Siemens-Energy) PM: User presentations on testing, inspection, and monitoring	AM: EPRI seminar on ST valve diagnostics, lube-oil testing, etc PM: User presentations, panel discussions
Tuesday, August 29	AM: User + vendor presentations PM: Vendor presentations	AM: Vendor presentations PM: Vendor + user presentations, roundtable	AM: Vendor presentations PM: Siemens Energy + vendor presentations
Vendor Fair, 5 – 8 p.m.			
Wednesday, August 30	AM: Siemens-Energy, HRST, and IAFD PM: GE Gas Power	AM: Siemens-Energy PM: GE	AM: MD&A and GE sessions PM: GE sessions
Thursday, August 31	AM: User presentations, open discussion PM: No sessions scheduled	AM: User presentations, open discussion PM: No sessions scheduled	AM: User presentations, roundtable PM: No sessions scheduled

PPCUG	Low Carbon Peer Group
AM: GE and Beamex PM: Training by ABB, GE (Mark VIe), and Process Innovations Labs	AM: No sessions scheduled PM: Technology updates on IRA, energy storage, and off-shore wind
AM: ABB, PSM, and Black &Veatch PM: GE	AM: Advanced geothermal and hydrogen updates by users, Siemens-Energy, and PSM PM: CCS and nuclear
AM: Siemens-Energy, HRST, and Emerson PM: Siemens-Energy, E+H, and MD&A	AM: LCPG Focus Group (users only) PM: LCPG Focus Group (users only)
AM: User presentations PM: No sessions scheduled	AM: LCPG Focus Group (users only)

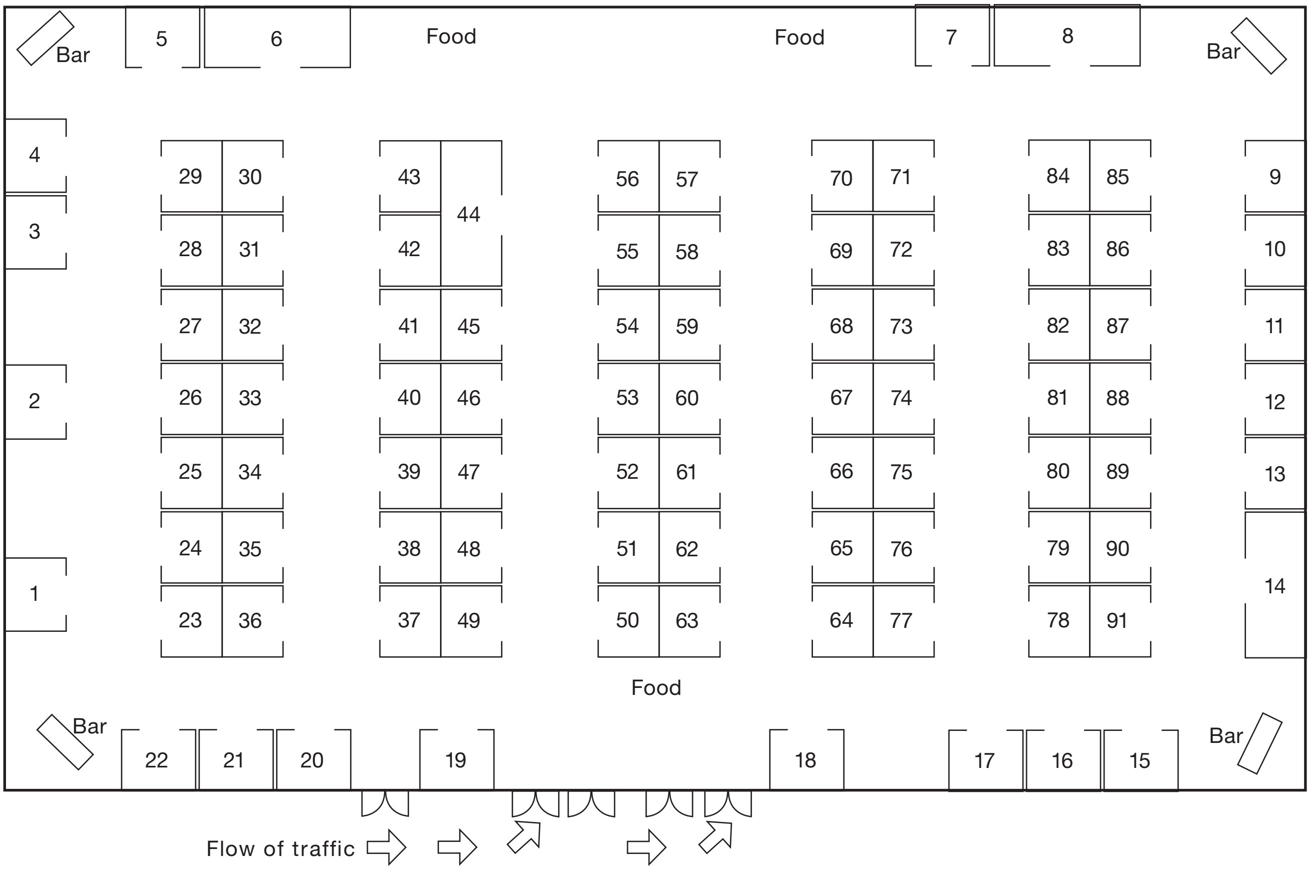
International Association for the Properties of Water and Steam

IAWPS is a global non-profit association involving 25 countries in all aspects of the formulations of water and steam and seawater, as well as in power-plant cycle chemistry. It provides internationally accepted cycle-chemistry guidance for power generation facilities in Technical Guidance Documents freely downloadable from the organization's website at www.IAPWS.org. Specific TGDs for combined-cycle/HRSG plants include the following:

- Procedures for the measurement of carryover of boiler water into steam.
- Instrumentation for monitoring and control of cycle chemistry.
- Volatile treatments for the steam-water circuits of power plants.
- Phosphate and NaOH treatments for the steam-water circuits of drum boilers.
- Steam purity for turbine operation.
- Corrosion-product sampling and analysis.
- HRSG high-pressure evaporator sampling for internal deposit identification and determining the need to chemical clean.
- Application of film-forming amines in power plants.

Vendor Fair

Tuesday, August 29, 5:00 – 8:00 p.m.



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Bosch Rexroth	64
Brush Services	35
C C Jensen	30
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Company	Booth no.
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Voith US	25
W L Gore & Associates	28
World of Controls FZE	12

Booth number order

Booth no.	Company
1	SVI/Bremco
2	Hexagon ALI
3	HRST
4	Sulzer Turbo Services Houston
5	Allied Power Group
6	Arnold Group
7	Gas Path Solutions
8	MD&A
9	Advanced Turbine Support
10	Durr Universal
11	Senior Flexonics Pathway
12	World of Controls FZE
13	Curtiss-Wright EST Group
14	GE Vernova
15	Emerson
16	Electromechanical Engineering Associates
17	EthosEnergy
18	Cust-O-Fab
19	Siemens-Energy
20	Marioff, NA
21	TG Advisers
22	PSM
23	Groome Industrial Service Group
24	Environex
25	Voith US
26	Riverhawk
27	PowerFlow Engineering
28	W L Gore & Associates
29	CRDX - Carbon Reduction Systems
30	C C Jensen
31	ORR Protection Systems
32	US Cleanblast/Premium Plant Services
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38	Hy-Pro Filtration
39	CleanAir Engineering
40	Rotating Equipment Repair
41	Alta Solutions
42	ABB
43	TTS Power
44	Doosan Turbomachinery Services
45	TOPS Field Services
46	Flange Bandit
47	Lectrodryer
48	Industrial Air Flow Dynamics
49	AGT Services
50	Shell Oil Products
51	Power Services Group
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53	BBM-CPG Technology
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60	Fluitec International
61	Macemore
62	Nord-Lock Group
63	Environment One
64	Bosch Rexroth
65	Process Innovations
66	Donaldson
67	Bearings Plus
68	Parker Hannifin
69	Cormetech
70	IC Spares
71	Electric Machinery - WEG Group
72	Hydralube
73	TesTex
74	National Mechanical Services
75	Rayker Mechanical Services
76	Beamex
77	K Machine
78	National Electric Coil
79	NRG Energy Services
80	Structural Integrity Associates
81	Mobile Excitation Services
82	CFM/VR-TESCO
83	Dekomte de Temple
84	Millennium Power Services
85	Filter-Doc
86	Taylor's Industrial Coatings
87	Rochem Technical Services
88	Engineered Pump Services
89	Sidewinders
90	Precision Iceblast
91	Pioneer Motor Bearing

RECAP: Safety top of the mind at the 2022 Combined Conference

The 2023 edition of the Power Users' Mega Event—incorporating the annual conferences of the Combined Cycle (CCUG), Steam Turbine (STUG), Power Plant Controls (PPCUG), and Generator (GUG) Users Groups, plus the Low Carbon Peer Group—is only a couple of weeks away (August 28-31, Omni Atlanta Hotel at CNN).

Don't miss what many users believe is the industry's most comprehensive conference/vendor fair and networking opportunity for supervisory personnel, engineers, and technicians involved in plant operations and maintenance. Gas and steam turbines, generators, HRSGs, control systems, and emissions controls are all high-profile presentation/discussion topics on the agendas of the five participating groups.

Recall that a ticket to any of the user-group meetings gives you access to all. Meals and vendor fair are joint activities.

Keep up on program developments by visiting www.powerusers.com to review current agendas. A mobile app is available onsite to advise attendees on last-minute agenda updates (details at the registration desk).

CCJ's highlight reel from last summer's meeting, which follows, offers the opportunity to evaluate the depth of content you can expect at this special event.

The confluence, in one hotel in San Antonio, Tex, of knowledge, experience, and expertise on how to keep the nation's aging gas-turbine-powered generating facilities operating in the face of shoestring budgets, supply-chain disruptions, and labor shortages, was perhaps unprecedented.

Over 350 users participated, with a slightly higher number of vendor representatives.

Critical condenser safety event

If you never thought a condenser could explode (as opposed to over-pressure), don't feel bad. Neither did most of the attendees in the CCUG session listening to a representative from a major Texas utility explain how it happened at one of their combined-cycle plants.

If you operate a plant with a "performance" fuel-gas heater (FGH) taking heat from the water/steam cycle (in this case from the intermediate-pressure circuit), you will most certainly want to review this presentation and consider the recommendations arising from the utility's fleet assessment of this situation.

Like most catastrophic (or potentially catastrophic) events, several unique factors had to align, as detailed in the HRSG Forum session covered in CCJ No. 72, p 42. Above all, the plant was in an abnormal outage during which the ST/G was forced out of service, and the GT/Gs were maintained in "ready" mode for the grid, meaning that fuel lines were at pressure up to the emergency stop valves.

Other factors included, but were not limited to, a leaking FGH isolation valve; plugs in the tubing of the FGH shell-and-tube exchanger having fallen out; the pressure drop across the FGH pushing natural gas into the water/steam circuits, then through the drain lines terminating at the condenser; and others.

You have to review the referenced article to fully appreciate the details behind the factors which ultimately led to a buildup of natural gas in the condenser over an 11-day period to a percentage between the lower explosive limit (5%) and the upper explosive limit (17%).

When a welder struck an arc to replace a 1-in. drain line on the condenser's outside wall, an explosion occurred followed by a shock wave felt across the facility. The welder was not required to test for presence of combustibles because the hot work was outside the condenser.

Thankfully, no injuries occurred, no condenser tube leaks resulted, but six overpressure rupture disks on top of the condenser blew out and landed across the facility (one narrowly missing a worker), there was major damage to some structural steel inside the condenser, and the low-pressure turbine cover lifted 6 in. when bolting threads failed.

The bountiful list of after-event recommendations range from identifying all vessels where gas can accumulate to reassessing FGH design, especially the need for bypass valves.

Catastrophic arc-flash event

Also at the CCUG, a representative from a 750-MW, non-utility combined-cycle plant in the Northeast reported on an arc-flash event with the 230-kV line into the plant, which resulted in a 10-in. hole in the ground when it hit below, and the loss of ac power to the plant.

With no black-start capability, the relatively inexperienced crew onsite (and an operator in the control room who had "just qualified") at the time had to get the emergency diesel/generator (EDG) online and synchronized, a process which should have taken three minutes but ended up taking 15.

The arc-flash event occurred when someone at the facility next door, a large warehouse operation, used a man-lift to replace a bulb on an outdoor light pole/fixture under the transmission line. It was discovered later that the neighbor firm had no plan/procedures in place for work near an energized line.

Miraculously, the worker on the lift was not harmed. Nor was the person from the fire department who responded to the emergency and used the truck ladder to rescue the person on the lift. He performed this without knowing whether the line was energized or not. There was no collateral damage to the combined cycle.

Again, a confluence of factors had to line up for this event to occur. One was the fact that the normal power feed breaker did not open on loss of ac power, which meant that the EDG could not synch to the 480-V bus. The plant revised the procedure for EDG ops to include what to do if the normal power breaker does not open, and simplified what was previously a confusing EDG control scheme layout.

The light poles under the line have been removed, a physical barrier has been installed 20 ft off the centerline of the overhead line, and warning signs were hung along the fence line adjacent to the T line. All pre-job briefs now include a discussion of hazards associated with work near the 230-kV line.

Turning gear: Achilles heel?

Meanwhile, over at the STUG meeting, a utility expert noted that the steam turbine/generator's turning gear (TG) could be a "pinch point" for ST/G reliability in plants that are starting and stopping more frequently to follow renewables. The utility had experienced a catastrophic failure of a TG motor caused by imbalance and a spare motor was not readily available.

It's easy to forget that, in many cases, the TG probably was designed to operate perhaps 10 times a year, but under future operating scenarios, this person noted, that could increase to 500 or more (yes, multiple starts per day). Having the requisite spare

parts in inventory or readily accessible is advisable, or perhaps even a motor in stock that could fit several different units.

Also, good to distinguish the number of hours the TG operates versus the unit itself and plan/adjust maintenance and spares accordingly.

The presentation slides under the STUG tab at www.powerusers.org are replete with descriptions of different types of TG units and drive motors, photos of failure mechanisms, and recommendations for safety, spares strategy, and inspection procedures and frequencies.

Control-system supply chain

Attendees in the PPCUG room wrestled with serious supply-chain challenges. Among them: Extending the use of processors slated for obsolescence because replacements are not available, "allocations" (read, rationing) of CPUs (central processing units) for specific families of controllers, lead times which have been extended by 50% to 100% since 2019 for many components and systems, and plants having to postpone and reschedule control system upgrades and other work, with suitable incentives and discounts offered, to ease the pressure on OEMs.

Thankfully, these issues have caused one control-system supplier to change its procurement system which the OEM presenter acknowledged was "not that sophisticated." For one thing, they relied on too many single-source suppliers, one of which, in another admission, was their own company. Today, the OEM has visibility into its sub- and sub-sub supplier network, or what he termed "digital surveillance" of the supply chain, and could more appropriately forecast delivery times and/or problems.

Generally, control-system specialists expect these challenges to last at least another 18 to 24 months.

Briefs

The Power Users highlights reel also included the following:

- Owners are now seriously studying the impact on performance of extracting significant quantities of low-pressure steam for a carbon-capture process on the premises.
- A utility operator said they were entering a "no man's land" with respect to the hours some of their units were running. "How do we instrument these assets for safety and reliability and feel better" about operating them, he asked?
- Cold-weather action items are tracked and managed by one utility's power operations center, a centralized M&D facility, serving most of the assets in the fleet, as regulators like Ercot and NERC issue new winterization rules and standards.
- Steam-turbine valve maintenance is being neglected at too many plants, said one consultant. Contrary to popular belief, grit blasting does not remove oxides, which are responsible for 80% of valve sticking problems.
- The travails of designing and periodically testing (twice annually) a black-start plant with an 850-Vdc, 13.7-MW, 3.4-MWh battery unit starting a single GT/G in California was discussed by a major non-utility owner/operator.
- An OEM updated the GUG audience on a new robotic wedging technology designed to re-tighten wedges faster and without wedge removal but does require a "rotor out" outage and about a shift's worth of time to install.
- Another ST/G OEM, in a STUG session dedicated to recent service bulletins and top issues, said his firm is now recommending that all ST/Gs undergo annual last-stage blade inspections and that they are discovering "numerous and surprising" indications in critical locations of HP and IP shells in units 15 to 20 years old. CCJ

COMBINED CYCLE USERS GROUP

The 13th annual meeting of the Combined Cycle Users Group, launched in San Antonio in fall 2011, is a cornerstone of Power Users' 2023 Combined Conference in the Omni Atlanta Hotel at CNN Center, August 28 – 31. Coverage of the group here is in two parts: 2023 conference overview and 2022 conference report.

2023 conference overview

Technical program for the upcoming meeting was developed by the all-volunteer steering committee of engineers and managers identified in the sidebar and accompanying photo—many with decades of relevant experience. A preview of the presentations scheduled for the week beginning August 28 follows.

Most sessions are *user only*. Non-users wanting to participate must be approved by the steering committee to gain admission. Presenting vendors are allowed in the room only when it is their time to present.

Expectation is that most of this year's presentations will be made available to owner/operators through the Power Users website a few months from now. Slide decks from 2022 and earlier meetings already are accessible to registered users. If you are not registered, sign up now at www.powerusers.org: It's easy and there's no charge.

Monday, August 28. The CCUG technical program begins in earnest with a three-hour workshop (9 a.m. to noon) on "Mastering Desuperheating and Attemperation." Ory Selzer of IMI Critical Engineering covers physics and design evaluation before moving on to application-specific challenges in HRSG, turbine bypass, and auxiliary systems.

The afternoon session includes a roundtable on lessons learned from LOTO events followed by presentations on film-forming amines, turndown or shutdown: combatting the effects of increased cycling, and hydrogen as a fuel for gas turbines.

Tuesday, August 29. Morning session starts with a roundtable on preparation for, and operation during, extreme hot weather and concludes with an EPRI presentation on process chemistry in combined-cycle plants. In between are user presentations on DCS replacement (Where do you start?) and high dewpoint in generator hydrogen, and vendor presos on the use of water-mist fire suppression systems to replace CO_2 and enhanced SCR and CO system management to meet today's operational challenges.

The afternoon features the following:

- A roundtable on human and organizational performance.
- Supply-chain mitigation.
- HRSG roof liner and casing problems, why they occur, and repair options.
- Gas-turbine SCR in a changing world.
- Effects of cyclic operation on superheater link piping and manifolds.

Tuesday ends at 5 when the three-hour Vendor Fair begins.

Wednesday, August 30. The morning session opens with "Duct Burner Issues and Flame Monitoring" by HRST, followed by these presentations from Siemens-Energy personnel:

- Plant flexibility and integration with intermittent generating assets.
- Lessons learned on large forced outages.
- Asset management in an evolving market.
- Short-term layups.

Note that presentations by Siemens-Energy are not available through the Power Users website. Access them via the company's Customer Extranet Portal at https://siemens.force.com/cep.

Amy Sieben of Industrial Air Flow Dynamics closes the morning program with "HRSG Drum Inspection."

Wednesday afternoon is all GE Gas Power. The presos are available only at https://mydashboard.gepower.com:

- Plant assessments for life extension.
- Transformer maintenance planning.
- Recent experience on water-chemistry challenges and FAC on in-service HRSGs.
- Benefits and methods of improving combined-cycle plant start time.

Thursday, August 31, the final day of the conference is morning-only. Two roundtables are on the program: Lack of skilled craft workers and how that can affect your maintenance outages, and Post-outage checklists—lessons learned. Remainder of the morning program will be filled by user presentations, not finalized at press time.

CCUG steering committee, 2023

Chair: Brian Fretwell, director of mechanical services for engineering and major projects, *Calpine*

Vice chair: Robert Mash, plant manager, *GE Power Services, River Road Generating Plant*

Phyllis Gassert, program director for operations excellence, *Talen Energy*

Steven Hilger, PE, plant manager, *NAES Corp, Dogwood Energy Facility*

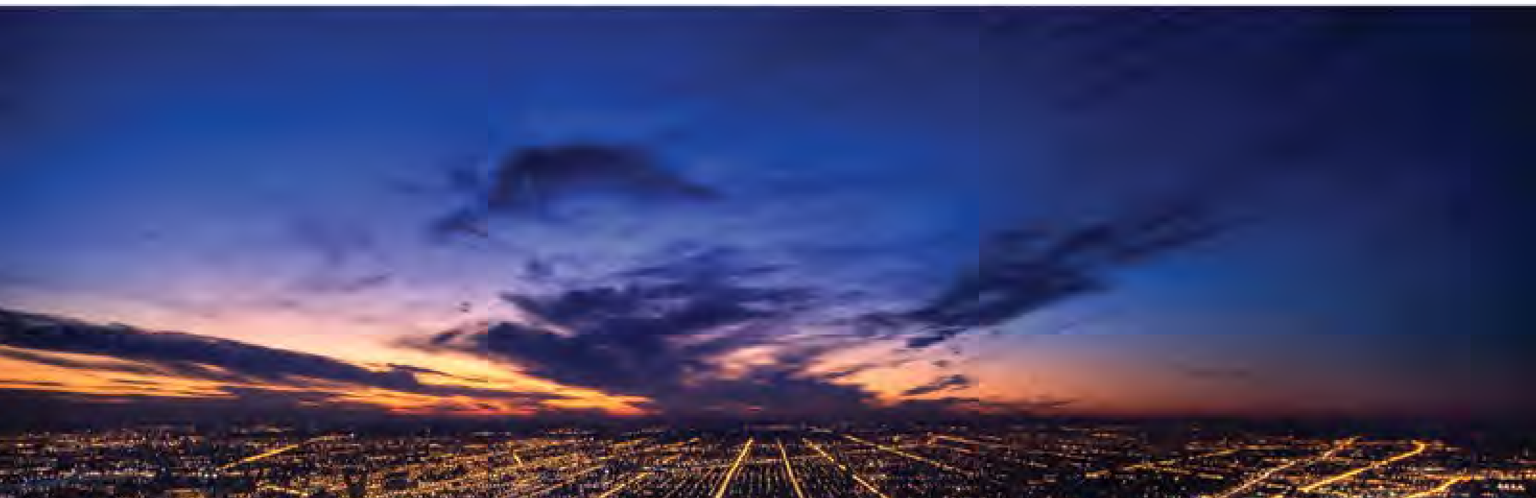
Jason Jauregui, production team lead, *CAMS, Woodbridge Energy Center*

Aaron Kitzmiller, PE, plant engineer, *Luminant, Fayette Power Plant*

Jonathan Miller, maintenance manager, *CLECO, Arcadia Power Station*

Ben Stanley, VP operations, *Consolidated Asset Management Services*

CCUG steering committee. Front row (l to r): Brian Fretwell, Phyllis Gassert, Robert Mash. Back row: Aaron Kitzmiller, Jason Jauregui, Jonathan Miller. Camera shy: Steven Hilger, Ben Stanley



2022 conference report

The Combined Cycle Users Group (CCUG) conference (San Antonio, Aug 29-Sept 1) once again served up an annual in-depth review, analysis, and most importantly, the conference's hallmark of user-led discussions, on leading issues affecting combined-cycle facility owner/operators.

The longer summaries below are based on notes taken during what CCJ considered some of the most relevant to the wider industry community. Shorter capsules are based on *available* slide decks located at www.powerusers.org. Those seeking deeper dives into specific topics should note the presentation titles listed at the end of each summary and access the source material on the website.

Get up to speed on vibration

Samuel Starnes, Reliability Testing Services Inc, kicked off the CCUG training session on the first morning of the meeting with a 117-slide tutorial on vibration analysis which included as sub-topics three units of measure (acceleration, displacement, velocity); location and mounting of probes (Fig 1) and sensor selection; data collection, quality, trending/alarming, analysis, and reporting; common machine faults; and case studies. If you prefer not to read a text book on the subject, this will serve as a substitute.

"CCUG Training Session: Basics of Vibration Analysis"

Online HRSG inspection links offline inspection, maintenance

Amy Sieben, I.A.F.D., advocates for combining external thermographic inspections of HRSG casing, penetrations, and doors (Fig 2), and internal "inspection" by monitoring control room parameters and basic HRSG design parameters—including pinch points, approach temperatures mass flows, pressures, and others.

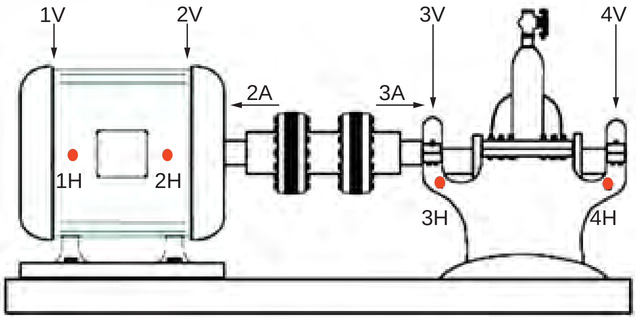
Identifying where performance is off helps you prioritize where to place attention during the outage. By doing both external and internal inspections consistently, and combining with offline inspections during the outage, you can also track drifting performance year to year and ensure better maintenance outcomes. At the heart of Sieben's strategies are fundamentals of HRSG design and operation, for those less seasoned.

"Online Inspection—Tying Offline Inspection and Maintenance All Together"

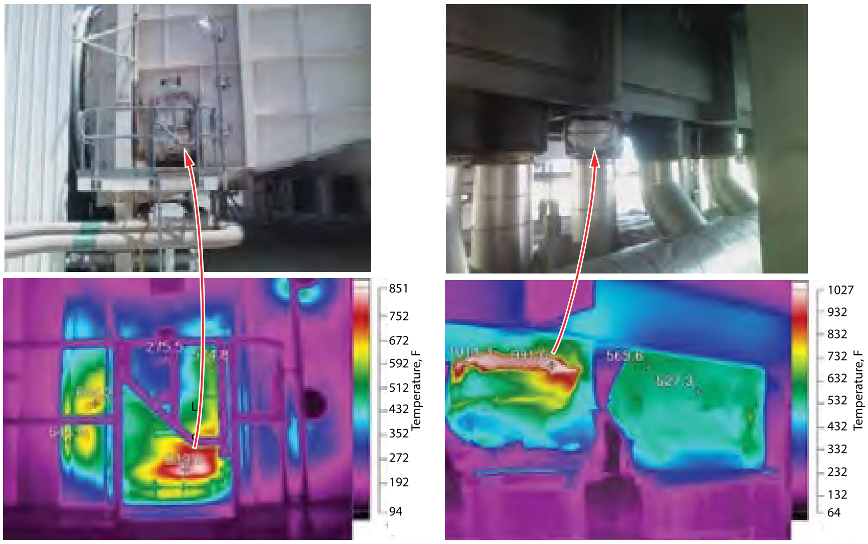
Winterizing, cold weather prep

Recent cold weather grid-wide events in Texas and the Northeast have prompted renewed interest in, and regulation of, formal winterization programs and plans. This Texas owner/operator tracks and manages fleet-level winter readiness action items through its centralized power optimization center (POC), with each plant having specific checklists. The POC is considered "an edge" other owner/operators may not enjoy.

Although, in response to an audience question, the presenter said not much new M&D hardware was added



1. Basics of vibration analysis, a 117-slide tutorial, covers key topics and is a valuable refresher for plant personnel. Presentation is crisp and easy to understand, as the sensor location diagram for the pump illustrates



2. Thermographic analysis of access door (left) and expansion joint (right) clearly indicate where potential problems exist

3. Cold-weather events in the South in recent years have focused attention on powerplant winterization. A user presentation showed steps taken by one power producer to mitigate the effects of severe cold snaps—transmitter and instrument enclosure at the left and transmitter enclosure at the right



(some "smart" heat-trace panels mostly) at the plants (Fig 3), though some of the M&D capability at the center was enhanced. There are now five stages of "alerts" generally based on ambient temperature forecasts. An Emergency Operations Center is located adjacent to the POC, where tabletop scenario exercises are conducted annually. "There are lots of winter PM work orders to comply with regulatory requirements," the presenter said.

The editors consider this a must-view slide deck for all personnel at plants facing new NERC, FERC, ISO, and/or fleet-level requirements, especially those sites with outdoor steam turbine/generator decks.

"Winterizing at Luminant"

Repair versus replace: P91 non-return valves

Bill Kitterman, Bremco, and Will Medlock, SVI Industrial, take you on a virtual onsite and in-shop tour of a non-return P91 valve replacement, followed by an in-situ seat repair for the same type of valve. Seats are not replaceable but can be refurbished (Fig 4). Valve repair can be up to 90% less expensive than a full valve replacement. Keep in mind that a valve repair of P91 material does require regular post-weld repair inspections based on accepted methods of examination until end of life or when the component is replaced.

"Case Study on Repairing versus Replacing P91 Non-Return Valves"

New HRSG inspection tools available

Shawn Gowatski, TesTex, updated attendees on three new HRSG inspection tools developed with EPRI funding:

- Low Frequency Electromagnetic (EM) Technique (LFET) to inspect finned tubes typical of economizer and evaporator sections from the outside surface for pitting and generalized wall losses.
- The "Claw," capable of inspecting the 360-deg circumference of tube-to-header welds in the first two rows of accessible superheater and reheater tubes using the Balanced Field EM Technique (BFET).
- HRSG Internal Access Tool (Fig 5) with a remote-controlled crawler used to insert an RFET (Remote Field Eddy Current) probe into headers 6.5 in. diameter and larger to inspect evaporator and economizer section tubes from the inside

Reams of testing and support data are available in the slides.

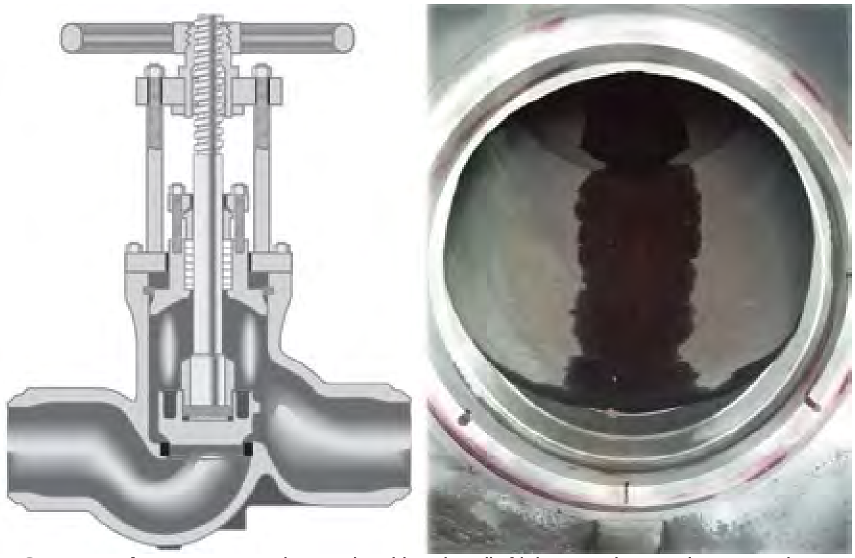
"HRSG Inspection Tools"

Perfect storm, but the lightning was arc flash

When someone lists operator error, equipment failure, instrument failure, hardware and software issues, and acts of God/nature as causes, you know the plant had a bad day. In fact, "perfect storm" doesn't do justice to the human and equipment failures which preceded the potentially catastrophic arc-flash event on the 230-kV transmission line at an outdoor plant in the Northeast with no black-start capability.

Fortunately, no one was injured—just a 10-in. hole in the ground below the T-line (Fig 6)—and there was no collateral damage to the plant but the ensuing outage lasted more than half a day. But the industry should be collectively grateful that these are the kinds of good people who volunteer to present at CCUG to help others learn from their experiences.

An accident at the commercial warehouse facility next door caused the loss of the T-line when a worker



4. Seat repair. Non-return (stop-check) valve (left) has an integral seat and hard-face overlay, meaning the seat must be refurbished in-line. When the inspection team guided by the plant's PM plan identifies what it believes is a crack, and a dye-penetrant exam confirms same (right), seat replacement should be scheduled for the next outage. That involves machining out the Stellite seat material (normally removing 0.125 to 0.250 in. of material) and doing a second dye-pen exam to confirm the crack has been removed. Such a valve repair typically costs about 15% of a replacement valve (installed)

5. Internal access tool (left), remote-controlled, inserts eddy-current test probe into headers 6.5 in. diameter and larger to inspect HRSG evaporator and economizer tubes from the inside. Tool is managed by computer, game-box-like controller, cable reel, and electronics package at right, located below the header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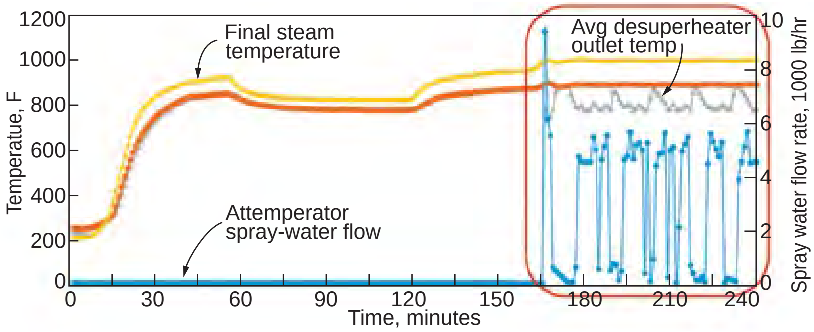
6. Arc-flash event on a 230-kV transmission line punched a 10-in. hole in the ground below the line



7. Plant interested in improving reliability turned to data analysis for help. In this case, the analytical effort revealed attemperator hunting, or the rapid modulation of HP-attemperator spray-water flow during starts, as an area for improvement

8. Typical factory test stand to evaluate pump performance

on a manlift was attempting to change out some street lighting bulbs near the line. Operator and crew, who had just recently qualified in the powerplant control room, made some errors (not helped by unclear procedures) starting the emergency diesel/generator (EDG) and a three-minute sequence turned into 15. But the normal feed breaker had failed to open on loss of ac power, so the EDG couldn't synch to the 480-V bus. The list goes on.

The recommendations following this event are a veritable safety minute expanded. Among the measures taken here:

- Install physical barrier 20 ft on either side of the T line with hazard signage.
- Revise procedures to include what to do if the normal power breaker does not open.
- Change EDG controller layout to eliminate sequence confusions.
- Remove light poles under the T-line.

"Plant Trips and Lessons Learned"

40 is the new 30—extending the life of your HRSG

The primary message delivered by Anand Gopa Kumar, HRST, is that the life of an HRSG can be extended to 30+ years, and even up to 40, with good O&M practices driven by data analysis. Kumar reviews HRST's assessment process, then applies it in several case studies focused on (1) impacts from attemperator hunting as illustrated in Fig 7, (2) HP-evaporator feed pipe stress, (3) creep life assessment of an HP superheater, and (4) recurring and economizer failures. Findings are ranked based on priority and a criticality score of 1 to 100.

"HRSG Life Extension and Long-Term Planning: A Data Driven Approach"

Remediate, rather than replace, turbine oil

Recent test results suggest, according to John Hayes, Lubrication Engineers Inc, that sites with turbines experiencing lost demulsibility and other degradation factors of Group I and II lubricating oils can remediate it by displacing the original volume of oil with Group I oil at 5-20%, rather than completely replacing it or using expensive additives. Other slides comprise a quick tutorial on types of lubricating oils and performance impacts from degraded oil.

"Group 1 Turbine Oil, A Return to Reliability"

Is your CO catalyst impairing your NO_x catalyst during turndown?

NO_2/NO_x ratios higher than 50% lower catalyst performance, high NO_2 levels are typical during load turndown and startups, and CO catalyst can increase the NO_2/NO_x ratio by converting NO to NO_2. Andy Toback, Environex Inc, uses two case studies to show how NO_2 levels change with load and fired or unfired HRSG conditions. Conclusion is that CO catalysts designed for high VOC (volatile organic compounds) conversion, attributed to conservative design VOC levels submitted by turbine suppliers, exacerbate the NO_2/NO_x levels. However, some catalyst formulations are available which convert less of the NO to NO_2.

"Is Your SCR/CO System Ready for Turndown?"

Field testing, remote monitoring of critical pumps

Pump performance degrades over time as components wear and clearances erode. So you should periodically field-test your critical pumps at full-load conditions (Fig 8), advocates Jay Marchi, ProPump Services LLC, to optimize efficiency, identify issues, plan for maintenance, and keep availability high and costs at a minimum. New technologies are available for field testing and assessing pumps and drivers, and "they are only going to get better." Users experiencing loss of expertise or budget pressures should also consider remote monitoring to "bring the experts to your rotating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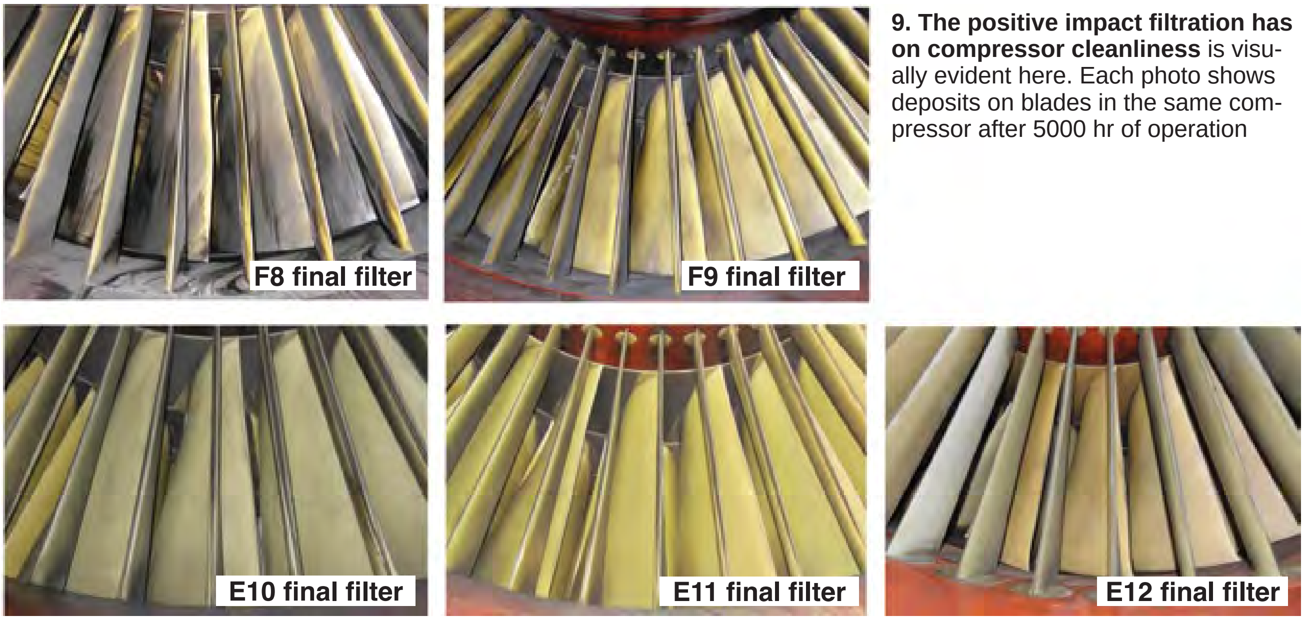


9. The positive impact filtration has on compressor cleanliness is visually evident here. Each photo shows deposits on blades in the same compressor after 5000 hr of operation

equipment."

"Advantages of Periodic Field Testing of Critical Pumps"

High-energy piping now requires more 'energy' from users

The 2007 ASME B31.1, addressing high-energy piping systems, was updated in 2020 and includes more detail and entirely new sections, written O&M procedures, and requirements for documenting operating hours, modes of operation, temperatures, pressures, transients, and much more, observes Amy Sieben, I.A.F.D. Sites also need to record weld examinations, hanger inspections, and NDE inspection results. Piping upstream and downstream of attemperators should also be included because "it is the most highly fatigued piping in the entire plant." If you are still working off of the 2007 version of the code, Sieben's slides are a must-view.

"B31.1 Covered Piping Systems Requirements and Hanger Inspections"

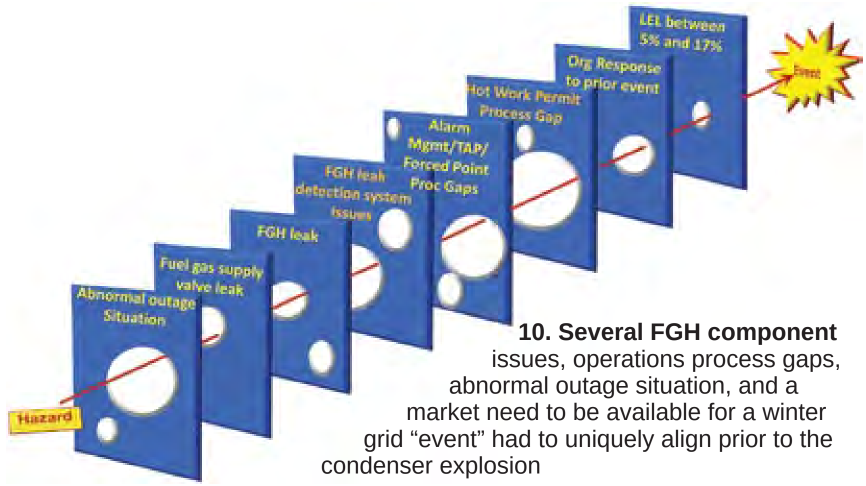
Up your game in filters

By no means should users think that an E10 final filter is "the maximum filter class" for a gas turbine, says Florian Winkler, EMW filtertechnik GmbH. Winkler illustrates his message with extensive ISO 29461 test data comparing E10, E11, and E12 HEPA filters running on a W501F gas turbine for 5000 hours (Fig 9) for a range of parameters. "Better filtration always pays off," he concludes.

"Better Filtration Pays for Itself – The Impact of (H)EPA GT Filters"

Condenser explosion? Yes, you read that right

During an abnormal plant outage, and precipitated by faulty fuel isolation valves, natural gas accumulation in the steam turbine/generator condenser led to a catastrophic explosion which rocked a 2 × 1 501G combined cycle in Texas but fortunately did not injure or kill anyone, and caused only minimal equipment damage.



10. Several FGH component issues, operations process gaps, abnormal outage situation, and a market need to be available for a winter grid "event" had to uniquely align prior to the condenser explosion

Before this event, no one at the plant imagined that fuel gas could build up inside the condenser. And if you can't either, you owe it to yourself and your colleagues to view the slides.

One of the unique aspects of the 11-day outage was that the gas turbines were being held in a state of readiness to support the grid during a period of extraordinary demand. That meant

Self-imposed duct-firing temperature constraints by operators

- Up to 20 MW per unit could be recovered
- Even a 10% recovery per unit could mean over $1.6 million annually

Industry cooling-tower issue causing condenser to underperform

- Cooling water 3-4 deg F high, resulting in loss of 1.3 MW and 9 Btu/kWh per unit
- Potential annual loss is greater than $600k

Hidden problem with inlet fogging in two units was reducing plant output

- Additional 2 deg F of inlet cooling recovers 3.5 MW and 72 Btu/kWh per unit
- Potential annual loss is greater than $600k

Slow degradation in turbine performance during peak generating season

- Generating loss of 2 MW and 200 Btu/kWh attributed to infrequent water washing
- Left unchecked, this would have amounted to an annual loss greater than $300k

11. More than $3-million of potential value was identified through the thermal performance audit of a 4 × 2 highly flexible combined-cycle plant, over half extracted immediately (via duct firing) or pretty quickly (via fogging)

12. Valve overhaul to identify issues requiring correction begins with dismantling and thorough inspection of parts (left). Typical repairs include correcting wear and tear of seats, discs, and /or stems caused by iron oxide that has exfoliated from boiler tubes and steam piping (right). The solid-particle erosion shown occurred in fewer than 20,000 operating hours and 35 starts

fuel-line pressure was being maintained up to the fuel-gas heater (FGH) valves. Unbeknownst to the plant staff, one or more of the heat-exchanger tubes were not plugged sufficiently, the heater's fuel leak detector wasn't working properly, and the isolation valve leaked (Fig 10).

When a welder came to repair a 1-in. line on the outside of the condenser, the arc ignited the fuel in the condenser, six rupture disks on top of the unit blew out (and were later found strewn throughout the plant site), bolting holding the center LP turbine cover failed and the cover lifted about 6 in. The truly unfortunate factor in all this was that the fuel gas accumulated to within the relatively narrow explosive limit range of 5% to 17%.

This presentation should win an "all conference" award, not only for the clarity of the content but the owner/operator's subsequent efforts to ensure that the learnings permeate the industry. The must-view slide deck will be especially instructive for anyone at plants with gas performance heaters getting the heat from the HRSG's IO water supply lines.

You'll be rewarded with a cogent list of a relatively large number of fleet-wide recommendations being undertaken by the owner/operator, which are then tailored to each individual plant—surely an excellent starting point for the many other plants with similar design features.

"Condenser Explosion Event"

13. "Ready cards," a modern version of the "flash cards" you may remember as elementary-school spelling and arithmetic aids, are useful for conducting "two-minute" drills to keep safety and project goals aligned in the minds of personnel before work begins

There's gold in them thar gaps!

Hidden value can be unlocked through a thermal performance audit and addressing gaps to restore performance, stressed Jeff Schleis, EthosEnergy. Case study results reveal valuations from $300,000 to $1.6-million annually (Fig 11) by undertaking the modest actions recommended in the report issued to the client. Assessment is based on interviews with plant staff, six months of operating data (with remote access to the historian), and plant design data.

"CCGT Performance Is Key to Net Zero"

ST/G valve issues, repair strategies

If you have main steam valves approaching three to five years in age, or 25,000 hours of operation, MD&A's minimum recommendation for inspection and repair, you owe it to yourself to view these slides presented by Dale Gould and Dean Casey. This is especially true if you are past the first five years of plant operations, when valve issues begin to rise. There are no industry or independent maintenance practices, only OEM guidelines, for these valves in combined-cycle facilities, making presentations like this one even more valuable.

Generally, inspection and repair are targeted at: restoring clearances to OEM specs—such as bushing removal and replacement, hardened inserts, and scale removal; achieving concentricity, so that the valve operates precisely on its centerline; sealing and resurfacing to ensure no steam cutting; and attending to foreign-object barriers, such as strainer baskets. Case studies replete with photos drive home main points.

"Steam Turbine Valve Common Issues"

HGP parts—understanding, mitigating risks

All hot-gas-path (HGP) components for life extension have associated risks, Mechanical Dynamics & Analysis's Jose Quinones, stressed, whether they are OEM new, OEM repaired, third-party repaired, third-party new, or originating from other users. His overriding message is that there are options to evaluate and mitigate these risks, illustrated with "quick" case

VIKING VESSEL SERVICES
introduces the
TUFF TUBE TRANSITION
(US National and International Patent Pending)

Viking Vessel Services presents a new, innovative process, called the Tuff Tube Transition, or TTT (Patent Pending). The TTT is a sleeve type connection for tube-to-tube & tube-to-header repairs, and new ASME Section I header assemblies and stubbed headers. The TTT eliminates costly open butt welds and the need for a back-purged system during welding.

High Alloy Tubes repairs, using a grade such as T91, require purging when the system cannot be blocked, and are conventionally dammed on each side of the butt weld. A football needle or gas lens is placed up to the open gap in the butt weld, and with a conventional repair, this is the only line of defense for shielding. If oxidation occurs due to a lack of backing gas, this discontinuity can render a crack in the root, and will ultimately cause service failure. Our TTT does not require ANY back-purging on ANY alloy, for both repairs and new header assemblies.

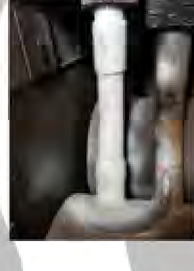
The TTT eliminates the need for Non-Destructive Testing, such as RT (or Radiographic Testing). On a recent job with over 150 tube-to-tube tie-ins, utilizing T91 grade tube materials in the HP (or High Pressure) Section of the HRSG, an RT examination performed both before and after Post Weld Heat Treatment, would have required over 300 RT shots for soundness in a conventional repair. The TTT drastically reduces the cost for this activity and also the downtime for safety precautions involved with the use of Radiographic Testing. In conjunction with the time saved by eliminating RT , in this particular case study, production time was reduced from 2 weeks to just over 2 and half shifts, and with an average weld fit up time of 20 - 25 minutes per tube-to-tube tie-in.

The TTT's self- fit-up and alignment, allows for a faster and more reliable joint alignment. With T91 tube material for example, conventional butt welds require time-consuming fit-up alignment equipment, as T91 material needs to be at a 400 to 450 degrees Fahrenheit pre-heat temperature prior to any thermal activities, such as tacking and welding. With the TTT being a secure fit-up, a simple clamp can be placed, which does not interrupt the thermal pads providing pre-heat, which are wrapped around the component. This gives the user the added advantage of not having to also hand lay out bevels or utilize mill-hogs for fit-up.

Research points to the vast majority of tube failures being in the Heat Affected Zone of the weld toe in the tube-to-header connection. The thermal expansion difference between tube and header is causing the tube to literally pull away from the header, or induce a fatigue crack, causing the service failure in the tube connection. Based on FEA Analysis performed on both conventional and TTT lines, the TTT demonstrates a far stronger, and more durable connection. Due to the design of the TTT line of products, the TTT has a 50-75% increase in service life and cycle fatigue durability, compared to conventional connections.

In a nutshell, The TTT provides a far better connection, is significantly easier to install during a repair situation, and enormously increases the life expectancy before another repair is required. There is a **minimum** of 50% cost savings over conventional repairs by utilizing the TTT for repairs or new header assemblies.




studies showing how three third-stage blades from three different GT models were assessed, and how two led to successful life extension and one (not cooled internally) did not.

"Unintended Reliability Risk Through Part Replacement/Obsolescence"

A fresh approach to safety

No one argues that safety is paramount in industrial work spaces. However, some safety programs are demonstrably more successful than others. MD&A's Matt Barnes gave the CCUG audience the benefit of his company's program focused on (1) positives rather than negatives, (2) people as the solution and not the problem which has to be controlled, and (3) safety as an ethical responsibility, not bureaucratic accountability to the higher-ups. The results he presents are worth a look.

These four simple principles anchor the effort:

- Focus on a few things that really matter and do them well.
- Push organization learning and risk reduction more than compliance.
- Tell employees "what to do" less, "what they need" more.
- Focus on and measure the capacity to work safely.

"Extended Safety Discussion"

Black start using battery technology

Black-start grid support was added to this 2013-vintage 2 × 1 combined cycle in the Bay Area. Main goal is to get one of the state's nuclear plants back online as soon as possible. This is reportedly the second F-class gas turbine site with battery black start (the first is in Louisiana) but the first at a combined-cycle facility.

You can probably imagine all the special regulatory requirements, especially for air emissions, but some of the practical considerations are worth noting, mostly focused on the limited energy that a battery can provide. In addition, this plant has to conduct functional readiness/emergency tests twice annually, and one fully black-start test every three years by Cal ISO, without violating air permits.

The 13.7-MW/3.4-MWh/850-V dc batteries supply an instantaneous load of 12 MW to get one gas turbine/generator to 184 MW. Once the turbine/generator is synchronized to the grid, you "can't go back." Things have to start quickly, the presenter noted. Capacitors have to energize big equipment like boiler feed pumps and fuel-gas compressors (gas feed line pressure is 250 psig but the turbines require 500 psig). Another wrinkle: Batteries have to be fully charged at all times, limiting their life to five years.

"The GT synchronizes through its 230-kV line so we had to get creative about how to do that," the presenter said.

"Battery Connected as a Black Start"

What's keeping your insurance guy up at night?

It's been a bad past decade for insurers and in recent years the power industry hasn't been helping. That's the implicit message delivered by Chris Black, Lockton Companies, who cautioned the audience that insurers will be paying very close attention to steam turbine/generators for which insurers (and owner/operators) have suffered "an unprecedented number of major losses."

Specific areas for added scrutiny include avoiding the worst-case scenario, which Black describes as a lube-oil system fire with ST/G overspeed and subsequent fire; overspeed trip testing, sequential trip validation; dc lube oil system design and testing; valve maintenance and testing; and frequency of maintenance.

Black also touched on lingering issues with gas turbines, transformers, hydrogen fuel supply systems, winterization, supply chain, and battery systems. Another cautionary word: "Your word is not always good enough—you will need proof."

"Insurance Hot Topics"

Two aux transformer failures, one plant

A 2002-vintage plant in the southeast US experienced two ST/G excitation transformer failures (two separate units) within 18 months of each other. The first was during startup, the second during baseload operation. Fortunately, spares were available for both occurrences. Presentation reviews post-event inspections, OEM-driven inspections conducted during the next outage, mitigation tools (for example, monitoring), and root-cause analysis questions.

"Excitation Auxiliary Transformer Failure"

Always an 'extra mile' when it comes to safety

Safety is always a popular and critical topic at CCUG, evidenced by a closing presentation with ideas for promoting better work environments, including: drain-valve locations, central first-aid stations, two-minute drills to help workers think about what's about to happen with a task (Fig 13), "ready cards" for engaged employees and empowered leaders, confined space barriers, hoses colored for service (such as red for air, blue for water), and others.

"Safety Roundtable"

GENERATOR USERS GROUP™

The ninth annual meeting of the Generator Users Group, launched in fall 2015 in Las Vegas, is an important component of Power Users' 2023 Combined Conference in the Omni Atlanta Hotel at CNN Center, August 28 – 31. Coverage of the group here is in two parts: 2023 conference overview and 2022 conference report.

2023 conference overview

Technical program for the upcoming meeting was developed by the all-volunteer steering committee of engineers and managers identified in the sidebar—many with decades of relevant experience. A preview of the presentations scheduled for the week beginning August 28 follows.

Expectation is that most of this year's presentations will be made available to owner/operators through the Power Users website a few months from now—except for those made by GE and Siemens-Energy. Access the GE PowerPoints at https://mydashboard.gepower.com; the Siemens-Energy presentations on the company's Customer Extranet Portal, https://siemens.force.com/cep.

Slide decks from 2022 and earlier meetings already are accessible to registered users. If you are not registered, sign up now at www.powerusers.org: It's easy and there's no charge.

Monday, August 28, begins with a training workshop on stator endwinding support systems, presented by Siemens-Energy, GE, and NEC, which ends with lunch. The afternoon program is dominated by presentations from users and EPRI. Here are the highlights:

- Generator sweep frequency response testing.
- Generator monitoring.
- Generator inspection/data app.
- Case study of a generator ground fault after two years in service.
- Stator winding ground fault: collateral damage from a core-iron hot spot.
- Generator case-history findings.
- Brushless exciter experience.

Tuesday, August 29, features presentations by vendors and consultants until the afternoon break, when owner/operators take over the podium. Yet another preseo on endwinding support systems kicks off the program, with Jason Sinkhorn of EME Associates focusing on design, philosophy, and construction. Following Sinkhorn are:

- Brushless exciter system overview by Daniel Besmer and Jacques Leger of Electric Machinery.
- Advances and case study on EMI monitoring by Consultant Kent Smith, representing Cutsforth.
- A rapid 7A6 field rewind case study by engineers from MD&A.
- Turbogenerator rotor rewind: Maximize the value of maintenance, Rob Rettler, Toshiba America Energy Systems.
- Generator fields: Testing, evaluations, and repairs, Jamie Clark of AGT Services Inc.
- Generator high-speed-balance case studies by Keith Collins of MD&A.
- Generator rotor concerns, Howard Moudy, NEC.
- Core restacking in the horizontal position, Rhett Smith of EthosEnergy Group.
- Circulating currents and overheating issues associated with isolated-phase bus ducts, Mohsen Tarossoly, EBI.

Topics of the user presentations are:

- Generator protection auto-trip philosophy.
- NERC compliance challenges.
- Excitation-system upgrade and replacement case history.

Tuesday's technical program ends at 5 when the three-hour Vendor Fair begins.

Wednesday, August 30, features presentations by Siemens-Energy in the morning and GE in the afternoon.

The Siemens-Energy lineup:

- Issues and maintenance practices for (1) gas (air/H_2) coolers, (2) hydrogen gland seal rings, (3) hydrogen seal-oil systems, and (4) generator bushings.
- Generator additive manufacturing.
- Fleet major findings.
- Changing operating regime
- Stator core inspection and repair experience.

The GE lineup:

- Model 324 phase connection cracking—including TIL-1965/1966 retirement and its replacement with a new TIL.
- Model 390 phase connection cracking, with a focus on RCA progress.
- Collector brush design history and maintenance best practices, plus RCA progress and supply-chain status.
- TIL-2119, "Generator Pole-to-Pole Connection Replacement."
- Velomitor radio interference.
- CTS hydrogen leakage PSIB: Reinforce replacement of new design.
- RCA of 89SS switch failure.
- 18Z/21Z aluminum spacer: Risk with potential stator rewind.
- Stator-bar putty repair.
- Stator-core integrity/aging factors.
- Fault event investigation.
- Fast stator rewind: Its applicability and benefits.

Thursday, August 31, features user presentations and open discussion. Here are some of the topics identified before press time:

- AeroPac I main lead failure.
- Blocked rotor cooling holes.
- Collector flashover event and related supply-chain issues.

Keep in mind that meeting information is updated regularly on the GUG pages of the Power Users website at www.powerusers.org. Alternatively, come up to date when you register for the conference.

GUG steering committee, 2023

Chair: Jeff Phelps, consulting engineer, *Southern Company*
Vice Chair: Craig Spencer, director of outage services, *Calpine*
Dave Fischli, director of engineering and programs, *Duke Energy*
Andres Olivares, generator specialist, *Calpine*
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Doug Coleman, generator engineer, *Duke Energy*


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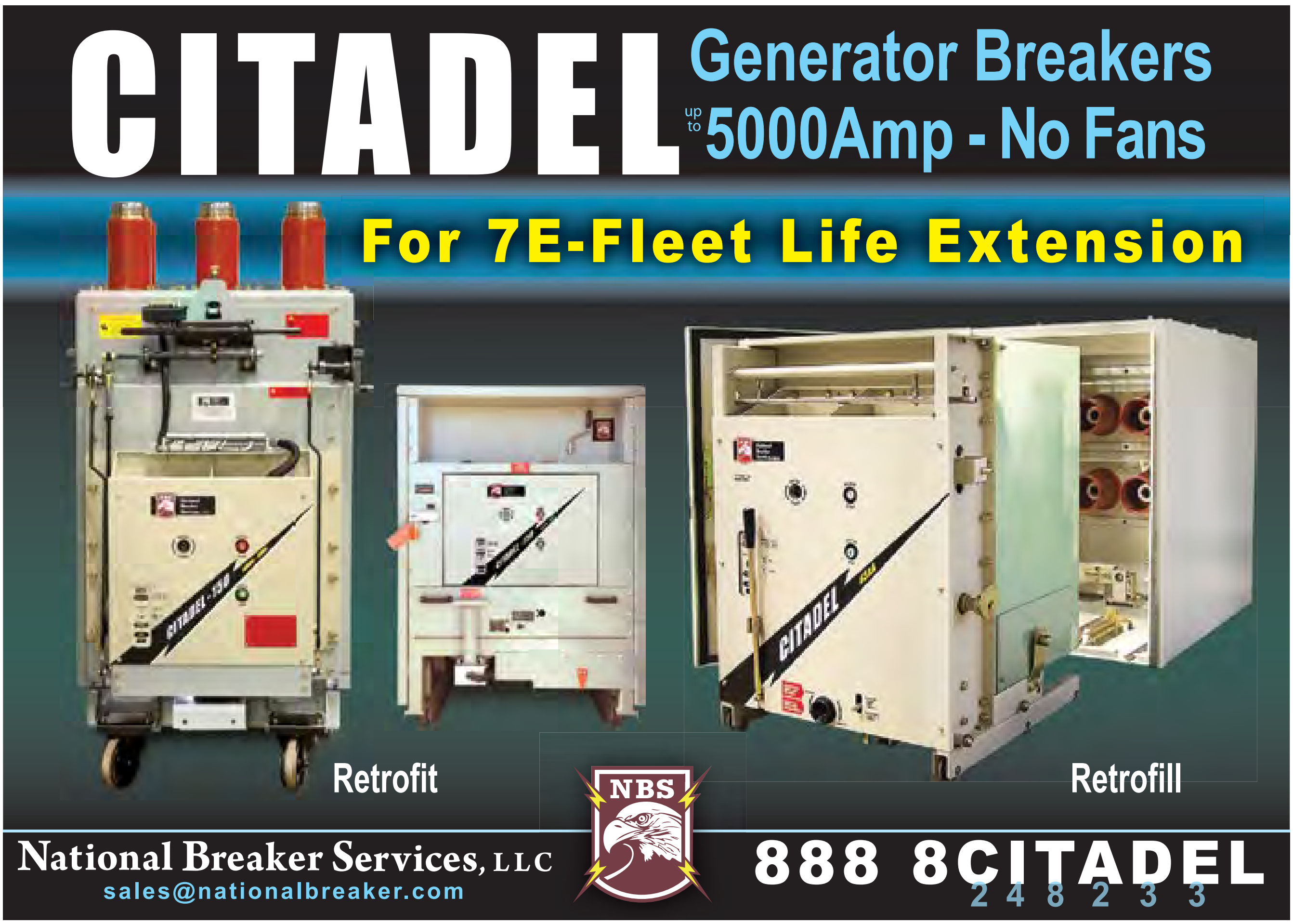
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2022 conference report

The Generator Users Group (GUG) appeared the busiest of the five organizations participating in Power Users' Combined Conference and Vendor Fair (San Antonio, Aug 29-Sept 1), hosting two-dozen presentations by owner/operators, third-party equipment/services providers, and consultants; another 20 presos or so by OEMs GE and Siemens-Energy; three tutorials on generator insulation systems; and a couple of roundtables.

Two-dozen presentations (in round numbers) are abstracted below. Slide decks for them are located at www.powerusers.org for those seeking deeper dives into specific topics. Presentation titles are provided in italics at the end of each summary to facilitate your search.

Only two OEM presentations are reviewed below; editorial personnel were unavailable to listen in on the others. The tutorials by GE, Siemens-Energy, and National Electric Coil were not provided for posting on the Power Users website. However, access to the OEM presentations identified by title on www.powerusers.org can be arranged through your plant's customer service representative.

Alternatively, most of the material presented by the Siemens-Energy speakers is posted on the company's Customer Extranet Portal (https://siemens.force.com/cep). If your organization owns and/or operates Siemens-Energy power-generation equipment and you do not have access to that portal, use the link to request it.

For access to the GE presentations, visit the OEM's MyDashboard website at https://mydashboard.gepower.com.

Meaningful stats help guide improvement in plant performance

Equipment quality and personnel safety are top of mind at user-group meetings. The first presentation after lunch on Day One is valuable for the guidance it offers regarding generator components and processes to focus on at your plant to maintain top performance. The owner/operator's database of regulated and unregulated assets is extensive: 227 non-hydro generators representing 48 different models from nine OEMs.

Stator windings are at the top of the "failing equipment" category with issues affecting 20% of the total fleet. Stator cooling water was next at 13%, followed by isophase bus/flex links and the rotor, each 10%. Brush rigging came in at 7%, seal-oil system at 6%, and AVR, exciter, and stator core each at 5%.

Process shortcomings were most evident in vendor execution, 24%; PM scope/inadequate frequency, 22%; and inadequate process/procedure, 14%. Installation error was next at 10%, with OEM design deficiency right behind at 8%.

Causes of poor quality identified included loss of vendor experience, substandard planning, poor procedures, complacency, lack of training, etc. Human performance tools that could have prevented many of the issues were better procedures and adherence to them, more positive attitude, when to stop work when problems arise, pre-job briefing that includes the consequences of incorrect actions.

The presentation can help you develop a better vendor qualification process, improve your procurement specifications, provide more effective vendor oversight, and improve vendor accountability.

"Vendor Quality Challenges"

Solutions for condensation in metal-enclosed bus ducts

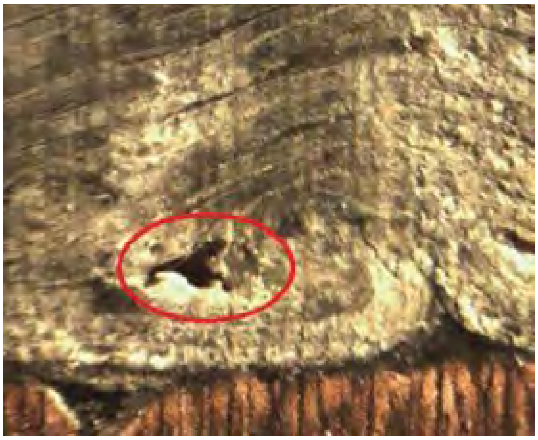
"Metal-enclosed bus ducts should be part of your regular preventive maintenance program," began Mohsen Tarassoly, EBI (Electrical Builders Inc), "but half of your issues will stem from condensation or water intrusion." Designs for bus enclosures haven't changed since the 1990s, but welded and bolted designs are more susceptible to moisture. None of the designs account for the frequent cycling these busses are exposed to, aggravating the situation.

The heart of the presentation focused on solutions, including drain plugs, isolated phase bus (IPB) insulator heaters, strip heaters, dry air systems, forced-air cooling systems, gel packs, and dessicants. Some of these impose their own maintenance concerns, he cautioned. During the Q&A, one audience member suggested that you turn on your forced-air system for several hours before starting the unit, especially in humid climates like Florida.

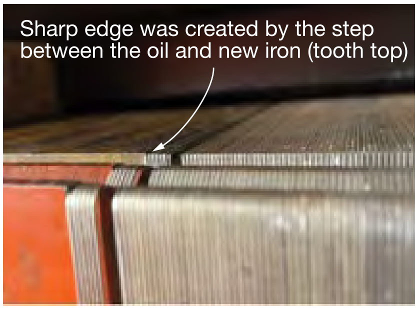
"Anti-Condensation Measures for Metal-Enclosed Bus—What You Need to Know"

Stator-bar failures traced to insulation voids

A member of the GUG steering committee spoke about his company's experience regarding premature failures of stator windings attributed to manufacturing issues. Of particular concern was that some failures



1. Insulation voids typically were identified with failing stator bars



2. Vendor failed to verify the transition from the original iron to the newly stacked iron, resulting in a 0.019 in. step between them. This difference was significant enough to prevent the wedges from sliding in. Concern was it could compromise the outer corona protection layer of the coil which could damage the bar over time

occurred even after all electrical tests had been passed. Resulting lost production obviously had a negative impact on the bottom line.

Most of the failed bars had voids in their insulation (Fig 1)—typically in the transition/bend area. Speaker reviews the types of tape available and the pros and cons of using each, plus proper taping procedures, electrical testing, etc. Rewind issues at two of the utility's plants contribute to the learning experience.

"Stator Winding Manufacturing Issues"

Learn from experience gained by colleagues

A major utility's four-person generator brain trust shares its findings on the topics below—nuggets for virtually every owner/operator.

- Stator rewind lessons learned: winding support-cone findings (misaligned phase-lead banks), step found between new and existing iron after restack (Fig 2), bottom coils damaged during installation, modified wedges to prevent partial blockage of core vents, FME event.
- Partial rewind resulted in a full rewind: OEM used third-party winders. Their lack of experience and familiarity with winding design contributed to extensive growth in project scope, plus work quality issues. Bar and tie damage were a result.
- Use of improper materials: Capping compound used for series connections was of an older formulation than used today, with lower thermal transfer properties. This resulted in specialized online monitoring post rewind and potential derate of the machine. The fix requires installation of a new inner nozzle shield to increase cooling.
- Bar manufacturing issues, in particular a lack of consistency in the shape of replacement bars which caused tolerance, alignment, and bar-to-bar spacing issues.
- Non-seg bus phase-to-phase fault.
- Generator terminal and PT-cabinet water intrusion.

"Generator Lessons Learned"

Why proper alignment is critical to rewind success

Speaker provides a valuable backgrounder on the importance of correct alignment of stator-endwinding support system components during a rewind and follows with a case history of what went wrong on the rewind of a 7A6 generator when new connection rings were not properly supported during installation. Key elements of the presentation include the following:

- A review of the stator winding support system, including core iron/frame and slot components (filter materials and slot wedging system). Plus, endwinding support components.
- A review of the purpose of the support system, including: mechanical support the stator winding, allow for thermal expansion/contraction, and minimize/restrain dynamic forces during normal operation and fault events.
- Imperative that the endwinding support system is correctly aligned prior to winding installation. Challenges such as the complex 3-D shapes of stator bars/coils are covered. Points to remember: The installed position must accommodate thermal expansion without binding, provide adequate spacing to prevent the risk of voltage stress, and assure a uniform and symmetric endwinding assembly to withstand operational forces and fault events.

"Importance of Correct Alignment of Stator Endwinding Support System Components During Rewind"

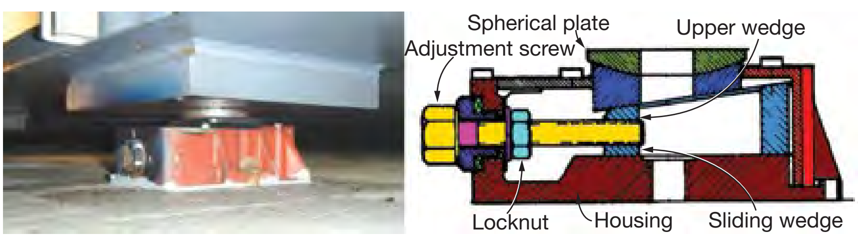
Fixators: What you should know about them

User group meetings are a great place to learn from the industry's top talent in the owner/operator, vendor, and consultant communities. Information shared may include new regulatory initiatives and how they could impact plant operations, findings by colleagues that might affect your facility as well, case histories of importance, and backgrounders on equipment and components of significance that you might know little about.

At the 2022 GUG meeting, several backgrounders received high marks from attendees—including one on fixators (Fig 3), a continuously adjustable alignment wedge assembly for machine mounting. Important to recognize is that fixators are not shims, and the speaker presented a table comparing the two.

Suppliers of fixators claim they allow faster alignments than shims on new installations because you avoid the need for jacking up a machine, installing the shims, and then lowering the machine to check if it is level. If not, the process is repeated until the result is satisfactory.

Leveling and alignment by way of fixators is much simpler: For initial leveling, turn the adjustment screws a couple of turns and check. If not level, repeat. For alignment, identify the low points among the 16 or more fixators that might be installed on an F-class generator and raise to the



3. A fixator is a continuously adjustable alignment wedge assembly often installed on large generators. An F-class generator typically requires 16 or more fixators. They may be single-shaft center-anchored or dual-shaft side-anchored

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4. Healthy flex link is at left, the effect of overheating at right

degree necessary using the adjustment screws.

The presenter said his company had fixator issues on about 10% of its generators so equipped. Most often, vibration—sometimes attributed to a soft foot—was the underlying cause. Three case histories give the details.

Given fixator adjustments may be required over the life of your generator, experts recommend inspecting them at every turbine major, minor, and hot-gas-path inspection and cleaning and lubricating as required. Be prepared: Some fixators might have to be replaced.

"Fixators: Not as Fixed as You'd Expect"

Keeping flex links in top condition helps promote generator reliability

Flexible links provide an electrical connection between two rigidly mounted conductors, thereby allowing relative thermal growth/movement between them. Links may be of the laminated, wire-braid (Fig 4 left), and wire-rope type. Common locations include (1) between generator terminals and isolated phase bus, (2) main leads and bushings, (3) connection rings and main leads, and (4) neutral bushings or Y point.

Common issues include the following:

- Mechanical failure attributed to (1) broken wires or laminations caused by fatigue or fretting, (2) incorrect installation, and (3) material creep/deformation.
- Overheating (Fig 4 right) caused by loose hardware, poor mating surfaces, and/or corrosion; poor ventilation; marginal connection or hardware design.
- Inattention to installation/maintenance best practices. It's important to digest OEM bulletins, properly torque connection bolts, maintain a high level of cleanliness, follow OEM procedures to the letter, etc.

Causes of three flexible-link failures are described in detail in the slide deck. Plus, corrective and preventive actions are provided for each. This is "not difficult stuff." It's all about learning the correct way to install and maintain your equipment and staying committed to the task at hand.

"Flex Link Maintenance"

Owner, OEM, industry colleagues, user group share info to resolve main-lead issue

Unplanned outages of a particular generator model traced to failures of main leads experienced by several owner/operators were a topic of discussion on the GUG and IGTC (International Generator Technical Community) forums early in 2021. Users were concerned because the failures occurred within months of the OEM performing NDEs that indicated the main leads were fine.

The OEM responded within a few months, recommending replacement of the main leads. The most likely cause, it said, was copper separation at the main-lead flange braze joint which could result in a generator ground fault and damage to surrounding components. The improved main-lead design offered has a more robust joint between the main-lead flange and the main-lead conduit.

The presenter said his company has eight of the 49 affected units and that no failures had occurred at any of its sites. An NDE inspection at one plant revealed no findings. The owner's concern was the hefty hit on its budget if all of the susceptible main leads were replaced. Plus, there was a 45-week lead time associated with the OEM's repair.

Have a look at the slide deck to see how the owner developed its own repair with help from industry colleagues to upgrade its main leads, saving time and money in the process.

"Main and Neutral Leads Mod for Modular Units"

What grounding-brush issues may be telling you

Shaft grounding can be accomplished by using a carbon brush, soft metal-bristled brush, or soft metal strap (often braided) to ride on the shaft surface and safely discharge voltages which can build up within the shaft train. The author explains where shaft voltages come from and what happens when a shaft grounding brush (SGB) malfunctions (it could cause a nuisance trip).

Next comes a series of slides that explain how you can identify a malfunction before it impacts operations—for example:

- High shaft voltage.
- No/low shaft brush current.
- Bearing and seal electrolysis. Fig 6 shows that this damage is "real," possibly requiring repair or replacement. Vibration conducive to a forced outage also is a possibility.
- Magnetization of components.
- Artificial vibration. An orbital plot of this phenomenon is included.
- Artificial rotor-winding ground indication. Point made: Online rotor-winding-to-ground resistance measurements may be influenced

International Association for the Properties of Water and Steam

IAWPS is a global non-profit association involving 25 countries in all aspects of the formulations of water and steam and seawater, as well as in power-plant cycle chemistry. It provides internationally accepted cycle-chemistry guidance for power generation facilities in Technical Guidance Documents freely downloadable from the organization's website at www.IAPWS.org. Specific TGDs for combined-cycle/HRSG plants include the following:

- Procedures for the measurement of carryover of boiler water into steam.
- Instrumentation for monitoring and control of cycle chemistry.
- Volatile treatments for the steam-water circuits of power plants.
- Phosphate and NaOH treatments for the steam-water circuits of drum boilers.
- Steam purity for turbine operation.
- Corrosion-product sampling and analysis.
- HRSG high-pressure evaporator sampling for internal deposit identification and determining the need to chemical clean.
- Application of film-forming amines in power plants.

6. Poor shaft grounding can cause bearing and seal electrolysis. Damage such as that shown may require repair or replacement

by induced voltage.

Users are advised to check brushes weekly for functionality or need for replacement. Responsible persons should be alerted if a significant SGB event occurs or recurring minor events are experienced. Also, check turbine and generator parts and rotors for residual magnetism; degauss down to 2 G or less, if possible.

"The Many Faces of Shaft Grounding-Brush Issues"

HV bushings—inspection, testing, failures

James Joyce, MD&A's generator repairs operations manager and a popular participant in user group meetings, presented a comprehensive tutorial on the inspection, testing, and maintenance of high-voltage bushings (HVB) at the 2022 GUG conference. The slide deck is highly illustrated with many excellent photos, such as those in Figs 7-9. The presentation is of value to anyone having HVB responsibilities.

"High-Voltage Bushings—Inspection, Testing, Manufacturing, and Failure Examples"

Bus-duct failure investigation

Case history begins with a review of the basics of isophase bus duct design, including topics not typically covered in presentations on IBD at most industry conferences—such as induced voltages and resulting current flow in the various types of enclosures: discontinuous or insulated, continuous bonded, and discontinuous bonded housing arrangements.

Inspections were focused on locations where current may flow that it shouldn't and where current can't flow that it should.

"Isophase Bus Duct Issues and Resolution"

Focus your attention on the things causing you problems

Sounds like a no-brainer, but the retired former owner's engineer, who made a career out of fixing problems, offers valuable advice, especially for those new to generator O&M. Consultant Jim Stone began with a few words on viewpoint, noting the following:

- Everyone is trying to make a profit.
- Everyone is short/tight on expertise.
- The less *they* know/have, the more *you* must know/have.
- If no one does it, it won't get done.

Next, he reviews how generators fail—mostly for mechanical reasons:

- Insulation fails from debonding, delamination, voids, cracking organic breakdown, abrasion, and/or contamination.
- Things break, caused by high-/low-cycle fatigue or overload (usually thermal).
- Things loosen.
- Things stick, wear, catch, lose resilience, etc.

The capacity to discern is critical, he says. Someone has to know what's what and what matters every step of the way. That can be you or someone you hire who does. Or you can rely on supplier experience. Remember: Having someone look who doesn't know, adds nothing.

The expert also offers his thoughts on the complicated nature of generators, the need for good specifications, the importance of design reviews, inspections and test plans, the value of documentation, commissioning, the perils of nonconformance, and what to track during manufacturing and construction.

"Getting What You Want—that is, Ensuring Quality"

Online diagnostics for generators

Thomas Laird, a principal electrical systems engineer for PSM, begins his presentation with the requisite list of products and services available from his company and its sister firm, Thomassen Energy. Next, he discusses key steps in PSM's generator major and minor inspections and how the company uses online diagnostics to assist in outage planning.

Focus is on electromagnetic signature analysis (EMSA), using a radio frequency current transformer (RFCT) to assess rotor, excitation, and isophase condition. A flux probe is used to assess field-winding condition.

Anyone involved in outage planning would likely benefit from a review of this slide deck.

"Using Online Diagnostics to Assist in Generator Outage Planning"

Generator literature searches

Jane Hutt's recent passing leaves the generator community short a guiding light to technical information resources on these rotating machines. Hutt's presentation at GUG 2022 was her last and quite possibly her best effort on the subject.

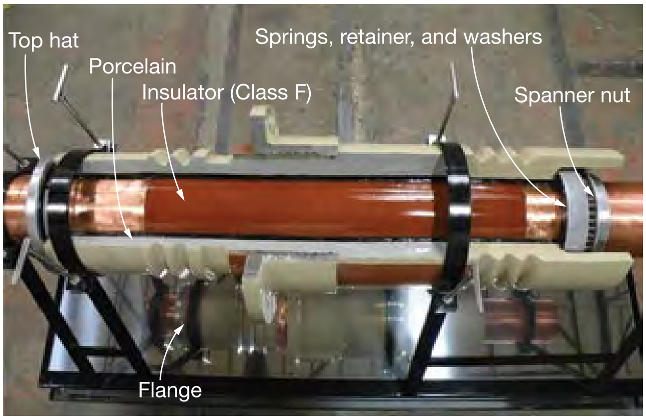
By way of background, Hutt was the primary developer, webmaster, and site manager of the Web-based International Generator Technical Community (IGTC), which serves about 6000 member engineers, technicians, and academics worldwide involved in the design, service, maintenance, and reliability of electric generators. Plus, she was an advisor to the board of directors of the Generator Users Group, which operates under the Power Users' umbrella.

Her slide deck offers a comprehensive, thoughtful guide for conducting an efficient literature search of the internet, industry technical societies, conferences, IGTC, and other sources. It provides excellent guidance on where to look and what information to trust—particularly on the failure and repair of generator equipment.

An Approach to Performing Time-Efficient Generator Literature Searches

Considerations in the rewinding of stators

Gary Slovisky, NEC's director of



7. HV bushings are designed to carry the current and voltage from the 3-phase generator to the isophase bus bars and neutral connections. They are bolted to the frame with a gasket system to ensure that no generator atmosphere can exit around the mounting flange or terminal plate

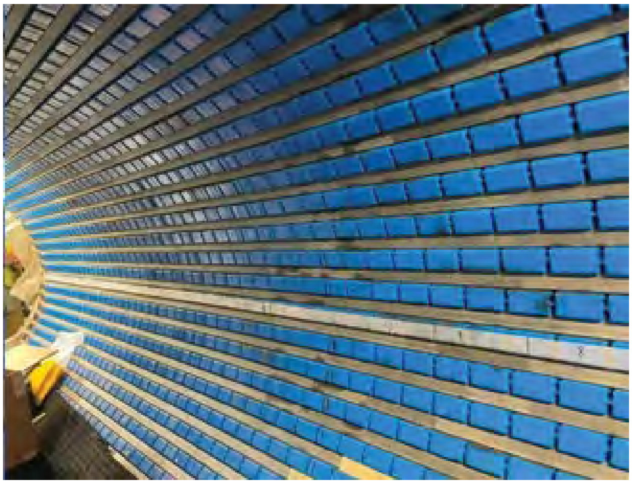
8. Leaking asphalt is a failure mode associated with aging HV bushing systems. Recall that old-style bushings have an asphalt liner that separates the porcelain from the core copper stud. An O-ring gasket holds the asphalt in place when it becomes liquefied, so if the gasket fails, asphalt runs out of the bushing. Degradation of gasket sealing components, conductor insultation, and porcelain insulator cracking can lead to HVB failure and adversely impact generator operation

9. If a failure occurs near the bushing an inspection is required. Failure-prone areas include the air-side flex links (photo, revisit Fig 4)

10. Belly band tightening with proper shim design

generator services, began by saying that understanding "why" a rewind must be performed is an important first step. For example, is it because of age/deterioration? Or might it be

11. Bottom-bar install and HiPot



12. Stator wedge install

design weaknesses and/or unit idiosyncrasies?

Understanding "what" also is very important, he said. What design or unit idiosyncrasies are problematic or can be improved? What rewind components are critical to quality and can they be reused or upgraded, or should they be replaced? Slovisky then identifies components generally reused as part of the rewind. Next step: Stator-core testing and requalification using El Cid and Core Loop or Full-Flux tests.

Focus of the presentation is on GE's 7FH2 generator. The slide deck likely would be of use to anyone with responsibilities relating to stator rewinds. It offers good general information on the following:

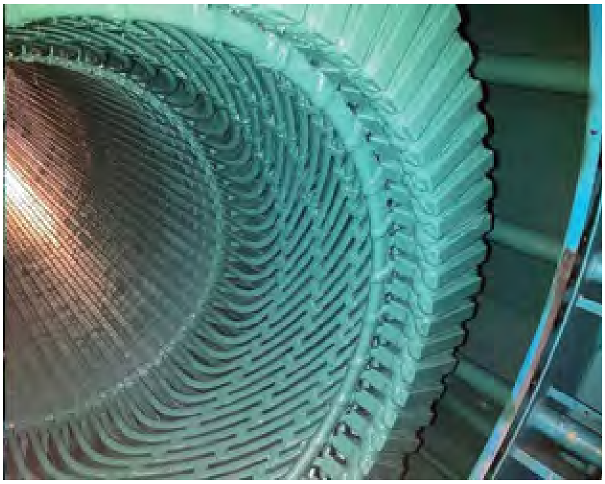
- Rewind decision.
- Specific problems—such as dry ties, vibration/resonances, rigid phase leads.
- Endwinding redesign and modification.
- Pros and cons of the various stator ground insulation systems.
- Tangent Delta testing.

"Effectively Rewinding High-Voltage Generator Stators"

Better core monitoring may allow an increase in maintenance intervals

Derek Hooper, president, B-Phase, describes a new technology which promises to give local temperature and stator-bar motion in the slot during operation. Objective is to extend the time between maintenance outages given the availability of more meaningful information. Users may find it beneficial to follow the development of this technology at future GUG meetings.

"Generator Core Monitoring"



13. Stator rewind completed in 26 days

Hydrogen, the preferred cooling medium for large generators, demands respect

Hydrogen must be purged from generators prior to entry or exposure to air to prevent fire or explosion, which can occur with minimal ignition energy. Recall that the lower explosive limit for hydrogen in air is 4%. The upper explosive limit is 76%.

For maintenance, the inert gas of choice for purging hydrogen is CO_2, followed by an air purge. Once maintenance is complete another purge is needed to remove the air prior to recharging with H_2. In emergencies—such as fire, loss of shaft seal, low H_2 purity (less than 92%)—the generator is flooded with CO_2.

Andrew Slaugh, senior applications engineer for Airgas, told attendees that the traditional method of using CO_2 from cylinders for purging can be challenging. For example, it can take several people to monitor and maintain the purge flow: There can be interruptions in purge flow because of dry-ice formation, empty cylinders, change-out of cylinders, etc. Plus, it can take many hours to complete the purge.

An alternative is Airgas' TurbinAL purge system which is said to provide uninterrupted gas flow at all times with no operator actions and with no power required for purging—as well as other benefits.

Presentation is valuable for its review of the fundamentals of safe hydrogen purging. It is recommended reading for anyone involved with hydrogen filling and removal.

"Implementation of a Reliable CO_2 Purge System"

Troubleshooting with EMSA

Cutsforth's presentation offers some good observations on approaches to effective troubleshooting. The case study profiled, in progress, using Electromagnetic Signature Analysis, revealed increased activity in the 30 Hz to 100 MHz band, which typically indicates an issue with the isophase bus duct. However, the problem could be external to the bus duct—such as with the GSU or another non-generation-related source.

The continuously elevated EMSA level indicates that the source is not cyclical in nature—such as plant lighting. Next step likely would be to get the utility's generator engineering group involved in the analysis. Stay tuned.

"Troubleshooting"

The challenging nature of recent core issues on H_2-cooled generators

AGT Services' Jamie Clark, well known to users for his deep knowledge on the nature and repair of various generator issues—such as loose cores and low insulation values on stator and field windings in large hydrogen-cooled machines—opened his presentation at the 2022 GUG meeting with this statement: "The past 24-36 months has been very 'eye-opening' with respect to GE's 7FH2 generator fleet."

He then discusses why four planned minor outages morphed into majors during the spring 2022 outage season. AGT Services was awarded two of the four projects—each requiring a full stator rewind and field exchange. One reason for the dramatic turn of events is simple arithmetic.

More than 5000 generators (about 60% with GE nameplates) have been built since 1995 with design stator lifetimes of 25-30 years and design field lifetimes of 10-15 years. Do the shop and personnel resources required to test, inspect, and repair, and make new windings, to keep these generators operating reliably exist—especially given the recent retirements of highly experienced engineers and technicians? There are no simple solutions.

Clark outlines the work scopes for both projects completed by AGT Services and provides many photos to help define both the challenges faced and the repair work done (Figs 10-13). Think of this slide deck as a useful tutorial for those associated with generator maintenance.

Other presentations available through the Power Users website cover a sudden excitation increase (field), summary of fleet-wide issues, failure during pre-commissioning, and main lead failure.

STUG™
STEAM TURBINE USERS GROUP

The 10th annual meeting of the Steam Turbine Users Group, launched in Richmond in summer 2014, is a cornerstone of Power Users' 2023 Combined Conference in the Omni Atlanta Hotel at CNN Center, August 28 – 31. Coverage of the group here is in two parts: 2023 conference overview and 2022 conference report.

In its infancy, STUG focused primarily on GE A10 and D11 steam turbines; today it covers steamers for combined cycles made by all the leading OEMs.

2023 conference overview

Technical program for the upcoming meeting was developed by the all-volunteer steering committee of engineers and managers identified in the sidebar and accompanying photo—many with decades of relevant experience. A preview of the presentations scheduled for the week beginning August 28 follows.

Many sessions are *user only*. Nonusers wanting to participate in a particular session must be approved by the steering committee to gain admission. Presenting vendors are allowed in the room only when it is their time to present.

Expectation is that most of this year's presentations will be available to owner/operators through the Power Users website a few months from now—except for those made by GE and Siemens-Energy. Access the GE PowerPoints at https://mydashboard.gepower.com; the Siemens-Energy presentations on the company's Customer Extranet Portal, https://siemens.force.com/cep.

Slide decks from 2022 and earlier meetings already are accessible to registered users. If you are not registered, sign up now at www.powerusers.org: It's easy and there's no charge.

Monday, August 28. The STUG technical program opens with an EPRI seminar, which runs until lunch. Discussion topics for the open forum include the following:

- ST valve diagnostics.
- Lube-oil testing and maintenance.
- The effects of flexible operation on high-/low-temperature steam-path components.

The afternoon begins with the steering committee's Seth Story of Luminant moderating a roundtable discussion on conference expectations and "knowing our fleets." A panel discussion on GE combined-cycle steam-turbine valves is next. Participants from three major utilities (Dominion, Duke, and Luminant) discuss historical experience plus valve upgrade options and experience with them. Three user presentations follow. One covers an IP- to LP-turbine crossover failure.

Tuesday, August 29, is all-in on vendor presentations until 4 p.m.—specifically:

- Steam-system metal-bellows expansion joints (Senior Flexonics).
- Return to service following abnormal operating events (TG Advisers).
- Boiler-feed-pump steam turbines—recent issues and challenges (Ethos Energy Group).
- HyFit (Nord-Lock Group) coupling-bolt solution.
- Turbine insulation and warming systems from Arnold Group.
- Advances in EMI monitoring, plus a case study (Cutsforth).
- Using real-time data analytics to improve asset reliability and performance (Black & Veatch).

Siemens-Energy and FPL close out the afternoon with the OEM presenting on the following topics:

- Low-load operation.
- Short-term layup.
- Hydraulic fasteners.
- Steam-turbine modernization options for combined cycles.
- Lessons learned from forced outages.

And the utility explaining major outage findings for an uprated BB-43 steam turbine, plus lessons learned while taking steam-turbine performance measurements.

Tuesday's technical program ends at 5 when the three-hour Vendor Fair begins.

Wednesday, August 30, opens with a two-hour MD&A session covering the following:

- Turbine outage-management case study.
- Steam-turbine high-speed-balance case studies.
- Outage planning.

GE presents for the remainder of the morning on its Technical Information Letters and top issues, plus turning-gear failure modes, maintenance, and

STUG steering committee, 2023

Chair: Matt Radcliff, consulting engineer, *Dominion*

Vice Chair: Mark Johnson, staff ST fleet engineer, *FPL*

Eddie Argo, team leader, *Southern Company*

Jake English, steam turbine program manager, *Duke Energy*

Jay Hoffman, maintenance manager, *Tenaska Virginia Generating Station*

Connor Hurst, engineer, *Teco Energy*

John McQuerry, director of outage operations, *Calpine*

Lonny Simon, maintenance engineer, OxyChem

Seth Story, director of fleet mechanical engineering, *Luminant Generation Services*

Brandon Stewart, maintenance team leader, *Southern Company*

Jared Harrell, production superintendent, *OxyChem*

STUG steering committee. Front row (l to r): Seth Story, Connor Hurst, Jay Hoffman, Matt Radcliff. Back row: Lonnie Simon, John McQuerry, Eddie Argo, Mark Johnson, Jake English. Camera shy: Brandon Stewart, Jared Harrell


SAVE THE DATE
Wärtsilä Users Group Conference
Oct 16 – 19, 2023
Hyatt Centric Las Olas
Fort Lauderdale, FL
ANNOUNCEMENT
Power Users, Inc. has partnered with the Wärtsilä Users Group to support their forums and user group conference.
Wärtsilä and MSHS will be joining the group to share industry updates
USER REGISTRATION WILL OPEN THE WEEK OF AUGUST 14TH
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best practices.

In the afternoon, the OEM is at the podium to discuss these topics:

- Interval extensions possible with NextGen Valve and experience to date.
- Updates on Alstom rotating components and structures.
- D-11 turbine-shell findings, repairs, and replacement experience.
- Benefits and methods of improving the start times of combined-cycle plants.
- Improvements in outage execution at combined-cycle plants.

Thursday, August 31, the final day of the conference, morning-only, features presentations by representatives of leading utilities. Only one topic was released to the editors by press time: "LP Gland-Case Replacement on a 57-year-old Unit."

However, meeting information is updated regularly on the STUG pages of the Power Users website at www.powerusers.org. Alternatively, you can come up to date when you register for the conference.

2022 conference report

Presentations by owner/operators, equipment/services providers, and consultants at the Steam Turbine Users Group (STUG) conference (San Antonio, Aug 29-Sept 1) are abstracted below. The longer summaries are based on notes taken during what CCJ considered some of the most relevant presentations to the wider industry community. Shorter capsules are based on *available* slide decks located at www.powerusers.org. Those seeking deeper dives into specific topics should note the presentation titles listed in italics at the end of each summary and access the source material on the website at www.powerusers.org.

Address past 'pain points' in future bid specs

The first 12 slides in this "big picture" presentation by Eric Prescott, EPRI, address the general industry landscape for future capacity options (more specifically, renewables) driving the need for flexible, dispatchable combined cycles, and the impacts on steam turbine/generators (ST/G). However, the meat of the message is how to incorporate experience with ST/G damage mechanisms into bid specifications.

Balance of the slides are a glimpse into the publicly available EPRI report (No. 1024903), "QA/QC Practices for the Procurement of Steam Turbine and Generator Equipment."

"Evaluating Equipment and/or Component Upgrades In Consideration of Future Operating Flexibility Challenges"

Index of EPRI resources

Eric Prescott, EPRI, followed his first presentation (immediately above) with an overview of EPRI's resource locator (released April 2022) for ST/Gs, organized by equipment subsystems (Fig 1)—including steam path, high-temperature rotors and casings, low-temperature rotors and casings, secondary piping and valves, bearings and lube-oil systems, monitoring and control, and others. Resources for each subsystem are categorized as:

- Operation, flexibility, and resilience.
- Maintenance.
- Component health and condition monitoring.
- Inspection.
- Materials and repair.

"EPRI Steam Turbine Resource Navigator P219, Steam Turbine and Auxiliary Systems"

Users' top concerns 'entering no-man's land'

The quandary many users feel about their ST/G assets was palpable during the opening roundtable discussion, perhaps best indicated by direct or near-direct quotes:

- We're experiencing new failure mechanisms based on operating regime changes.
- "Bang for the [investment] buck on combined cycles is really low."
- We have a 21-year-old ST/G with 40,000+ hours that's never been opened.
- We've entered "into a no-man's land on some of this stuff—we have no data points in our fleet."
- "I'm worried about 'Sanford & Son' engineering being applied to these assets online."
- "Old timers' knowledge is no longer available."
- "How can we 'feel better' about operating these assets?"
- Money for the sunset assets is being deferred, even though their end-of-life dates are being pushed farther out.

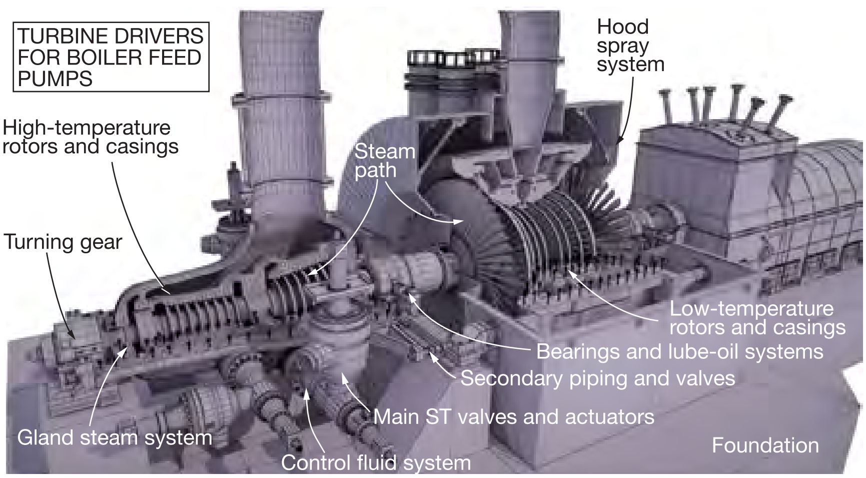
Other interests expressed included how best to laser-scan reheat stop valves in preparation for an outage, managing salt-induced damage at outside installations near the ocean, and learning of any experience with a particular vendor's combined HP/IP turbine section. A few users were concerned with future issues like how the need for process steam in carbon-capture systems will change ST/G operating conditions and potentially require new components.

Heavy outage season—a tale of two vendors

The pride and joy of STUG are presentations like this one, in which a user with responsibility for dozens of ST/Gs in his company's fleet dispassionately describes experience with two different vendors, not to throw shade but to work out how both vendor and user can improve the experience.

One vendor was contracted for major outage work on two HP/IP turbines at different sites, the other for packing/seal replacements on two D11 units (from different suppliers) at different sites. The slides include a blow-by-blow account of how the work transpired and the all-important lessons learned. Among the major ones:

- Insist on early data review between user and vendor before the manufacturing of packing rows begins.
- Do not allow packing to be final-machined until operating data have been fully reviewed and the rebuild strategy for the machine is defined.



1. EPRI's resource locator identifies reports of value to staff responsible for operation, inspection, and maintenance of steam-turbine subsystems identified in the diagram

- Best practice is to send a segment from each row to the packing vendor for reverse engineering.

But don't deprive yourself of the details supporting these and other recommendations, especially if you are or will be soon undertaking the first major for an ST/G (the situation for two of the units described here).

"Vendor Shop/Field Considerations During a Heavy Outage Season"

Turning gear, motor reliability may need a fresh look

The almost incalculable value of a great user's conference presentation is learning about a forced outage or safety event that happened at someone else's plant and making sure it doesn't happen at yours.

In that category is surely one from the Steam Turbine Users Group on turning-gear reliability. The utility presenter was a steam-turbine expert with decades of experience.

There were two important threads woven together in this presentation: (1) A description of a catastrophic failure of a TG motor (Fig 2) at one of his utility's plants, and (2) the larger implications for maintenance, sparing, and even the impact on the industry as a whole.

Regarding the second, the presenter noted that the TG (Fig 3) could be a "pinch point" for ST/G reliability in plants that are, or will be, starting and stopping much more frequently to follow renewables.

It's easy to forget, he added, that the TG probably was designed to operate perhaps 10 times a year, but under future operating scenarios that could increase to 500 or more (multiple starts per day).

The utility in question has many 40- to 55-year-old ST/Gs from a variety of OEMs. Unfortunately, all four of the utility's steam-turbine experts, each with 40+ years of experience, left under an early-out program. Now the utility is planning to have 16 GW of solar and 5 GW of wind over the coming years. These are conditions familiar to many utilities. But the catastrophic failure of a TG motor caused by imbalance set off alarm bells, especially since a spare motor was not available and the unit was out for an extended period.

In spring 2019, plant per-

2. TG motor failed catastrophically (two days after this photo was taken) when a solid-state relay failed and the control system attempted to engage the rotor while operating at full speed

3. Fresh maintenance and reliability regimes may be required for a TG and motor designed for perhaps a dozen starts annually and undergoing an order of magnitude, or two, more as the plant follows renewables

sonnel noticed pieces of steel from the TG bull gear in the oil sump (Fig 4 left), and deformation of the gear teeth (Fig 4 right). The root cause was determined to be an attempted engagement of the TG by the control system during full-speed operation resulting from the failure of a solid-state relay.

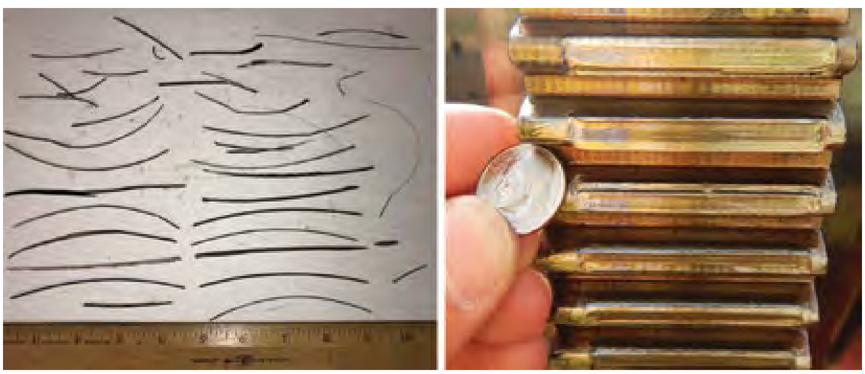
With this event as a backdrop, the presenter then turned to a tutorial of sorts on the function of the TG, basic nomenclature, different types of gearing and motors, motor interlocks, the importance of the air or hydraulic supply in the lock out/tag out (LOTO) boundary, proper tools for rigging a bull gear, and other topics.

Some of the recommendations for adjusting TG maintenance and sparing include:

- Have a spare motor, ideally one that could serve several different ST/Gs; spare bull (ring) and pinion (clash) gear; chain (if your unit has one); and several solenoids, even a complete assembly.
- Install a black-start unit with permanent reaction arm.
- Identify proper tools and their location so they can be available quickly in the event of an unexpected outage.
- Discuss issues with operations and visually inspect at least once a year prior to an outage.
- Measure and set correct backlash during outage.
- Inspect the lubrication system during outages or more frequently.
- Pull the TG out during major outages for a complete test.
- Have a battery pack to turn the rotor as backup.

To dive deeper into keeping your TG reliable, the presenter suggests obtaining a copy of EPRI Report No. 1019645, "Turbine Generator Auxiliary Systems, Volume 6: Turning Gear Maintenance Guide," published in 2010.

"Turning Gear Maintenance and Failure"



4. Plant personnel noticed pieces of steel from the TG bull gear (left) in the oil sump and deformation of the gear teeth (right)

Inspect LP crossover bellows at every opportunity

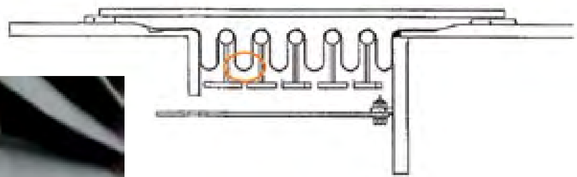
If you have aging ST/Gs from this particular OEM (check out the slides to find out), be aware that several units with over 100,000 operating hours have experienced significant recent failures of the LP crossover bellows. Two presenters from two different utilities teamed up to describe failures and remedies at three units in their respective fleets (not all are combined cycles). One presenter advised the audience to "inspect these components at every opportunity."

When the staff at one plant pulled the cover and insulation off of an "indoor unit with a generous turbine deck," he described what was found: "It was ugly." At another plant, an unexpected steam leak was heard, although the unit operated for an additional nine days. Cause was determined to be metal fatigue caused by repeated expansion and contraction and steam-pressure stress (Fig 5); no operational data anomalies were identified around the period of the event.

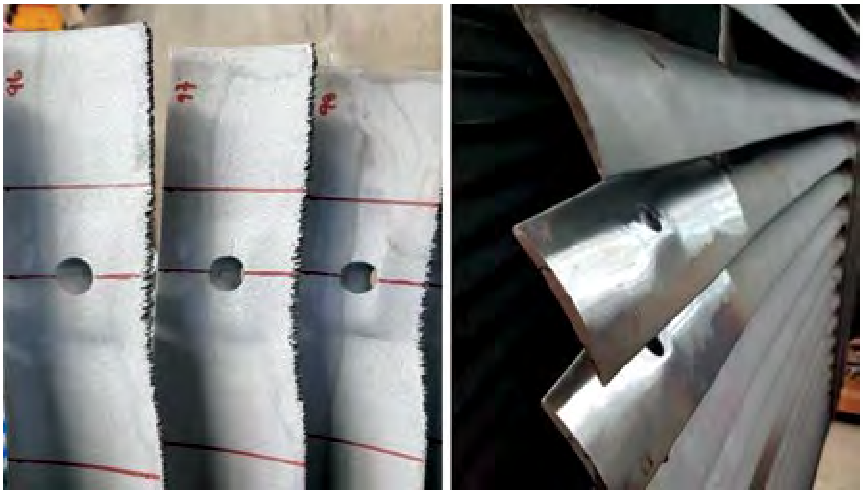
At one plant, the replacement component was upgraded to 2-ply Inconel 625. At another, the 2-ply 16-gage Type 316 stainless steel was upgraded to 2-ply 16-gage Inconel; a third unit ended up with 18-gage Inconel because of supply-chain issues.

These are not the only failures of this component worldwide the OEM has experienced.

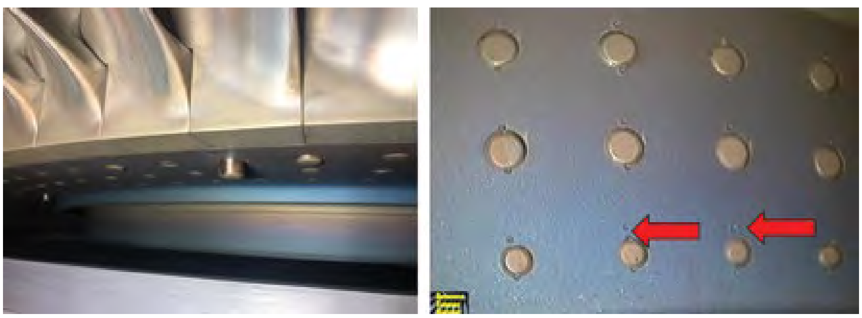
"Crossover Bellows—Two Failure Modes"



5. A 66-in.-diam bellows in this turbine's aft IP section failed after 113,000 hours of service (2007 COD) from metal fatigue attributed to repeated expansion and contraction, and steam-pressure stress



6. Water-droplet erosion of L-0 blades was repaired in-situ by removing the damaged base material (left), replacing it with a coupon, and adding a Stellite nose bar to the leading edge (right)



7. Check for migration of L-0 dovetail pins in your inspections (left). Here inadequate staking (right) was the cause of pin migration

User roundtable discussion

A variety of experiences were reported during the roundtable following the Day One presentations. One user reported having a bellows in the condenser gland seal piping "fall into the bottom of the condenser only two years after it was replaced."

Apparently, several to many users are experiencing issues with turning gears. Advice passed around the room: Watch amps on the motor; check bearing temperatures – bearing metal temperatures "can be deceiving"; check eccentricity; and pay attention to vibration. One user reported a bowed-rotor event resulting from a TG issue.

Another audience member asked if anyone was experiencing issues with the glands to the exhaust hood of a side-exhaust ST/G.

Watch this varnish vanish

If you are having issues with varnish in your lube or control oil systems, or if you never thought varnish was that important, then Axel Wegner's (C C Jensen, Oil Maintenance) slide deck is for you. It serves as a quick primer on the topic, beginning with the claim that the company's "varnish removal unit," or VRU, is the safest and most efficient technology for dealing with the troublesome byproduct of circulating oil systems at elevated temperatures. Prevention through oil changes and bleed-and-feed strategies are only half the story.

C C Jensen's VRU is described as a depth-filter absorption/adsorption process with advanced agglomeration, which can remove both soluble and insoluble varnish. Wegner also extols the benefits of online oil condition monitoring.

Sadly, Axel Wegner passed on May 5 (2023) at age 55.

"Demystifying Varnish Analysis and Mitigation"

Cut L-0 blade damage repair costs in half

David Archambeault, EthosEnergy Group, told STUG attendees that they can cut costs of damaged L-0 ST/G blades by 40% to 50% using in-situ repair techniques rather than by replacing blades. The slides take you through repair case studies of the most common damage mechanisms—water-droplet erosion (Fig 6), foreign object damage, and cover or tenon cracking.

"In-situ Repair and Upgrade of L-0 Steam Turbine Blades"

Consider PAG fluids for EHC, lubrication

The theory of the case presented here is that polyalkalene glycol fluids (PAG) are superior to phosphate esters in electrohydraulic control (EHC) applications and to petroleum-based oil (mineral) for lubrication. Paul Jarvis, Oilkleen, explains that in EHC systems, PAG fluids exhibit hydrolytic stability, meaning they will not degrade when exposed to water contamination.

In lube-oil systems, PAG fluids can eliminate varnish formation. Photographs supplied of reservoirs after years of service with PAG are dramatically cleaner than with alternatives.

"Keys to a Successful Conversion"

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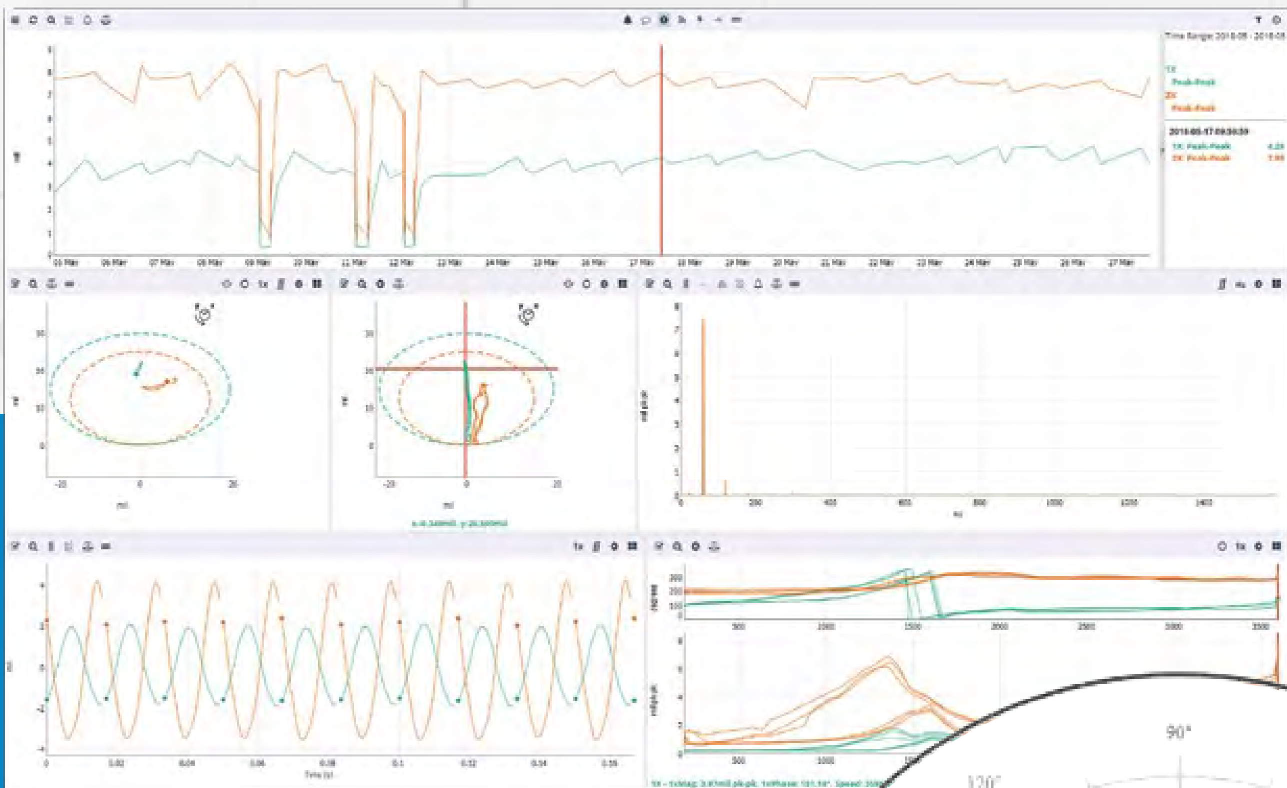
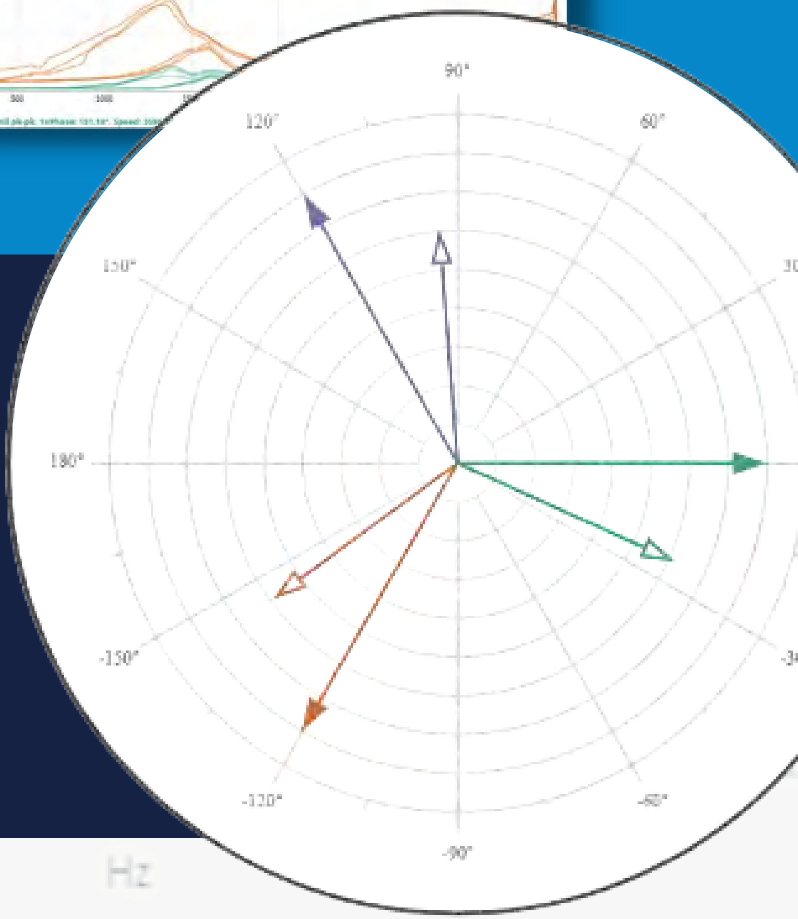




DATA VIEWERS:

- Trend
- Waveform
- Spectrum
- High Resolution Spectrum
- Torque Waveform
- Phasor Diagram
- Envelope (Amplitude Demodulation)

Cycling damage illustrated—and remedied

A plethora of ST/G cycling damage/failure mechanisms and major structural repairs are discussed and illustrated in a set of slides from Brian Grant, Advanced Turbine Support. While most are focused on the L-0 stage, low-pressure-section diaphragm nozzles and moisture drains and high-pressure packing gland seals also get attention (Fig 7). Closing words of advice: Do not rely only on info supplied by the OEM when planning repairs or assessing contingencies.

"Steam Turbine Cycling Risks"

Integrated monitoring lowers EFOR, cost per kilowatt-hour

The potential benefits of a comprehensive asset management and equipment reliability program, anchored by an integrated monitoring platform, are clear in at least four cases involving large power companies (Fig 8). So says David Bramhall, Cutsforth, who led the audience through a description of the company's InsightCM™ monitoring platform, with a focus on vibration and electromagnetic interference (EMI).

An eye-popping result at one plant: After putting together a list of equipment to inspect during an outage based on EMI readings, one plant added the isolated phase bus, not originally on the outage target list. Subsequently, 13 insulators were discovered to have moisture damage, which would likely have led to a forced outage in the near future.

"An Integrated Monitoring Platform Approach"

Poor maintenance, ops aggravate valve issues

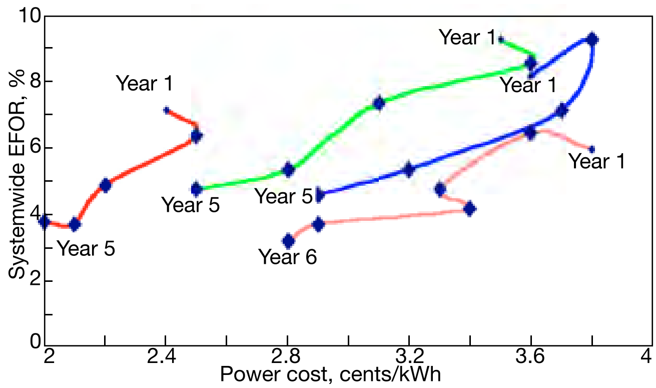
Dennis Watson, Independent Turbine Consultants, had some pretty stark words and observations for the STUG audience. Valve maintenance is a basic aspect of ST/G upkeep but is being neglected, he said. Most plants in his experience are not properly matching temperatures during starts and stops, aggravating oxide buildup.

Most germane to his presentation, though, is that when valve vendors tell users that oxide cleaning is "extra" cost, they interpret that as "optional" even though "80% of valve-stem sticking problems are caused by high-temperature oxides and inadequate removal when "cleaned." And grit blasting does not clean valve surfaces, it only polishes them. Check out the slides to learn how to do better—such as applying honing techniques with 50 and 80 grit emery cloth for deeper cleaning of critical components (Fig 9) and try bar tests to check balance chamber concentricity to the valve-stem bushing.

"Steam Turbine Valve Maintenance

Refresh on vibration standards

Gabor Tanacs, Siemens-Energy, in



8. Dynamic performance gains are possible when integrated monitoring is applied, though the evidence does not appear overnight addressing rotor-bearing vibration issues, mostly referred the audience to several standards because there are "inconsistencies" in what is monitored for rotor vibration.

The standards are ISO7919-2, "Mechanical Vibration—Evaluation of Machine Vibration by Measurements on Rotating Shafts," ISO10816-2, "Mechanical Vibration—Evaluation of Machine Vibration by Measurements on Non-Rotating Parts," and ISO13373-3, "Condition Monitoring and Diagnostics of Machines—Guidelines for Vibration Diagnosis."

Tanacs also listed common and uncommon causes of vibration, some of which are unique to the KN fleet. Mass imbalance, rubs, rotor-support degradation, and misalignment are the common ones. Steam instability (partial arc, steam whirl), bearing instability, and bearing loading are less common.

This presentation, "Rotor Vibration Troubleshooting," and the other two Siemens-Energy presentations made at the STUG 2022 meeting ("Erosion Monitoring and Corrective Actions" by Larry Smith, and "Application of the New 8.7-m² Steel Blade for the Existing Titanium L-0 Fleet" by Todd Bentley) are not available via the Power Users website. Contact steve.radke@siemens-energy.com for access.

Exercise caution with UT inspections of pinned L-0 buckets

Data in this user presentation clearly reveals that an ultrasonic (UT) inspection of L-0 pins in-situ from one side after sandblasting can be quite different from a UT done in the shop under controlled conditions. How different? The shop inspection identified over 170 pins with indications, the field inspection 725. The discrepancies greatly complicated the outage. The second part of the presentation compared several different methods for removing pins, with a valuable lessons-learned conclusion (Fig 10).

"Pinned L-0 buckets: Variability in UT Inspection Results and Pin Removal"

D11 HP/IP shells: 'Nightmare of 2013' and other bad dreams

User's discussion of observations and lessons learned during the second major of three D11 ST/Gs (commissioned in 2002) includes the "nightmare of 2013," when weld repair of HP/IP shell cracks (Fig 11) had distorted the shell at the horizontal joint, extending a 49-day outage to 95 days. Other issues present and depicted in the slides are HP/IP shell creep, packing and spill strip replacements, N2 offset machining and replacement, turning-gear issues,

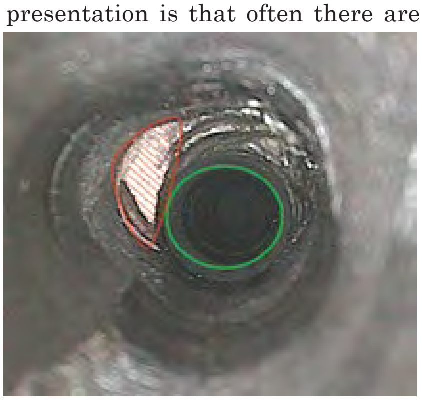
9. D11 stop valve pressure seal head as found stuck and galled (left); it was only grit-blasted during recent outage. Condition at right is after proper restoration of fit areas using 50- and 80-grit emery cloth bolting issues, and a rotor-bow incident.

Regarding the last problem, an 11-in. rotor bow was first observed in 2007, but despite the OEM's repair, the bow returned in 2012, and increased to 21 in. by the second major. User elected a non-OEM shop for a different repair strategy because the first one was not successful.

"D11 Second Major Observations/ Lessons Learned, including L-1 Inspection Findings"

L-0 risks illustrated for many makes and models

One overriding learning from this presentation is that often there are no indications of problems with L-0 stage blades during unit operation. This is astonishing, really, when you see the types and extent of some of the damage experienced by this owner/ operator across a variety of steam-turbine designs, machine ages, operating regimes, L-0 blade materials, rotor attachment methods, and OEMs over the last five years (Figs 12-14).



10. Removal of L-0 pins may not be as easy as you might think. Photo shows blade finger damage caused by drilling off-center in an attempt to remove this pin

The seven ST/G L-0 damage case studies examined in this slide deck have varied root causes. Recommendation: Increase inspection frequency! Conduct visual, borescope, and/or dye penetrant inspections during every major outage, especially since they don't require disassembly of the LP turbine. And pay attention to the OEM service bulletins.

"L-0 History and Concerns Including Recent Outage Experiences"

Major outages: Plan the work, work the plan

The best way to minimize outage time is to create a detailed, long-term maintenance plan for the unit, and an experienced turbine services firm can help. Tim Keen and Neil Jones, MD&A, take you through the obvious, like scope, schedule, and budget, but also overlooked factors like special tooling that may be required, structural steam-path audits, comparing clearances to those taken at the last outage, casing horizontal joint gaps and diameter out of roundness, valve operation, and coupling alignment.

"Outage Planning Focused on the First/Second/Third Majors"

Steam-path audit essential for restoring performance

Every ST/G major should include a structural steam-path audit as part of the lifecycle maintenance plan, say Neil Jones and Tim Keen, MD&A. The audit is an assessment by experienced steam-path engineers based on visual inspection of the rotating and stationary steam-path components and limited dimensional checks.

The inspection is best performed immediately after blast cleaning, but is not, caution the presenters, a substitute for nondestructive testing. Balance of slides review key inspection areas and typical findings richly illustrated through photos.

"Steam Path Audit and Lifecycle Management"

Upgrades, spares available for Rexroth actuator components

MD&A not only stocks over \$1-million in spare parts for Rexroth LP-turbine valve actuators (Fig 15), but has designed and implemented upgraded components to solve customer problems and extend operating life. Anthony Catanese's journey in slides begins with photos of common issues experienced with these actuators, then moves into design modifications for spring can retainers, pistons, packing glands, and disc spring coatings.

"Rexroth Turbine Valve Actuators"

11. Weld repair of casing cracks, such as those shown here, was linked to shell distortion to the degree that a planned 49-day outage went to 95 days

GE addresses recent TILs, top issues

In what GE ST/G owner/operators should probably consider essential information, Matt Foreman and Paul Roche introduced the OEM's session by addressing what they called the "top issues" (and their associated TILs). In order of appearance, they are:

- L-0 CAE dislodged mid-point sleeves (TIL 2294).
- KA 24 ICS (Alstom) steam-turbine IP rotor cracking (TILs 2052, 2205, 2230, 2315, 2316).
- Regular (daily) control and stop valve testing.
- Annual last-stage-blade inspections, now recommended for all ST/Gs.
- Finger dovetail L-0 cracking (TILs 1847, 1874).
- Critical D11 casing findings (numerous), some of which are "surprising" in units 15-20 years old.
- Moderate-to-severe main-stop/control valve (MSCV) casing cracks in less than 15 years of service.
- N2 packing-head replacement experience (TILs 1627, 1748, 1749) to reduce premature failure of the shell.
- D11 HP/IP horizontal joint leakage.

Slide decks for the Top Issues and TILs identified above are not available via the Power Users website. To access, log into your MyDashboard account on the GE website.

Is poor insulation impacting cooldown?

This is the question GE's Peter Eisenzopf asked indirectly as he discussed results from a fleet data review of 300 ST/G units. Insulation matters is the abridged conclusion. New insulation installed during an outage may not be "high quality," he stressed, and encouraged users to request an insulation quality study during their next GE-driven outage. The study confirmed that cool-down performance is improved by replacing current material with world-class insulation. There was not a clear answer when an audience member asked if there is a spec available for "world class insulation."

"Importance of Insulation and Indicators of Concern" Not available via the Power Users website. To access, log into your MyDashboard account on the GE website.

Add expertise during your STF 30 (Alstom) ST/G outage

If you have an Alstom STF 30 ST/G, you won't want to miss this presentation on outage experience at a 2 × 1 combined cycle by an owner/operator

12-14. Results from seven L-0 case studies illustrate damages that can occur and not be evident when the unit is operating

with six sister ST/G units in the fleet. One of the more valuable contributions you'll find in the slides are the decisions made by the operating/engineering folks as issues were discovered with the equipment.

Detailed lessons learned provided at the end can be summed up with three considerations: Have more expertise on hand, such as a turbine field advisor/engineer (TFA) as part of the contract and/or a commissioning expert for new complex components; increase communication between shop and field (to discuss dimensions, for example); station site personnel at the shop during critical phases; and order parts 12-18 months ahead of the outage.

"Alstom ST Major Outage Observations/Lessons Learned"

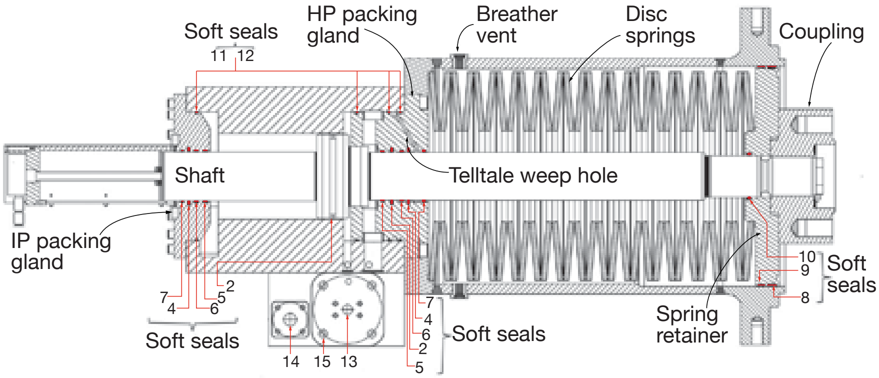
First outage experience: lessons learned, plus fun photos

This owner/operator presentation on experience with its first outage (10 year) on a Mitsubishi TC4F 573-MW ST/G in a 3 × 1 configuration includes as a bonus experience with a 2021 outage of HP stop valves, HP control valves, intercept valves, and reheat stop valve. One issue here was OEM's lack of tooling.

A more salient piece of advice in the lessons learned from the big turbine outage: "Always make friends with a local machinist." Other suggestions include: ensure actuator soft parts and piston rings are in alignment with type of oil, test all OEM tooling during the outage, and sharp-tooth packing is worth more than a dull tooth.

While the details of both outages are worth reviewing, this quote from the plant after restart says much about how the outage went: "The unit did not even squeak when put on turning gear and spun up."

"Mitsubishi CC ST First Major Outage Observations/Lessons Learned"



15. Upgraded components are available for Rexroth valve actuators, often described as complicated because of their bells and whistles

16. Debris on turbine blades could not be removed and the Stage 12 airfoils were replaced

Diaphragm failure takes unit out five months after successful 20-year major

This presentation on a D11 first major outage (20 years in) includes a twist of an ending: While the ST/G major was very successful with a subsequent "exceptional startup," low vibration, and better than expected performance, four months later site staff observed a loss of approximately 20 MW, elevated reheat pressure, and other maladies. A month later, the unit was shut down to investigate.

Damage to rotor stages 12 to 18 was noted with debris on the blades which could not be removed (Fig 16). Rotor and diaphragms were sent to a shop in Houston, and extensive, surprising (considering the major concluded five months prior) damage to the diaphragms had to be repaired. Root-cause analysis report was being finalized but the direct cause reported was failure of the Inconel 82 partition repair which resulted in the blade damage and restricted the throat area of the turbine.

"D11 Major Outage" CCJ

Management of compliance risks focus of NAES meeting

Why would NAES Corp, the largest third-party O&M services provider to combined-cycle facilities, run a three-day conference on NERC-related issues and compliance for its people and select clients and industry stakeholders? For one thing, NAES has 130 plants under its purview and supports over 100 plants outside its portfolio.

Then you might ask: Why does NAES have over 20 subject-matter experts (SMEs) in its NERC Compliance Services Group, which also includes a Compliance Testing arm? The answer: Managing NERC compliance risks for clients is a business in itself, and a key area of growth for the company. It is also considered a competitive distinction by NAES executives.

As one presenter, from a major ISO, put it, "the operations staff does not have the desire, or time, to review or interpret regulatory requirements in real time." Put another way by another presenter, CIP (critical infrastructure protection) standards are now too complicated for the typical plant employee; many asset managers simply don't have the experience or the background to manage NERC compliance risks.

A NAES NERC services group leader added, "NERC now has to be taken into account for any project, big or small, that has potential to impact facility output." Scenarios he gave as examples include engine (GT) tuning, for which he listed six impacts of NERC standards; relay upgrades, which touch at least four NERC standards; and excitation control upgrades, which touch at least seven standards.

While the depth and breadth of the material presented was, well, almost overwhelming, much of it of most interest to combined-cycle owner/operators centered on EOP-011-2, recently adopted by NERC (but still in draft) addressing emergency operations and preparedness generally, and cold-weather readiness in particular.

One presenter suggested that valid bids into ISOs will be required to submit new weather-related data, such as minimum design temperatures, historical operating temperatures, and current cold-weather performance temperatures *as determined by engineering analysis*. EOP-011-2 includes deadlines and procedures for cold-weather preparation plans, identifying and tasking a responsible coordinator, definition of the "cold-weather period," assessment of winter readiness, and new monitoring requirements for detecting failures, especially in heat-trace systems.

Update: There is now a Standard Authorization Request (SAR), entitled "Extreme Cold Weather Grid Operations, Preparedness, and Coordination" (Oct 6, 2021), that would add some additional requirements to EOP-011. These would include requiring annual training for generator owners and operators, detailed root-cause analyses for any freeze-related failures, and retrofit of existing generating units to operate in "extreme" weather conditions for their locations.

As one concrete impact, additional operator rounds will be required when ambient temperatures fall below certain limits, such as rounds once per shift when temperature falls below 32F, two rounds per shift when below 20F, and so on. Anything that could initiate an automatic trip should be included on these rounds. Training in cold-weather operations will have to be provided to site staff.

Reflecting, one highly experienced industry engineer advised that temperature is only part of the equation. Wind direction and velocity also are meaningful factors, he said, as are duration and current plant state (running, offline, etc). He recalled working at a facility that could run/start/operate at -20F when there was no wind. But when there was a 20-mph wind from the West it struggled at +20F. After five years of operation, staff was still ill at ease when confronted with uncommon temperature and wind combinations.

One of the presentations provided some instructive real-world cold-weather horror stories, including these:

- A 2 × 1 combined cycle in Nevada, designed with a 15F heat-trace system, experienced 7F ambient. The GT inlet bleed valves started behaving erratically, and operators were cycling through fans to keep the air-cooled condenser operating. When the cold-reheat pressure transmitter froze, it tripped the plant. One week later, the plant was able to restart.
- A 2 × 1 plant in Washington state suffered a cold snap and heavy snow. Natural-gas demand in the area overwhelmed supply lines. Ice and icicles formed. The fuel-gas system alarmed on low pressure. When the third fuel regulation station failed to operate, the unit tripped. Moisture trapped in piping froze.
- At a third facility, $100,000 worth of transmitters had to be replaced after a cold-weather event; water buildup in low points of oil feed pipes froze, and ice built up on the cooling towers because they lacked drift eliminators.

The presenter concluded with the mention of a plant which had to spend $4.5-million to be capable of running during extreme cold weather.

Among the other jewels of knowledge shared at the conference:

- Lessons at the industry level tend to get lost rather than learned. For example, Ercot experienced catastrophic cold-weather events in 1988 and 2011, and then again this past winter.
- Texas has 190 registered "generation owners"; 100 of them are new in the last five years, which means they may not be battle-tested for extreme weather events.
- The 70-member North American Generator Forum (NAGF) focuses on the NERC activity which directly affects the generator segment, and has six working groups, one of which focuses on the emerging cold-weather standard.
- NERC may create a "resilience" standard (in contrast to reliability). NAGF is busy determining the "cost of resilience," a value to base investment on, since, according to the presenter from the group, organized markets do not support the value of resilience and the costs are born unequally among stakeholders. CCJ

Power Plant Controls Users Group™

PPCUG steering committee, 2023

Chair: David Martorana, operations program director, *Tenaska*
Vice Chair: Richard Chiafolo, consulting engineer, *Dominion*
Brian Hall, maintenance specialist, *TECO Energy*
Jason Justice, principal engineer, *Southern Company*
Eric Mui, controls engineer, *Talen Energy*
Peter So, director of project management and development, *Calpine*

The Power Plant Control Users Group conducts is sixth annual symposium at the Power Users Combined Conference, August 28 – 31, in the Omni Atlanta Hotel at CNN Center. The group, organized in 2018 to provide an open forum through in-person meetings and online seminars, disseminates information of value to owner/operators regarding the operation, maintenance, inspection, troubleshooting, and repair of control systems tasked with maximizing equipment performance and reliability.

While controls user groups serving the electric power industry typically focus on a given product—the Siemens T3000, for example—PPCUG presentations and discussions cover systems and equipment made by all OEMs and suppliers.

2023 conference overview

Technical program for the upcoming meeting was developed by an all-volunteer steering committee of industry engineers with deep controls experience identified in the sidebar and accompanying photo. An overview of the presentations scheduled for the week beginning August 28 follows.

Expectation is that most of the presentations will be made available to owner/operators through the Power Users website a few months from now—except for those by GE and Siemens-Energy. Access the GE PowerPoints at https://mydashboard.gepower.com; the Siemens-Energy presentations on the company's Customer Extranet Portal, https://siemens.force.com/cep.

Slide decks from 2022 and earlier meetings already are accessible to registered users. If you are not registered, sign up now at www.powerusers.org: It's easy and there's no charge.

You can get a good idea of the fine work this organization performs by perusing the summaries of presentations made by both users and vendors last year. They follow the 2023 overview immediately below. You're likely to find some best practices and lessons learned ripe for implementation at your plant.

Monday, August 28. The morning program begins with two presentations by Beamex: "Using Metrology Fundamentals in Calibration to Drive Long-Term Value" and "Optimal Testing Parameters for Process Instrument Calibration."

GE takes the podium after the break, speaking to the following topics:

- Asset performance management.
- Dispatch optimizer.
- PII—getting the most out of your PI system.

The afternoon is dedicated to training, with ABB, GE, and Process Innovations leading the "beginner" program before the afternoon recess. For maximum benefit, participants are urged to bring their own devices and to connect to their systems.

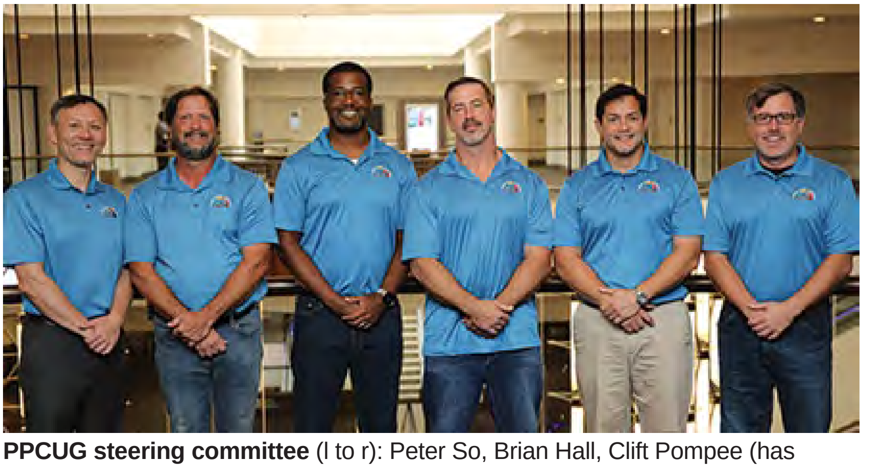
The program for experienced attendees following the break focuses on GE's Mark VIe turbine and plant control systems, including fundamentals of maintenance and troubleshooting, as well as on system architecture by ABB and Process Innovations.

Tuesday, August 29. ABB starts the day with "A Practical Approach to Alarm Management and Rationalization" and "Innovative Combined-Cycle Control Philosophy." Following the morning break, PSM speaks to "Operational Intelligence—Augmenting Your Plant with Self-Learning Algorithms and AI-driven Analytic Capabilities," and Black & Veatch to "Using Real-Time Data Analytics to Improve Asset Reliability and Performance Across a Combined-Cycle Fleet."

GE has the afternoon program. Here are its talking points:

- GE and Nexus together: Moving forward (cyber, HMI, platform, lifecycle).
- Pre-start checks.
- Sliding-pressure control and auto governor testing.
- Technology refresher.
- Alarm rationalization.
- Advanced attemperator controls.
- Lessons learned from the field.

Tuesday's technical program ends



PPCUG steering committee (l to r): Peter So, Brian Hall, Clift Pompee (has since transferred to the LCPG), Jason Justice, David Martorana, Richard Chiafolo at 5 when the three-hour Vendor Fair begins.

Wednesday, August 30. Emerson presents first, on advanced system logic. HRST follows on duct-burner flame-detector controls. After the morning break, Siemens-Energy takes command of the podium until the afternoon recess. Lunch interrupts from noon to 1 p.m.

Here's the Siemens-Energy lineup:

- Steam-turbine modernization options for combined-cycle plants.
- Live visualization of plant and equipment engineering.
- The challenges of effective OT cyber monitoring.
- Plant flexibility and integration with intermittent generating assets.
- Low-load operations.
- Operator training through web-based virtual plant simulators.

These presentations close out Day Three:

- I&C training and outage support, Endress+Hauser.
- Lessons learned of controls replacement with obsolete equipment, MD&A.
- Battery Energy Storage System black start.

Thursday August 31, the final day of the conference, morning only, is planned for a series of user and vendor presentations—possibly as many as eight. But details were not available at press time. Follow program developments on the PPCUG pages of the Power Users website at www.powerusers.org. Alternatively, you can come up to date when you register for the conference.

2022 conference report

The Power Plant Controls Users Group (PPCUG), at its 2022 conference (San Antonio, Aug 29-Sept 1), catalogued leading issues affecting plant control, monitoring and diagnostics (M&D), and automation systems. Presentation abstracts below are based on information available in the slide decks posted at www.powerusers.org. Those seeking deeper dives into specific topics should note the presentation titles in italics at the end of each summary and access the source material on the website.

Build a Mark VIe controller

If you'd like to learn how to build a controller for the Mark VIe control system, select variables and constants, add logic, change setpoints, and use the configuration, then these two sets of slides will get you familiar with the screens involved. The second training "lab" focuses on trip logs, historical data collection, and the PI historian.

"Mark VIe Controls Familiarization Lab 1: Variables, Logic Types, Cimplicity" and *"Lab II: Watch Window, Trender, DDRs"*

No historian? No problem

These user-provided slides show you how to "look at high-speed historical data from your GE Mark VI or VIe even if you don't have a GE historian." GE ControlST software, in an area called WorkstationST, has a feature called "Recorder" which has many of the same functions as a historian. In particular, the presenter drills down to explain how to set up the "continuous collection" feature of "Live Data Collection," and offers two methods for viewing the data.

"GE Controls ST Data Collection Tools"

Extract more value from PI

The seasoned PI administrator for a large fleet gives tips for extracting more value from your data historian, particularly in the areas of getting better data (compression and exception functions), improving analytics, and facilitating reporting. A real-world example of almost draining a chemical tank and suffering equipment damage illustrates some of the points.

"Making the Most of your PI Historian"

Plan for supply-chain disruptions

During a suite of vendor presentations, two OEMs addressed supply-chain challenges. One said a major chip supplier announced "allocations" around the primary CPU in the family of controllers used in the Mark VIe. The other OEM rep said lead times have been extended by 50% to 100% since 2019, but also implied that the worst was over.

"Our procurement systems were not really that sophisticated," one presenter admitted, addressing internal supply-chain issues. "We had too many single-source suppliers, poor visibility into sub-sub-suppliers, and no end-to-end forecasting."

This apparently has been rectified, in part through multi-vendor sourcing agreements and digital surveillance capability over sub-suppliers. The only recourse for users has been to postpone obsolescence-related replacements, collaborate more tightly on advance planning for upgrades, and expect and be prepared for controller failures.

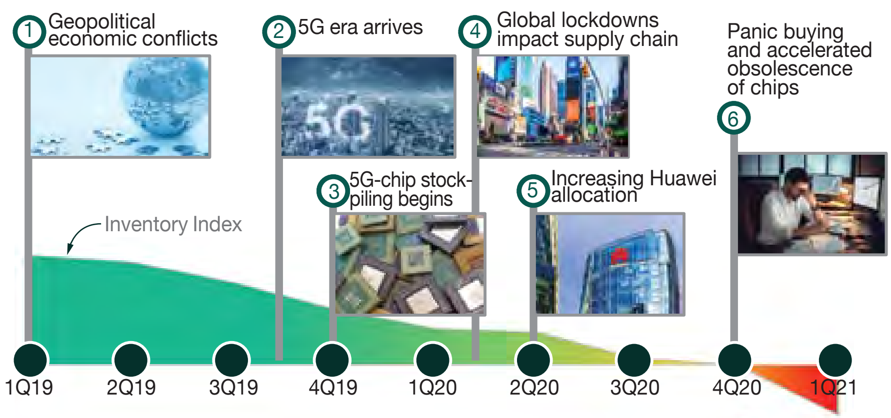
OEM presentations are not posted on the Power Users website. To access Siemens-Energy slide decks, write galen.george@siemens-energy.com. For GE, log into your MyDashboard account on the GE website.

Partner with a controls specialist

John Emery, Nexus Controls (a Baker Hughes business), urged users to consider a partnering arrangement with a controls specialist firm for "fully integrated controls and cybersecurity solutions." World-class training services, preventive maintenance, remote diagnostics, and even remote service, are available, along with in-kind and upgraded components, and advanced software.

"Controls Overview"

Supply-chain struggles to continue



1. Conversion to 5G networks drove chip stockpiling, and along with other factors—including global pandemic lockdowns—led to the supply-chain issues affecting plant control systems. Source: 1Q21 Gartner Semiconductor Electronics Forecast Update. Recall that Huawei Technologies Co is a multinational technology corporation headquartered in China

through 2023

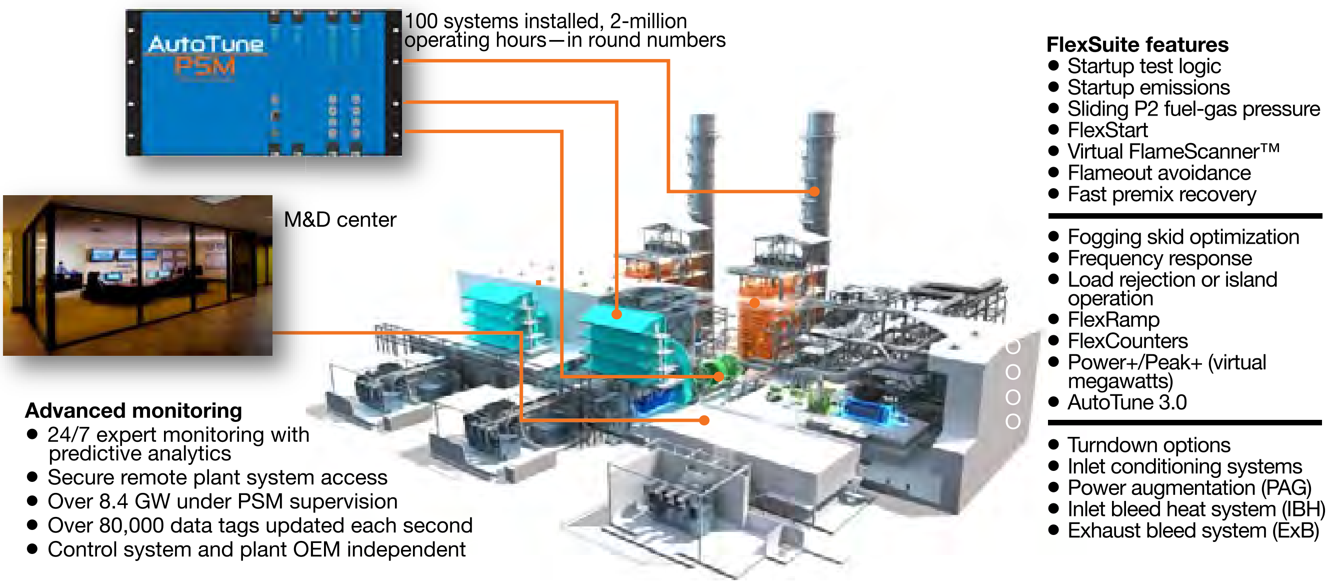
Carrying on the prevalent theme from controls OEMs, Jaime Butler, Nexus Controls (a Baker Hughes business) included a few valuable slides which help explain the supply-chain disruptions most users are experiencing for chips and other electronic components. The global pandemic was only one of the drivers.

Unfortunately, the conclusion is that, while inventory for unconstrained components will continue to build, products dependent on field programmable gateway arrays (FPGA), power management integrated circuits (PMIC), and microcontroller units (MCU) will continue to struggle. Butler suggests several proactive solutions to mitigate risk.

"Supply Chain"

Differentiate alarm audio tones

Most plants with digital control systems suffer from alarm overload in the control room and have applied better methodologies to reduce the number of alarms, prioritize them, and reduce the burden on operators without sacrificing their attention to the ones that matter. A unique feature of



2. Digital platform enables proven solutions for partial or complete plant optimization around a variety of engines, combustion systems, and control systems the alarm methodology described here, by a large-fleet user, is applying unique audio tones to indicate alarm priority.

Two real-world examples are included: A generator-field ground-detector test from the human machine interface (HMI) and turbine lube-oil leak detection.

"Alarm Management: Generator FGD Testing, Leak Detection"

OEM versus non-OEM: Get R.E.A.L.

"OEM and non-OEM suppliers are battling these days for the customer, and in some cases are practically giving away the hardware." So states a presenter from TC&E, a division of AP4 Group, in reviewing the merits of choosing one over the other, mostly illustrated through a series of questions posed to the audience. Four areas—reliability, efficiency, affordability, and longevity (R.E.A.L.)—are explored.

"OEM versus Non-OEM Controls"

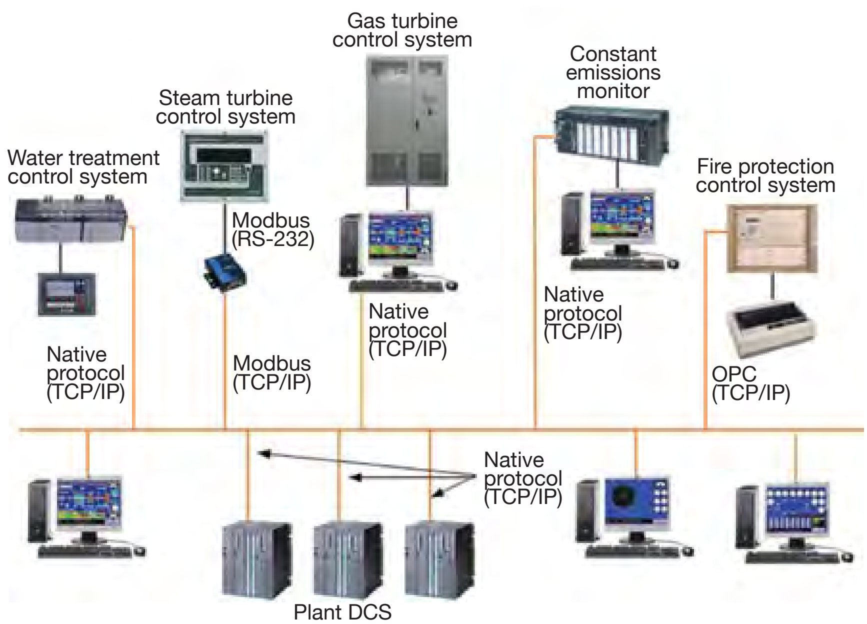
How to be an effective owner's engineer

Abel Rochwarger, GTC Control Solutions, a division of AP4 Group, offers lessons learned from controls upgrades of two gas turbines. Findings include mislocation of power supplies, errors in drawings, and missing SCR fault-detection coils. The mission, he says, of an owner's engineer is to avoid conflict and deliver good service.

"Controls Upgrade? Lessons Learned"

Migrate to EGD Mark VI-to-Ovation Interface

A representative from Emerson explains how to migrate from a "traditional" GSM-to-Ovation interface to an Ethernet Global Data (EGD) interface and the many advantages



3. Single HMI software solution enhances protection among the DCS and individual control systems, provides unlimited data-exchange capability, and assures automatic time synchronization among the various control systems which can accrue to the user—including accessibility of Mark VI alarm and events, avoiding an OPC connection thereby increasing communication speed, availability of monitored points in all Ovation applications, and capability to run in parallel with Mark VI HMI. The direct interface sets the stage for remote start/operation, single-window control room, Mark VI HMI replacement, and advanced supervisory functions in Ovation.

"Direct EGD Interface with GE Mark VI and Mark VIe"

Full suite of control, M&D solutions

Katie Koch, PSM, made clear that PSM has solutions for optimizing your control and M&D systems, and they include assistance with 24/7 M&D, optimization algorithms (Autotune, FlexRamp, FlexStart, and FlexFuel), hardware and interface replacements and upgrades, fleet-level benchmarking, actionable intelligence for performance improvements, and even a full digital twin. Twelve engine platforms, eight combustion systems, and nine control systems make up the company's experience base with these solutions.

"Digital Twins"

Single HMI, control retrofits

MD&A's Control Systems Division offers a variety of services for steam turbines, gas turbines, and generator exciters ranging from consulting and field engineering (including owner's engineer) to replacement parts for legacy systems. Presenter Joe Hovorka dwelled at length on MD&A's IBECS HMI which unifies and simplifies multiple legacy control system HMIs into one interface. IBECS is compatible with all major digital turbine controls, Hovorka noted. Seven case studies are presented, with attached one-page summaries of successful recent projects.

"Controls and Excitation Overview"

Automate generator gas-manifold purge

Mark Williams, Environment One Corp, stressed that automating the purging process can significantly reduce purge time required, consume less CO_2, and protect personnel in the event of an emergency. Slides review options for automating valves, tie-in points, example P&ID, and sample automation purge screen.

"Operator- Initiated Generator Purge/DHCP Upgrades"

Remedies for real-world controls issues

The range of issues detailed in this presentation from a seasoned controls expert working for a major fleet owner/operator almost defies current trends in user conference presentations. Each issue may not apply at your plant, but together they comprise almost a control engineer's log of issues and remedies.

Included are turbine-oil leak-detection alarm, water ingress into GT exhaust and accumulation under the plenum from offline water wash, excessive gas flow at startup (TIL-2319), enhancement of ECC correction algorithm for UCSB (TIL-2290), auto NO_x bias adjustment, liquid fuel system reliability, emergency bearing oil pump test prior to startup, steam injection bias, compressor bleed valve (CBV) flow issues, action of CBVs during startup, load commutated inverter (LCI) cross-connect, and isochronous control.

"GE Controls Enhancements"

Users visit Continental Controls during WTUI 2023

Western Turbine Users Inc, the world's largest organization of aeroderivative gas turbine owner/operators, conducted its 32nd conference last March at the San Diego Convention Center. With nearly 1000 industry participants from around the globe just 15 minutes from company headquarters, WTUI exhibitor Continental Controls Corp opened its doors to present CCC's recently expanded capabilities and resources for the manufacture of fuel-gas control valves.

With over 20,000 ft² under roof, Continental Controls offers in-house manufacturing and testing, vertically integrated with an internal machine shop, electronics assembly, and R&D lab.

CCC President Dave Fisher (Fig 1) and his management team conducted a facility tour, showcasing the latest technology used in producing parts for the company's products—like its AGV10 advanced gas-turbine fuel valve (Fig 2). Assembly and product testing stations were available for the users to explore, providing a comprehensive and first-hand understanding of operations while introducing them to the engineers and technicians who do the work.

First stop on the tour was the assembly area for the AGV10 valves used to meter fuel to gas turbines rated up to 28.5 MW—about the output of an LM2500 engine. There are only minor differences in the valve models (Fig 3) to accommodate specific turbine engines.

The valves are designed to provide an optimum interface between the control system and gas turbine. Valve control is linear—that is, fuel flow is proportional to the 4-20-mA fuel demand signal from the PLC.

1. President Dave Fisher welcomes turbine users to CCC's new San Diego facility

Keith Flitner, VP sales and marketing, said the valves have exceptionally fast response times and provide outstanding transient performance when used in gen-set applications. Plus, they also provide superior turbine performance in any mechanical-drive application (compressor and pump).

The high accuracy of the valve in the start fuel range assures the turbine will have excellent light-off and consistent starting characteristics.

At the second stop, Sales Engineer Eric Allen walked visitors through the company's Gas Substitution System (GSS) that allows fuel oil to be substituted for natural gas. Advanced substitution control is achieved through direct interface between the GSS and Engine Control Unit (ECU).

2. Keith Flitner, VP sales and marketing, explains the AGV assembly area to guests

3. The AGV10 valve meters fuel to gas turbines

At nearly any load condition and application, the GSS substitutes the maximum amount of diesel oil without sacrificing engine performance or power output. The GSS uses proven technology, field-tested with years of successful performance.

An upgrade to CCC's ECV5 fuel-valve-based system for NO_x control also was mentioned at the open house. It is capable of achieving near-zero ppm NO_x, capitalizing on the company's long history of advanced control logic software development and system integration experience.

4. Eric Allen, sales engineer, explains the gas substitution system to attendees

PressureWave+: HRSG deep cleaning effect

By Marc Keusch, John Weimar, and Kenneth Hutchison

As grid dynamics evolve, plant efficiency and fuel costs have become increasingly important for combined-cycle asset owners. Operators are requesting low-cost support to achieve incremental gains in performance of their assets to ensure they can continue running profitably with as minimal impact to other maintenance work as possible.

User challenges. On the gas side of finned tubes, two types of fouling often are observed in the cold end of the HRSG: corrosion and deposits (Fig 1).

Corrosion occurs when water and carbon steel interact, causing oxidation. Spallation of the material on the tubes (rust) leads to reduced surface area, impacting HRSG heat-transfer efficiency and potentially causing reliability issues (leakages).

Different types of deposits can accumulate on the finned tubes—typically these:

- Ammonia salts downstream of the SCR.
- Sulfur deposits if fuel has high sulfur content (natural gas or oil).
- Insulation debris, upstream damage, or broken equipment.
- Combustion byproducts from liquid fuel firing (ash and contaminants).

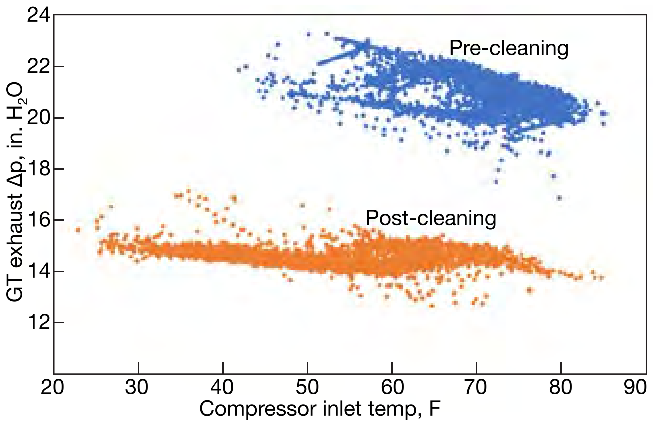
Fouling penalizes combined-cycle performance in two ways:

1. It increases gas-turbine backpressure (Fig 2). Recall that the HRSG is designed aerodynamically in the gas path. Fouling disrupts this flow, increasing the backpressure and slowing the rotation of the gas turbine. Result: Reduced GT power output and increased fuel costs to maintain the same mass flow at lower efficiency.
2. It reduces HRSG heat-transfer efficiency, thereby increasing the moisture content of the steam produced and reducing steam-turbine output.

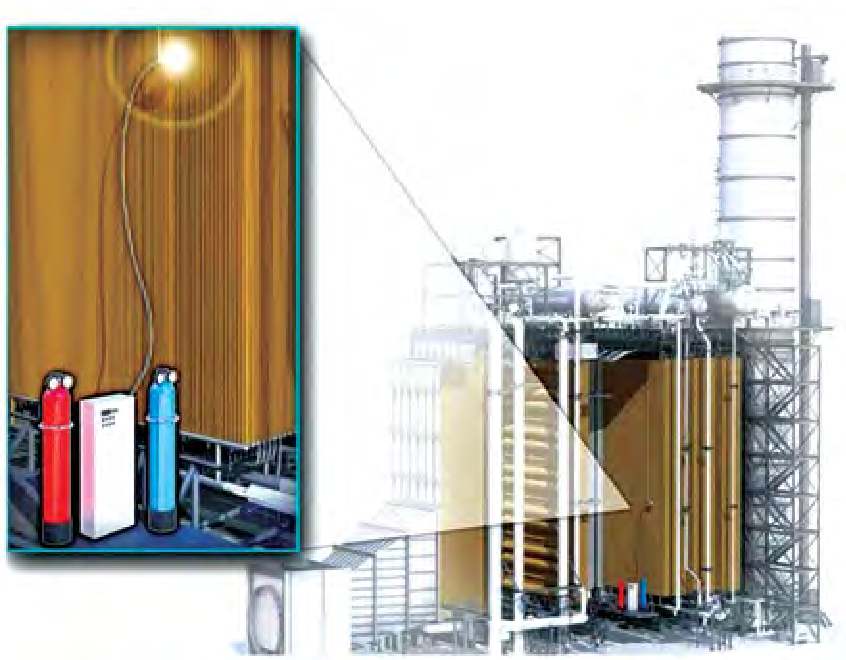
The deep cleaning effect. To remove fouling from HRSGs, a special bag is positioned between HRSG modules via rigging and a flexible lance. The bag is filled with a gas mixture which then is detonated. Combustion of the gases results in a pressure wave that propagates through the tube bundles and dislodges the debris, which then falls to the lower vestibule in dry form. The placement and spacing of the bags prior to the pressure-wave initiation follows a grid-like pattern throughout the equipment. Each cleaning grid is based on the studied pressure drop off over distance, and the degree and composition of fouling.

The standout benefit of PressureWave+ (PW+) is the engineered, deep cleaning of the tube bundles. The PressureWave+

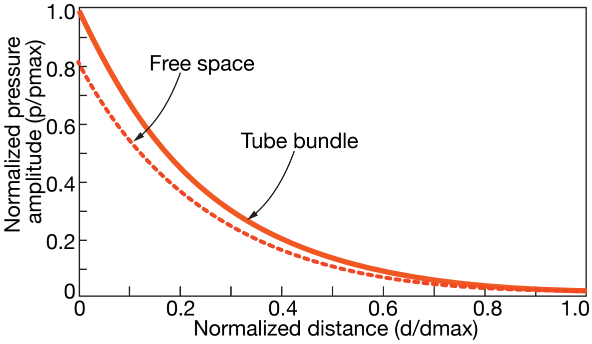
1. Two types of fouling often are found at the cold end of the HRSG—corrosion of heat-transfer surfaces (left) and deposits of ammonia salts, debris, combustion byproducts, etc (right)



2. Exhaust back pressure for a typical F-class gas turbine before and after cleaning



3. A special bag is positioned between HRSG modules via rigging and a flexible lance. Bag is filled with a gas mixture and detonated. Resulting pressure wave dislodges debris



4. PressureWave+ deep cleaning effect is characterized by curves of normalized pressure as a function of normalized distance both in the tube bundle and free space (Ref: R Steiner, https//www.linkedin.com/in/reto-steiner-a07a16111/recent-activity/shares/)

technology, developed by Bang&Clean Technologies in Switzerland, has been in use for over 20 years worldwide and has been applied successfully by GE on more than 375 HRSG cleanings in combined-cycle plants globally. Cleaning significantly reduces fouling made up from corrosion products, sticky salts, corrosive sulfur powders, and incompletely combusted fuel byproducts.

PW+ has proven effective in cleaning tube bundles of 10 or more rows deep while effectively removing fouling from tubes in bundles twice that depth. This includes tubing arrangements that are in alignment or offset and of different designs, as well as those impeded by structural members that could hamper access and cleaning efficiency.

User benefits. PressureWave+ technology provides plants these benefits:

- Cleaning risks to equipment and personnel mitigated through engineered technology.
- Safe continued work on the turbine and to the outside the HRSG during the cleaning.
- Deep cleaning in areas that cannot be reached by conventional technologies.
- Two to seven times more debris removed than with conventional methods.
- Cleaning done in 25-50% of onsite cycle compared with conventional methods.
- Faster cleaning following plant shutdown (even before HRSG is completely cooled).
- No water, no chemicals used on the tubing, thereby reducing corrosion potential.
- No scaffolding needed.
- Fast mobilization.

HRSG structural integrity. Many customers have asked if the PressureWave+ cleaning process is safe for the mechanical integrity of aging pressure parts. Multiple studies describe and systematically confirm safety and effectiveness.

First, effective cleaning deep into the bundles is possible without manual handling or high explosives. User-funded research institutes, Bang&Clean, and GE collaborated on data collection and analysis to define the results observed during outages. Fig 3 shows how the pressure waves interact with the tubing to clean deep into the bundles. This demonstrates the observed cleaning of tubes shielded directly from the PW+ tooling.

When comparing the pressure amplitude in the free space with that in the tube bundle, the amplitude within the bundle is higher. This amplification within the bundles is attributed to the interaction of the pressure wave shock front reflecting both off the tube walls and itself. This integration of waves (mach reflections) allows for removal of the debris that has built up on the back side of the tubing, thus increasing cleaning effectiveness (Fig 4).

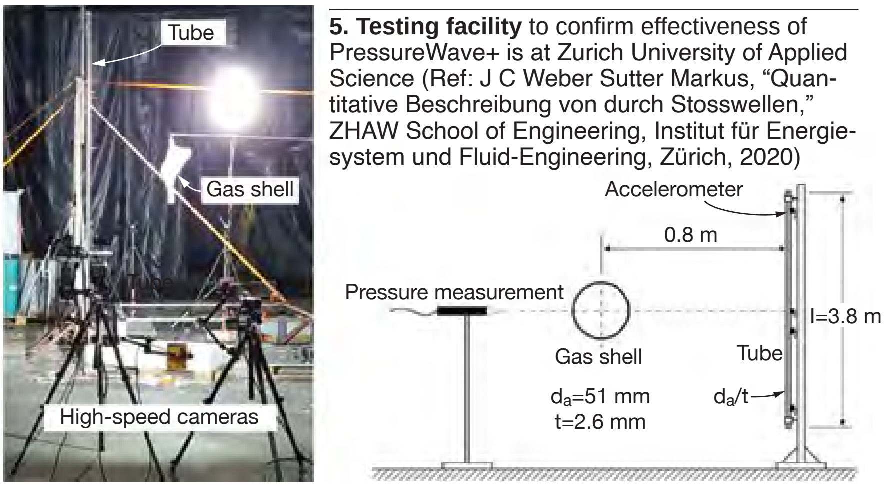
PressureWave+ wave propagation and its strength influence on structures was investigated and validated by simulation (Fig 5). Using existing and new data, numerical stress analyses were completed (Fig 6). The modeling led to this conclusion in the Zurich University of Applied Science review, "In the considered realistic load cases, a permanent deformation due to the detonation can be excluded."

The testing and modeling also detail impact and tube to weld seams experience the greatest stress. This is where the greatest deflection can be observed. It is assumed the resulting harmonic. This harmonic did not result in permanent deformation (Fig 7).

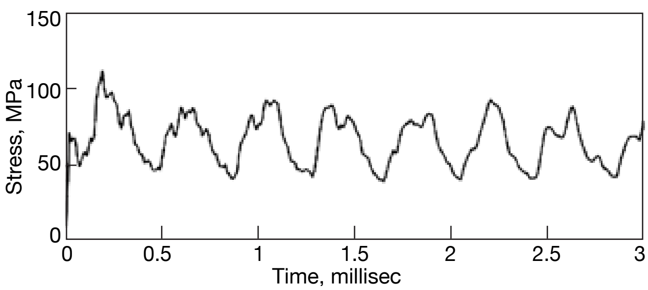
Finally, the PressureWave+ technology was originally designed to clean waste-to-energy boilers during operation. As such, the risk of causing damage to an online unit which would require shutdown was unacceptable and had to be mitigated. Pressure-wave strength and speed are optimized for where effective cleaning is possible, and the risk is mitigated for boiler components.

The evidence to support these claims includes the following:

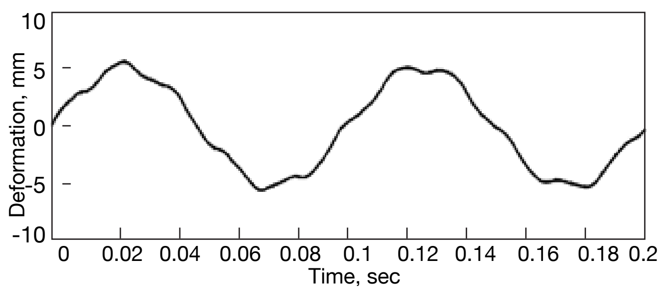
- Scientifically reviewed by the Zurich University of Applied Sciences.
- EPRI review of speed and energy of the pressure wave.
- Over 20,000 successful cleanings of steam generators since 2001.
- More than 375 HRSG cleanings.



5. Testing facility to confirm effectiveness of PressureWave+ is at Zurich University of Applied Science (Ref: J C Weber Sutter Markus, "Quantitative Beschreibung von durch Stosswellen," ZHAW School of Engineering, Institut für Energiesystem und Fluid-Engineering, Zürich, 2020)



6. Stress (von Mieses) in the pipe as a function of time, t (period of direct exposure to pressure waves)



7. Deformation in the center of the tube

HRSG maintenance: normal, major, preventive

The complex steam/water circuitry of heat-recovery steam generators, especially that in the multi-pressure HRSGs typically used in large-power applications, often requires special considerations when scheduling and performing maintenance and repairs. Many combined cycles go through multiple load changes daily—including on/off operation—which put intense thermal, mechanical, and water-chemistry stresses on components, thereby aggravating potential failure mechanisms.

Apart from the tightly packed tube bundles, inspection and evaluation of other components, such as ducts and valves, may be more straightforward. Important is to have a well-designed plan for normal, major, and preventive HRSG inspections and maintenance. Here SVI Industrial's highly experienced experts examine critical items in this regard.

"Normal" inspection, maintenance. Visual inspection and sometimes accelerated repair of select HRSG equipment items are possible during an outage. These include:

- Inlet and outlet duct liners.
- Dampers.
- Duct burners (for HRSGs so equipped).
- Valves.
- Outer evaporator and superheater tubes.
- Evaporator drums.

Also, some normal and preventive evaluation is possible with the unit in service. Example: Erratic operation of valves and dampers may become evident from sudden, suspicious changes in flow, pressure, and temperature data. Experienced operators often can detect a boiler tube failure by a change in sound, where follow-up acoustic monitoring may pinpoint the location. Diligent tracking of makeup water consumption can indicate a boiler tube leak, especially if the usage suddenly increases.

During outages, visual inspections of burners, ducts, and dampers will reveal damage that supports planning for later repairs or on an emergency basis if necessary. Drum inspections are very important to examine internals—including steam separators—to ensure all components are structurally sound and in proper alignment.

The presence of deposits and the coloration of drum internal surfaces can indicate either good or inadequate chemistry control. Borescope inspections of selected riser tubes may show iron oxide or other deposits, which suggests chemistry or water-treatment problems. With that latter thought in mind, important whenever possible during all visual inspections, is photography. Photos are very valuable for monitoring potential issues over time and for preparing reports discussing needed corrective actions.

Major maintenance. Any number of factors can lead to a major maintenance issue. These may include anticipated events—for example, catalyst degradation over time—to sudden boiler tube failures from perhaps a water-chemistry upset, metallurgical problem, or fatigue issue. Some of the most common major maintenance items include the following:

- Boiler tube repair or replacement.
- Harp or panel replacement.
- Catalyst replacement.
- Duct-burner repair or replacement.
- Main-steam stop valve replacement.

On rare occasions, replacement of a failed boiler tube might not be severely compromising if the failure occurs in an outer tube with easy access. However, from a statistical standpoint, failures most often occur in tubes buried within a harp or bundle. Such locations are very difficult to reach without extracting other tubes.

Potential tube failures emphasize the importance of operating the HRSG within proper ramp-rate guidelines, and in maintaining recommended chemistry at all times, acknowledging that unit cycling can make these tasks difficult at times. CCJ has reported on HRSG chemistry for many years, so this information is readily available in the publication's archives as well as from other sources—such as the Electric Power Research Institute (EPRI) and the International Association for the Properties of Water and Steam (IAPWS).

A full-harp replacement represents a major maintenance task that is costly, requires a precisely engineered component and field welding according to the ASME Boiler and Pressure Vessel Code. A critical point to remember: Often, upset conditions which caused an initial tube failure, have also damaged other tubes, making harp replacement the most practical option.

Catalyst replacement is a major maintenance issue, too, but if catalyst degradation is simply attributed to normal operation, then planning for catalyst change-out should be straightforward. By contrast, steam-stop-valve replacement represents a major undertaking that requires careful planning. Replacement of large pressure components is not easy.

FAC. Many HRSGs worldwide continue to be plagued by the phenomenon of single-phase flow-accelerated corrosion (FAC). In large part, this is due to the difficult-to-extinguish mindset of the need for reducing-agent/oxygen-scavenger feed to the condensate. FAC-induced failures in feedwater systems and economizers are said by some experts to have caused several fatalities in the power industry over the last three-plus decades.

For steam generators served by feedwater systems containing no copper alloys (which includes virtually all of today's HRSGs), reducing agents should *not* be used; an oxidizing water-treatment program—such as all-volatile treatment oxidizing (AVT(O))—is correct.

HRSG chemistry guidelines are covered in many documents available to you at no cost, but a key point regarding this discussion is that for HRSGs still on reducing-agent feedwater treatment, or that were on it in the past, nondestructive evaluation (NDE) of FAC-susceptible locations is critical.

These include the tight-radius elbows in economizers and evaporators, and other locations downstream of flow disturbances in the feedwater and low-/intermediate-pressure evaporator networks. Another issue is the phenomenon of two-phase FAC, which commonly occurs in deaerators and HRSG low-pressure drums. Visual inspections often can confirm this corrosion.

Wrap up. The importance of regular HRSG inspections and corrective maintenance cannot be overemphasized. Neglect of these tasks can lead to failures that cause unit outages and cost a company many tens of thousands of dollars for repairs and purchased power. More importantly, some potential failures jeopardize employee safety. That is the ultimate cost.

European Hrsg Forum

www.europeanHRSGforum.com

Ninth Annual Conference

The Ninth IAPWS European HRSG Forum (EHF 2023) took place in Prato, Italy, May 16 - 18. More than 80 attendees from 18 countries joined this event to discuss key global issues for combined-cycle owners, operators, plant personnel, service providers, and consultants. EHF is one of three associated annual conferences that include the Australasian Boiler/HRSG Users Group (ABHUG) in Australia and the HRSG Forum in the US.

The meeting was organized by the International Association for the Properties of Water and Steam (IAPWS) and co-chaired by Barry Dooley, Structural Integrity (UK), and Bob Anderson, Competitive Power (US).

Below are selected highlights from EHF 2023. You can dig into the details of the presentations by using the nearby QR code.

Carbon

For the first time at EHF, there were important presentations to address external environmental issues, namely carbon capture and hydrogen-blended fuels.

Jean-Francois Galopin, John Cockerill SA, Belgium, set the environmental stage early with *Carbon capture aspects associated with combined-cycle/HRSG plants.* He began with a review of global carbon-dioxide reduction initiatives and technology readiness levels for amine scrubbing/absorption, adsorption, use of membranes, and cryogenic distillation.

He then focused on carbon capture, utilization, and storage (CCUS), stating that "capture represents the largest portion of projects (47%), and storage is the largest output (27%) for the captured CO_2."

Galopin included examples of combined-cycle projects by Scottish and Southern Energy (SSE) and others in the UK, and two planned projects in the US (Calpine Deep Park in Texas and James M Barry in Alabama).

A few key points from his review:

1. The carbon market is booming, and tax incentives are growing worldwide.
2. No single technology is currently superior across industries in all markets.
3. Globally there are capture storage capacities of up to 50 years, but utilization needs to follow.
4. Absorption with the help of amines is the most mature capture technology.
5. Carbon is a cost. Capturing CO_2 in combined-cycle applications implies a loss of performance (an estimated 6% efficiency loss for 85% carbon capture).

On the following day, Cockerill's Raphaël Stevens discussed efficiency improvements and CO_2 emissions reductions in middle-aged HRSGs. He presented a case study of four HRSGs at the 600-MW Fujairah desalination and power project in the United Arab Emirates.

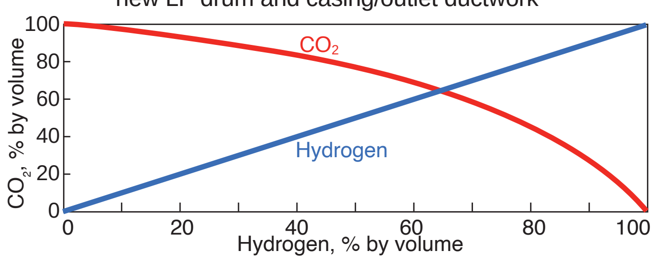
The objective is to retrofit a "heat-reclaimer" circuit within the outlet duct of each HRSG to recover surplus heat and improve unit efficiency, thereby reducing carbon emissions (Fig 1).

Project basics include:

- A new LP module (heat-reclaimer unit) between the HRSG and stack with a new LP drum and casing.
- A design that enables higher flexibility in desalinated water production while lowering carbon emissions.

Stack outlet temperatures were reduced from 178C to 134C. Anticipated total CO_2 reduction is 72,000 tons annually.

1. Heat reclaimers at Fujairah featured new LP drum and casing/outlet ductwork



2. How CO_2 emissions are impacted by hydrogen use

Hydrogen

NEM Energy's Francesco Perrone presented *The impact of hydrogen-fired* *gas turbines on HRSGs.* He explained the significance:

- Use of hydrogen fuel blends in gas turbines is in full development worldwide.
- As gas turbines become hydrogen ready, owner/operators need to know the potential impact on HRSGs and other downstream systems and components.

Perrone offered some specifics on "the physics of hydrogen":

- H_2 has a high mass-related heating value (LHV) of 120 MJ/kg, nearly two and a half times higher than methane.
- H_2 has a very low density, eight times lower than methane.
- H_2 may have a tendency to reduce ductility in carbon or low-grade steel (hydrogen embrittlement).

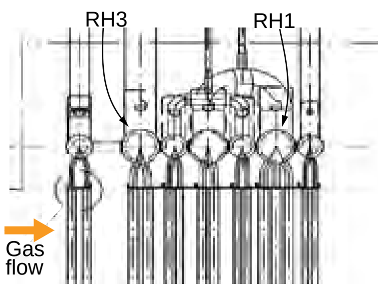
Also, according to Perrone, a blend of natural gas with 30% hydrogen can deliver about an 11% carbon reduction (Fig 2). One of his key points: "Hydrogen will be an important part of the future global power generation industry."

He then offered these thoughts from an HRSG design and manufacturing perspective:

Safety. H_2 has a wider explosive-mixture range and lower ignition energy compared to natural gas, but considering that hydrogen's auto-ignition temperature range is similar, no additional or different safety provisions are anticipated at this time.

However, Bob Anderson questioned this conclusion and suggested that the wider explosive mixture range, lower ignition energy, and lower density (causing H_2 to accumulate in attic spaces) may render current pre-start purge procedures ineffective.

Exhaust. Hydrogen co-firing may result in increased exhaust-gas volumetric flow and higher exhaust tem-



3. Tube failures occurred in RH3 (left) and RH1 (right). Tube material in RH3 is Type 304 stainless steel connected with a safe-end P91 nipple to the P91 header. Tube failures occurred mostly in tubes located directly below the steam outlet pipe on the header. By contrast, the RH1 tube material is T22. Failures occurred only in end tubes of the header modules peratures, and the HRSG must be designed to avoid exceeding the maximum allowable GT backpressure and overheating of HRSG pressure parts.

Emissions. Co-firing will most likely result in higher NO_x emissions. Potentially more space should be considered for future H_2-ready SCR systems.

Condensation. Co-firing results in higher water content in the exhaust (a concern for the "cold end" of the HRSG). The water dewpoint will increase with hydrogen content, especially above 50%. In most cases this can be handled with feedwater recirculation by increasing the mean water temperature setpoint. Also, if sulfur content increases, acid dewpoint could become a corrosion concern.

Supplemental firing. Hydrogen co-firing is also possible in duct-burner systems. Considering LHV and supply pressure, special provisions may be required to make an existing duct burner H_2-ready.

Reheater tube failures, remedies

Thamarai Chevlan, Siemens-Energy, presented *HRSG primary reheater tube failures and remedies*. The subject was Limak Enerji's 1200-MW Hamitabat Combined Cycle Power Plant in Turkey, commercial since 2017.

It features two Siemens SGT5-8000H gas turbines and two CMI triple-pressure horizontal-flow HRSGs. The original base-load design has been in cycling mode since commissioning.

HRSGs in both units suffered tube leaks in the primary (RH1) and final (RH3) reheaters after four years of operation. Primary-reheater tube failures (T22 material) occurred in the header-module end tubes. Final-reheater failures (Type 304 stainless steel material) were in tubes directly below the outlet headers. These tubes are connected with safe-end P91 nipples to the P91 headers (Fig 3).

Root cause of the RH1 failures was low-cycle thermal fatigue created by frequent cycling and temperature fluctuations which were attributed to poor attemperator control logic, leading to high-temperature oxidation and exfoliation in T22 tube materials.

Analysis also found misalignment of reheater headers during installation, and multiple failed parallel plates allowing gas flow bypass to the end tubes, raising the metal temperatures.

Root cause of the RH3 failures was low-cycle thermal fatigue caused by cycling, dissimilar metals (P91 and Type 304 stainless steel), and differential metal temperatures along the length of header producing differential expansion between adjacent tubes.

Chevlan reviewed the five stages of high-temperature oxide growth and exfoliation index in RH1 T22 tubing. He also provided a backgrounder on the parallel-baffle failures.

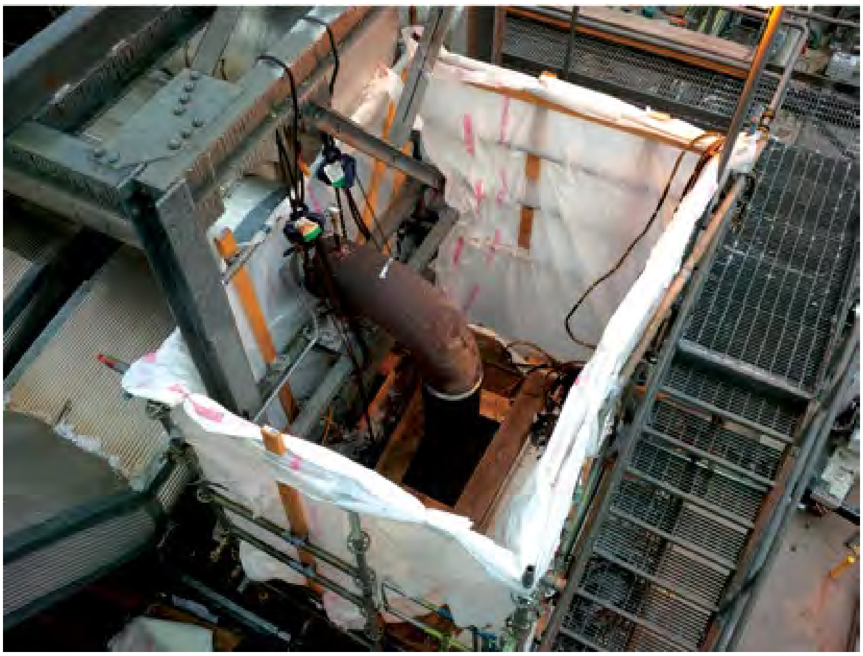
Cracked T22 tubes were replaced with P91, the short safe-end nipples on RH3 were replaced with longer T91 tubes, and gas bypass was minimized.

The following day, Sergio Gómez, BBE Spain, offered *Oxide growth and exfoliation (OGE) and other related mechanisms in the reheater of a combined-cycle HRSG boiler*. His presentation focused on the troubleshooting process—including leak detection, thermocouple installation, oxide thickness investigations, and metallographic studies.

Gómez's case study was an 800-MW plant, commercial since 2003, near Bilbao, featuring two GE 9FA+e gas turbines and a D11 steam turbine. The triple-pressure HRSGs were designed by Nooter/Eriksen and manufactured by Babcock Wilcox Española.

A key damage factor is increased plant cycling with more starts and fewer annual hours than predicted.

4. **Reheater tube failure** was attributed to oxide growth and exfoliation. Note the discoloration of the failed tube and at the end of the header. Leak was found in the tube wall, which is atypical; leaks generally are traced to a weld fissure



5. **Temporary shelters** protected people and equipment from the weather during welding and heat treatment

6. **Support steel** for a 24-in., Schedule 60, P91 reheat attemperator had to be removed to accommodate repairs and then reinstalled

As discussed during EHF 2019, reheater leaks (RH2) were attributed to oxide growth and exfoliation, and a key inspection indicator was discoloration of a failed tube and the end of the header (Fig 4).

Tube-failure maps indicated high oxidation and exfoliation in the inner and outer surfaces, and cracked tubes in gaps between modules and in the gaps between harps and casing sidewalls. Tubes at gaps operate at higher metal temperatures because of exhaust gas bypassing through the gaps.

Current status shows OGE in all tubes (cracked and non-cracked) and cracks corresponding to thermomechanical fatigue.

Design variations are now being reviewed for component replacement at the end of 2023.

Other topic-related presentations at EHF 2023 were:

- *EMUS-4 STRESS—A thermal-fatigue monitoring technique using electromagnetic acoustic transducers,* by Framatome et al.
- *The importance of careful assessment of aging HRSG HP superheater and reheater headers,* by HRST.
- *Creep-rate monitoring by diametrical measurement on superheater and reheater outlet manifolds and high-temperature pipes on combined-cycle gas turbines,* by EDF France.

Attemperation

Bill Kitterman of SVI/Bremco offered *Attemperators—repairs and replacements* with detailed case studies on the challenges of attemperator location, orientation, pipework materials, dimensional differences between old and new equipment, crane access, and the solutions developed to replace several reheat and hot-reheat (HRH) attemperators.

A key element in successful implementation was focused and detailed planning and collaboration between contractors and plant personnel.

During replacements, new support steel was fabricated and installed. One new attemperator (HP1, horizontal) was longer than the original and one of the hanger/guides had to be moved. Existing spray-water piping was modified and an isolation valve was added.

A new vertical HP attemperator was also required. Support steel had to be removed and temporary supports added. Daily meetings were held with regard to staging, insulation, weather containment, heat treatment, crane, and welding contractors to best use resources. Temporary shelters (Fig 5) were built to protect equipment and personnel from weather during welding and heat treatment.

The P91 HRH attemperator was installed beneath the HRSG, requiring removal and reinstallation of support steel (Fig 6).

Denis Funk, Flexim, Germany, offered *Attemperator leak detection to prevent steam tube damage* describing case studies at multiple units using standard clamp-on ultrasonic flowmeters for detection of leaking spray water.

Key takeaways:

- Easy installation, requires no pipe penetrations or unit shutdown.
- Better accuracy and turndown than existing differential-pressure flowmeters.
- Some owners installed permanent meters for continuous monitoring to detect small leaks early.

Other owners used portable meters to test all attemperator valves quickly during shutdown.

Operational improvement. Also on Day One, Bob Anderson, Competitive Power Resources, discussed *Improved attemperator control and startup procedure to avoid overspray and overshooting of HP superheater and reheater outlet temperatures*, a concept developed and implemented by Dave Buzza, formerly of AEP, a major US utility.

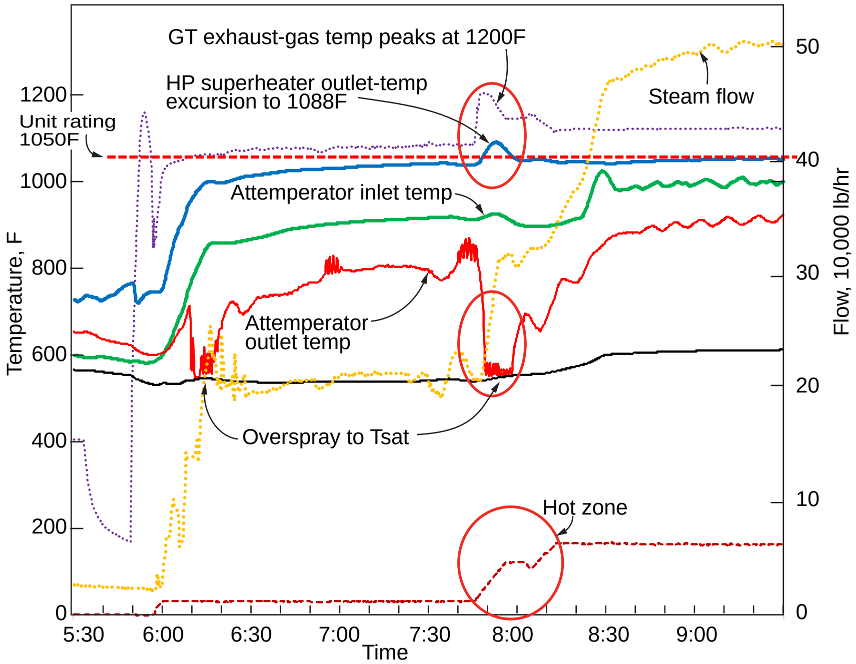
This work is now part of EPRI Program 218, HRSG Fundamentals (Volume 4), *Optimizing startup procedures and control logic for high-pressure and reheat steam attemperators* [2021 Product 3002021149].

The premise: Some HRSGs have poorly designed HPSH and RH surface-area distribution before and after the attemperator. If there is too much surface downstream (secondary) relative to upstream (primary), it is difficult to avoid overspray and avoid overshoot HPSH/RH outlet steam temperatures. He stressed: "This design feature cannot be easily changed."

Why is this discussion important today?

- GE F/H-class gas turbines have a very aggressive exhaust-temperature profile during HRSG startup.
- This profile makes it difficult to avoid overspray and HPSH/RH outlet-temperature excursions.
- Optional features, such as Variable Load Path, can mitigate the problem but most units do not have this feature.

Anderson discussed the typical legacy workaround: Reduce outlet-temperature setpoint (start spray sooner), and increase GT load as rapidly as possible through the Hot Zone to reduce the extent of temperature excursions (Fig 7). However, this can create a large upset of the attemperator control loop, and unstable operation. The result is overspray.



7. Improved attemperator control and startup procedures may be needed for some 7F/7H units because of their very aggressive exhaust-temperature profiles during HRSG startup (data here are for a 7F startup). This mitigates overspray and HPSH/RH excursions. Optional unit features—for example, variable load path—can help, but most units do not have them

This presentation offered key features of an improved startup procedure:

1. Ensure HPSH and RH are properly drained.
2. Use exhaust-temperature matching (lead and lag units) for early outlet steam-temperature control.
3. Maintain steam outlet-temperature setpoint at unit rating.
4. Establish stable steam flow path before loading the gas turbine through the Hot Zone:
   - Lead unit. ST operating on inlet pressure control with HP and HRH bypasses closed.
   - Lag unit. HP, HRH, and CRH all blended into lead unit with HP and HRH bypasses closed.
5. New attemperator's "enable" permissive only opens spray block valve and control valve when outlet temperature reaches 5 deg F above steam outlet-temperature setpoint.
6. Increase GT load in small increments (much less than 1 MW) until attemperator starts at unit rating plus 5 deg F. Attemperation will start without upset to provide stable spray flow and immediately lower the outlet temperature to unit rating.
7. Hold GT load steady for a few minutes until steam flow stabilizes.
8. Increase GT load in 1-MW steps to increase attemperator spray flow and decrease attemperator outlet temperature to predetermined target value (110 deg F above Tsat).
9. Hold GT load steady for a few minutes to allow steam flow to stabilize. Attemperator is now operating with maximum available steam flow, substantial spray flow, and ready to react in a stable manner when loading through the Hot Zone.
10. Unit is now ready to ramp GT load through the Hot Zone.
11. No changes to ST, GT, or HRSG systems from 5 min before ramping until 5 min after ramping, such as:
   - Ramping a second GT through the Hot Zone.
   - Changing the ST inlet-pressure-control setpoint.
   - Starting duct burners.

In addition to the procedure above, a feedforward model-based control logic is required. The new model-based attemperator control uses a table of attemperator outlet steam temperatures required as a function of HRSG heat input, which includes GT exhaust flow and temperature, and duct-burner fuel flow.

Attemperator outlet temperature values in the table range from 700F to 1000F resulting in highly accurate and stable control of HPSH/RH outlet temperatures.

Additional topic-related presentations at EHF 2023 included:

- *Efficiency increase due to ther-*

mal-shock-free attemperators, by Advanced Valve Solutions.

- *Development of innovative technology for attemperation in HRSGs,* by EPRI.
- *Ensuring reliable performance of turbine bypass systems in wet steam service,* by Koso Parcol.

Cycle chemistry

Barry Dooley updated attendees on cycle-chemistry control and flow-accelerated corrosion. This included the latest chemistry-influenced reliability statistics referred to as Repeat Cycle Chemistry Situations (RCCS) which continue to show an overall global improvement.

However, further improvement is needed. RCCS data from 118 plants indicates that 86% of plants have ineffective corrosion-products monitoring programs, 80% have reduced cycle-chemistry instrumentation when compared to the international (IAPWS) standard, 78% fail to monitor drum carryover, and about 73% are not challenging the status quo.

On Day Three, one user presented a proactive approach to understanding and implementing state-of-the-art combined-cycle chemistry guidance, successfully bringing the cycle-chemistry control of their combined cycles up to world-class standards. Madrisse Yede, Azito, Côte d'Ivoire, presented Cycle chemistry at Azito Combined Cycle Power Plant, a 460-MW installation in Abidjan.

Yede's presentation included:

- Initial chemistry guidelines from the EPC contractor.
- Customization of plant cycle chemistry.
- Current status and results achieved for control of FAC and steam purity.

His details included specifics of iron monitoring following the IAPWS technical guidance documents.

Alstom gas turbines were installed at Azito in 1999 and 2000. The plant became combined cycle with addition of a steam turbine in 2015. Azito now includes two Doosan dual-pressure HRSGs and one air-cooled condenser.

Both Alstom gas turbines received MXL2 upgrades in 2019.

Today, Azito runs baseload, providing 30% of Ivory Coast's power production.

Yede outlined the initial chemistry: ammonia for condensate and feedwater, trisodium phosphate (TSP) in LP and HP drums to raise pH, and carbohydrazide (reducing agent) for control of oxygen level.

Customization over time has included improvement in online monitoring instrumentation and total iron monitoring.

The original reducing agent was seen as an FAC promoter and was discontinued. Injection of TSP was also stopped. There was sufficient alkalinity with ammonia, and this eliminated the risk of phosphate carryover.

Chemistry target values were adjusted. LP drum-level pH was increased to 9.7-10 for better FAC protection while maintaining phosphate levels at 5 to 8 ppm. The condensate pH window was increased from 9.2-9.6 to 9.7-10 to prevent two-phase FAC in HRSGs and the ACC.

Continuous online instrumentation was also added. In the LP drum, a phosphate analyzer was installed for better drum/evaporator control. In the HP drum, a CACE analyzer was added to monitor drum purity and optimize blowdown.

Total iron monitoring was implemented to assess whether the cycle chemistry is optimized and whether FAC is occurring. IAPWS target values were established at <2 ppb feedwater, <5 ppb in drums, and <10 ppb in condensate (CPD).

Stated Yede, "Instrumentation is now 100% of the IAPWS standard for fundamental instruments customized to dual-pressure HRSG units operating on AVT(O) and PT in LP drums."

The plant has experienced no chemistry-influenced HRSG tube failures, and no steam-turbine phase-transition-zone damage. The plant just completed a full Thermal Transient Assessment.

Azito is now being expanded with a gas turbine, HRSG, and steam turbine to add 235 MW, for a total of 710 MW. It will become the country's largest operating plant.

In a related presentation, GE Power Services presented *Recent experience on water chemistry challenges on in-service HRSGs*.

FFS. Dooley also offered The latest international activities on film-forming substances, both amine- (FFA) and non-amine-based (FFP). He stated that overall, global applications illustrate reduced corrosion-product transport and general protection in water-touched circuits, but questionable film formation in steam circuits. He offered the key pre-application procedures required to provide optimum results and prevent problems of under-deposit corrosion and "gunk" formation. Examples of increased HP-evaporator deposits and UDC were also provided in cases where FFS was applied in HRSGs with existing high internal deposit density.

One specific FFS-related presentation was *Optimizing cycle chemistry and layup protection of a 420-MW Benson CCGT with non-amine-based surface-active chemistry* by Lubica Moravokva, ZSE, Slovakia. This featured the 410-MW single-shaft combined-cycle powerplant Malzenice which was mothballed from 2013 to 2018. Current operation is irregular/peak load.

In the HRSG, flow-accelerated corrosion has recurred in the LP and IP systems. The primary current issue is magnetite deposition in the HP evaporator attributed to two-phase FAC.

Ongoing operation will be cycling with unknown periods of standstill.

Plant design is AVT/OT chemistry, and Moravokva offered a chemistry review:

- Increased ammonia or oxygen injection is not seen as effective.
- Dosing of a solid alkali to IP and LP increases risk of TSP carryover.
- Film-forming chemistry is recommended for materials protection.

The plant considered two film-forming substances: a film-forming-amine product based on OLDA, and Anodamine HPFG (an FFP).

Since the end of 2021, Malzenice has been dosing Anodamine HPFG as an enhancement to the applied ammonia/OT chemistry in the water/steam cycle. Dosing is in the condensate line to a final rate of 1.5 to 1.2 ppm.

Visual inspection results were offered on hematite and hydrophobicity.

His summary and conclusions:

- Inspections have shown successful application and improved protection of visible areas.
- Steam purity has remained within OEM limits.
- The plant predicts an improved startup curve, with less iron content and lower potential damage (including that to the valves).

In a related presentation, Reicon's Ronny Wagner offered *Improved preservation and flexible powerplant operation with FFAs*. He provided a case study of an 800-MW combined-cycle plant in Germany, offering these conclusions following injection of FFAP (Odacon) in the main condensate line after the condensate pump:

- Iron concentration during restart in the IP section was reduced by 70%.
- Nitrogen injection for short-term protection and drying for long-term protection are no longer required.

Tube gas-side cleaning

Three presentations focused on HRSG tube cleaning:

- *KinetiClean™—A new, patented HRSG cleaning method*, by Groome Industrial Service Group.
- *PressureWave+ deep cleaning,* by Bang & Clean Technologies.

- *An independent HRSG inspector's evaluation guide to various commercially available tube-cleaning methods,* by Siemens-Energy.

Thermal transient update

Continuing a key feature of all related HRSG events, Bob Anderson presented an *Update and statistics on HRSG thermal transients* with a global perspective.

These international updates based on surveys at 64 plants between 2009 and 2022 included the following:

- 91% of 64 surveyed plants have no management policy to determine the root cause of HRSG tube failures so that repeat occurrences can be avoided.
- Management at 31% of surveyed plants permit operators to manually manipulate attemperator controls—a practice known to cause quench cracking of downstream pipework.
- Only 12% of surveyed plants perform routine inspection/maintenance of attemperator hardware to find or repair damage before pressure-part failure occurs.
- 82% of surveyed plants experience attemperator spray water leaking sufficiently severe to appear in DCS operating data. Leaking spray water during startup/shutdown/hot layup is known to be a major cause of cracking in steam pipework and tube failures.
- 93% of surveyed plants use master control/martyr block spray valve logic—a practice known to accelerate spray-water leakage.
- HPSH/RH drains fail to adequately remove condensate in 59% of surveyed plants—a condition known to cause tube failures.

Additional presentations at EHF 2023:

- *Control valve myth-buster,* by Emerson.
- *Drum level instrumentation compliance with PED and ASME requirements and maximizing service life,* by Clark-Reliance.
- *An update and summary of penetration seal solutions for HRSGs,* by Dekomte.

Sponsors and a look ahead

Sponsors for EHF 2023 were Advanced Valve Solutions, Bang & Clean Technologies, Clark Reliance, Dekomte, HRST, Koso Parcol, and Precision Iceblast Corp.

EHF 2024 will be held in Prato, Italy, in May 2024. CCJ

FILMFORMINGSUBSTANCES.COM

Sixth International Conference

By Steven C Stultz, Consulting Editor

The sixth annual IAPWS Conference on Film Forming Substances, held March 21-23 (2023) in Prato, Italy, was chaired by Barry Dooley of Structural Integrity Associates (UK) and David Addison of Thermal Chemistry (New Zealand). FFS conferences, sponsored by the International Association for the Properties of Water and Steam, are unique, as evidenced by the focus here on this narrow topic in cycle-chemistry control of powerplants and steam generating facilities.

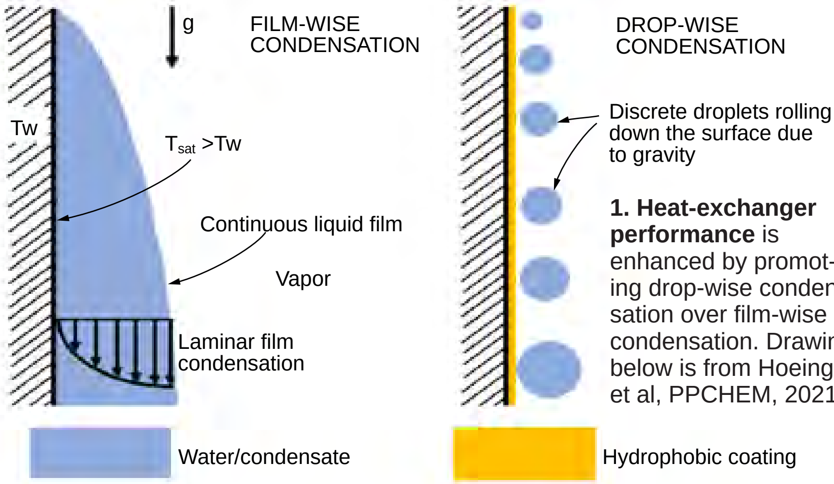
Film forming substances consist of two main categories of chemicals using the internationally accepted nomenclature: amine-based (FFA, Film Forming Amine, and FFAP, Film Forming Amine Product) and non-amine-based (FFP, Film Forming Products) which are proprietary compositions.

There had been general confusion on the nomenclature, but these terms introduced by IAPWS in 2016 have quickly become the global standard. For background, see CCJ's report on the Fifth International Conference (Issue No. 72, pp 71-78; click QR at left) and "Protection of metal surfaces: A wakeup call on film-forming substances" (Issue No. 60, pp 12-18; click QR at right).

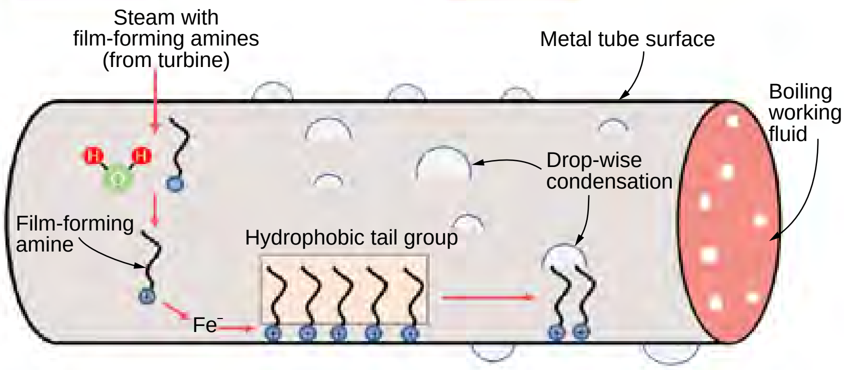
In 2023 the conference attracted 70 participants from 28 countries which included 20 plant operators/users and representatives from 11 FFS chemical suppliers.

As stated by Dooley, "The major activities at FFS 2023 were multiple presentations and discussion sessions outlining the current knowns and unknowns about FFS and their properties in relation to their application as corrosion inhibitors in fossil, industrial, nuclear, and other water/steam plants. Key research needs were documented by the conference attendees, which included the majority of global FFS suppliers, multiple users, research groups, and independent industry experts."

Below are notes and background for owners/operators of combined-cycle and other powerplants, in particular those facing the increasing need to protect their equipment and systems during recurring on/off cycles and layup.



1. Heat-exchanger performance is enhanced by promoting drop-wise condensation over film-wise condensation. Drawing below is from Hoeing et al, PPCHEM, 2021



The launch

Dooley and Addison launched the conference with an overview and some significant timely points. Interest remains paramount on the following potential benefits of FFS:

- Shutdown protection under wet and dry conditions.
- Avoiding boiler and HRSG tube failures from under-deposit corrosion and corrosion fatigue.
- Arresting both single- and two-phase flow accelerated corrosion (FAC).

They also launched the proceedings with a clear picture of future fundamental work requirements, including but not limited to:

- Recognition that much current work is on metal surfaces rather than on the oxide surfaces.
- Effect of FFS on growth mechanisms of Fe, Cu, and Cr oxides in water and steam.
- Uncertainty of stability limit and decomposition products for all FFA and especially FFP.
- Information on changing from one FFS to another.

Again, this is only a partial list. The opening presentation gave relevant details of each.

Dooley ended the launch with two Cardinal Rules:

Rule 1. Make sure plant chemistry is optimized before application of an FFS.

Rule 2. Conduct a complete review (due diligence) before an FFS application.

Note that comprehensive guidance on the use of FFS is openly available through IAPWS. Go to http://www.iapws.org/techguide/FFS-Industrial.html. Section 8 of TGD8-16(2019), pp 19-32, provides operational guidance for operators/users on the continuous addition of an FFS.

An HRSG in Spain

Andre de Bache, Kurita, gave a brief history of Cetamine® leading to Cetamine G85X, a single-component FFA based on OLDA (Oleyl propylenediamine). He followed with a specific example of Cetamine treatment for a 400-MW HRSG in Spain facing continuous startups and shutdowns. The original baseload water-treatment plan was giving very poor corrosion protection.

The NEM HRSG was commissioned in 2005. As a direct result of cycling, inspection results between 2017 and 2020 revealed generalized FAC on various internal surfaces, and gradual wall thickness decrease from inside LP evaporator tubes.

FFS dosing began in 2021. Resulting cation conductivity reports, particle counts, and blowdown water consumption were reviewed in detail.

Bache's conclusions: Cetamine G85X is offering beneficial protection during both cycling operation and preservation periods. It can be used as an additional treatment to conventional AVT or AVT+PT. It has reduced startup times and need for blowdown.

Steam condenser efficiency

2. Steamate™ PAP7010 field trial was conducted at a 3 × 1 combined cycle with a 395-MW steam turbine

Later in the day, Mahesh Budhathoki, Veolia, discussed steam-condenser efficiency improvements in a combined cycle using FFAs. This presentation began with descriptions of Polyamine Plus' (PAP) potential advantages to power producers—including the following:

- Offers a beneficial layup method when not using nitrogen.
- Allows faster startups.
- Reduces chemical cleaning expense.
- Provides general corrosion and FAC protection during operation.

Case study premise: The method tested allows complete system protection from a single feed point and improves condenser performance and efficiency. A driving factor seemed to be an increase in dropwise condensation (Fig 1).

The case history focused on shell-and-tube condenser cleanliness factor (CCF) using Steamate™ PAP7010 at an 885-MW US combined cycle equipped with a 395-MW steam turbine (Fig 2). Over a three-month period, CCF increased by 1.6%, and condenser backpressure was reduced by 0.6 in. Hg. This led to "improved condenser performance, lower fuel consumption, and (therefore) reduced carbon emissions."

The study was based on research that suggests:

1. The FFA investigated can enhance the performance of heat exchangers constructed of various metal surfaces by promoting dropwise condensation (DWC), and importantly,
2. DWC may not be achieved if FFA levels in steam and on the surface are not properly balanced.

Closed cooling system

One presentation focused on FFS in auxiliary closed cooling-water systems in Israel. The presentation by Yitzhak Nussbaum, Ezom, discussed various components comparing traditional treatment versus FFS. This complex site contains many systems, equipment from many OEMs, many materials, and a wide range of piping sizes and velocities.

Previous application was $NaNO_2$/sodium nitrite from 2015 to 2018. FFS began in 2018.

This detailed presentation concluded the following:

- FFS is a reliable anti-corrosion treatment in closed cooling-water systems.
- Working with FFS, especially in the early stages, requires patience and careful monitoring.

Food industry lab study

Discussing the food industry, Julia Jasper, Kurita Europe, addressed what she called the next generation of water treatment. Boilers in this industry have either direct or indirect steam contact to food, are either shell or watertube boilers, and traditionally use softened, RO, and demineralized makeup water.

Jasper's presentation covered details of corrosion rates in condensate and boiler water during laboratory tests using coupons. Her predictions based on FFS laboratory experience:

- Reduced blowdown and water discharge.
- Energy savings.
- Protection against corrosion and scaling.
- Single-component product solution.

A related presentation, by Ricardo Valezquez, Fineamin, evaluated the effectiveness of Fineamin® 39F use in Mexico, highlighting advantages of the product specifically formulated for the food and beverage industry. This application is designed to prevent corrosion and buildup of scale in low-pressure, softened water systems.

Other industrial

There was an interesting presentation by Flow-Tech Chemicals (Israel) on the use of heat-recovery boilers in the fertilizer industry, and application of ODA-based FFAP in a combined-heat-and-power (CHP) facility.

The sulfuric acid plant (Fig 3) uses boilers and shell-and-tube heat exchangers to recover heat from the chemical process and provide steam to the plant. Occasional leaks in the heat exchangers allow acid into the steam/condensate.

3. Several heat-recovery boilers and heat exchangers are used in fertilizer process

A blend of OLDA and alkalizing amines had been in place for 10 years. Field trials on a change to ODA-based FFAP for two boilers (15 and 25 MW) took place in 2022. Results of this FFS change were presented based on conductivity, pH, and iron transport.

Initial testing showed a substantial reduction in iron concentration of boiler water, well-protected steam and condensate lines, and validation of lab simulations for reduced short-loop condensate conductivity. Both heat-recovery boilers are now transitioning to Odacon®, a film-forming amine product by Reicon.

Nuclear

NPP Cernavoda in Romania consists of two 700-MW CANDU-6 nuclear units commissioned in 1996 and 2007. Unit 1 plans a midlife component refurbishment project in 2026 to include reactor fuel channels, calandria tubes and feeder, and HP turbine internals.

Unlike similarly aged plants, NPP Cernavoda will not replace the steam generators, given the improved tube materials and increased corrosion resistance designed into these units. Outage duration will be between 24 and 30 months, carrying high risk of standstill corrosion adversely impacting non-alloyed and low-alloyed carbon steels.

General corrosion could be caused

by the presence of water on surfaces of systems and components, and oxygen which may be diluted in water or be present by air ingress. Selective localized forms of corrosion (specifically, pitting) could also occur. There is also the threat of corrosion transport during subsequent operation.

The presenter, from Framatome, suggested that standard layup methods, both wet and dry, have limitations. Therefore, the site has chosen FFS technology.

A project roadmap was presented on incorporating FFS into other outage activities, looking at all components and subsystems of the primary heat-transport system and water/steam cycle, plus all linked standby and auxiliary systems.

FFS will be included for the feedwater system, reheater stage section after the HP moisture separator, steam generators, condenser, and deaerator. Updates on this important project will be presented at a future IAPWS conference.

Steam turbines

Jörg Kallweit discussed a biomass CHP plant in Luxembourg, highlighting its 8.4-MW turbine that was first examined and samples taken in 2020 (Fig 4). First option was online acid cleaning, second mechanical cleaning. However, the latter required turbine removal. A third option was online cleaning with FFS (amine-based FFA). Plant water treatment began in August 2022.

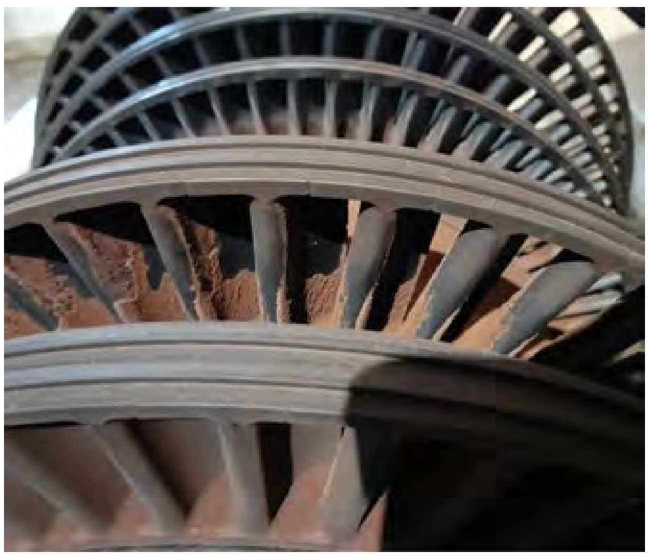
After 20 months, the following results were revealed:

Positive. Turbine output increased from 7.8 to 8.3 MW, with noticeable improvement in blade cleanliness (Fig 5).

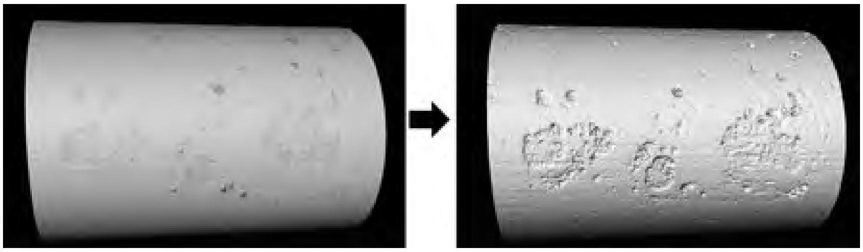
Negative. An increase in acid conductivity in steam. The solution is to increase silica in the condensate. If conductivity remains high, boiler blowdown will be increased.

Some research details

Dooley explained in the conference launch that there is now a wide range of FFS products and mixtures from at



4, 5. Turbine blade deposits at first inspection (left). Improvement after 20 months of FFS dosage is at right



6. 3D imaging by nano-CT allows visualization of local metal loss. Corroded areas in the image at left show up as darker spots where oxide is present. The oxide can be removed electronically to create the image at right

least a dozen vendors globally. This increasing range makes research, derivation of common guidance, and solutions difficult. Most importantly, research is focused on the properties of adsorbed films.

Deni Jero represented a consortium from Université de Toulouse, Odyssee Environmental, Université Paris-Saclay, and Université de Bordeaux, for an in-depth look at adsorption kinetics in the presence of a reducing agent by electrochemical impedance spectroscopy. From the industrial perspective, the goal is to understand FFS barrier formation as a function of temperature in absence of corrosion products, and to provide a methodology for monitoring adsorption and corrosion kinetics.

Andy Howell represented EPRI and gave details on tools that could characterize and evaluate the effectiveness of FFS in laboratory test projects—including scanning electron microscopy, X-ray spectroscopy, and other methods. He also discussed nano-computer tomography and analysis which can quantify local corrosion and visualize metal loss (Fig 6).

Universally, the presentations on applications of FFS to powerplants indicated reductions in the measurement of feedwater total-iron corrosion products. Some examples showed increase of CACE (conductivity after cation exchange). Mobilization of impurities (sulfate, for example) also was noted in some examples.

Scott Tucker, Hach, offered practical methods and best practices for monitoring iron-transport products and FFAs on a parts-per-billion basis, cautioning that "the lower you measure the more effect propagation of error will have on the results." He added that "the sample is usually the greatest limiting factor in obtaining a true or representative result, especially at low-ppb values." He presented Hach methods, equipment, and procedures with a focus on determining total iron.

Moving forward

On the third day, Thermal Chemistry's David Addison began with a summary of the science and the unknowns, and a pathway to an IAPWS ICRN (IAPWS Certified Research Need) by the IAPWS Power Cycle Chemistry Group. When developed and issued, the ICRN hopefully will stimulate additional research related to FFS. See Dooley's wrap-up analysis below.

Addison recapped the perceived and known benefits of FFS but was careful to point out the amount of work remaining.

Later that day, Wolfgang Hater (Germany) reiterated this with "Research needs for film forming substances applied in water/steam cycles," tracing published research (primarily FFAs) back to the 1940s.

He summarized positive research developments by looking at these effects:

- Surface layers.
- Heat-transfer improvements in boilers and condensers.
- Droplet formation.
- Corrosion protection, copper and aluminum.
- Cleaning effect, mass transport.
- Ion-exchange resins, membranes (not yet conclusive).

He noted the remaining lack of reliable and conclusive data, suitable test concepts, and benchmarking.

Dooley's wrap-up

In his review of the event, Structural Integrity's Dooley included the following, pointing to the future publication of the ICRN by IAPWS. He stated:

"Overall and in the conference conclusion it was clear that the understanding of FFS application has improved worldwide since 2014 but that there is still a large amount of fundamental work needed to understand the mechanisms of the now wide array of FFS available for plant application. Up to now most research work has been addressed to ODA followed by OLDA; the secrecy associated with some of the FFP products remains an impediment for the industry."

The following represents an outline of the research requirements which will be published in an IAPWS ICRN:

- Effect of FFS on growth mechanisms of Fe, Cu, and Cr oxides in water and steam. Better understanding will help to explain the effects of surface roughness and overdosing of FFS.
- Relation between surface coverage and degree of corrosion protection.
- Effect of FFS on boiler and HRSG tube failures (under-deposit corrosion and corrosion fatigue) and stress corrosion cracking.
- Film formation, kinetics, structure, equilibrium and stability (film thickness and porosity on water- and steam-touched oxide surfaces) for all FFS especially FFP.
- Thermolysis and decomposition products for FFA, and especially FFP, under oxidizing and reducing potential conditions.
- Uncertainty of adsorption onto oxide surfaces for all amine and non-amine FFS and how films are affected by other additions to the FFS. Characteristics of film layers and correlation with surface protection.
- Whether protection of superheated steam surfaces can be achieved for all amine and non-amine FFS.
- Increased steam-turbine performance for amine-based FFS (ODA) has been illustrated but research is needed to determine if FFS other than ODA reduce the surface tension.
- Can FFS improve steam-turbine efficiency and whether FFS, in general, can clean deposits from PTZ surfaces.
- Can FFS improve heat transfer in feedwater, boilers/HRSGs, and condensers.
- Impact of FFS on EDI and RO membranes.
- Impact of FFS on ion-exchange resins.
- Compatibility of FFS with other chemical additives (for example, chemical cleaning agents and dispersants).
- Relationship with any reduction of emissions.

FFS 2024

The FFS conferences are developed and supported by the International Association for the Properties of Water and Steam (IAPWS). FFS 2023 was arranged in Prato by Mecca Concepts (Australia) and the Combined Cycle Journal (US). The sponsors of FFS 2023 were Kurita Europe GmbH; Nalco Water, an Ecolab company; and Termanox Water Treatment Solutions.

Next year, the seventh FFS conference (FFS 2024) will be held in March, also in Prato, Italy.

Contact Barry Dooley (bdooley@structint.com or bdooley@iapws.org) for further information on FFS and the IAPWS FFS conferences. CCJ

The case against fast starts

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

Turbine Tip No. 18 from the PAL solutions library applies to most models of legacy GE gas turbines.

Fast starting was a feature offered on some General Electric Package Power Plants (PPP) as a response to electric-utility concerns following the Great Northeast Blackout of 1965. Power companies in the US and Canada became aware very quickly that they did not have adequate "emergency and peaking power" that could react urgently to power demands—particularly in blackout situations.

The apparent need was in situations where power was needed in a matter of minutes, not hours, as with fossil-fuel steam turbine/generators.

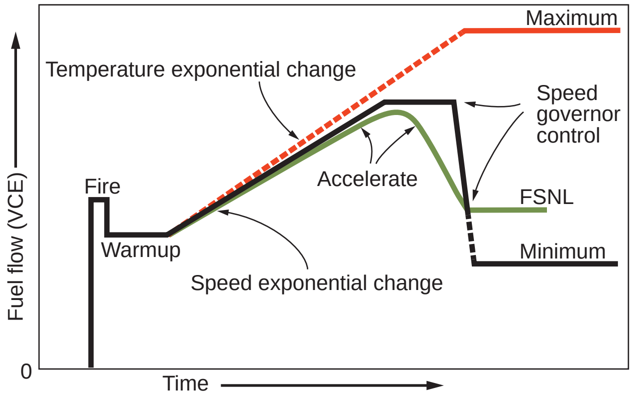
Normal starts of units with "black-start capability" typically took from five to six minutes to go from signal initiation to 100% speed. This was called full-speed/no-load (FSNL), which was 5100 rpm for Frame 5Ps and 6Bs and 3600 for Frames 7B-7EA. Interestingly, the first Frame 7, rated a nominal 40-50 MW and installed by Long Island Lighting Co in 1970, only came with an electric-motor starting device.

Gas turbines normally had specified warmup periods for "heat soaking" of internal turbine parts. The starting and loading sequences were controlled with reliability and long-term life in mind. Typical normal starts from 0 rpm up to FSNL consisted of the following steps (Fig 1):

1. Starting and warmup of the diesel engine, if applicable—30 seconds.
2. Firing and warmup of the turbine at 20% speed—60 seconds after sensing flame in the combustors.
3. Acceleration to FSNL:

- Shaft exponential—a set rate in Speedtronic™ controls.
- Rate-of-change of speed—0.5% increase in speed per second.
- Rate of increase in exhaust temperature—5 deg F/sec.

4. Fuel limit during acceleration—VCE is set in the Speedtronic controls.



1. Critical parameters from starting to full-speed/no-load (FSNL)

Typical loading rates to baseload were the following:

5. Operation at 100% speed (FSNL)—minimal time before synchronizing with the grid.
6. Normal loading to baseload—increasing from 0 MW to baseload in 90 seconds.

The times allowed were established by the OEM to safely bring the gas turbine up to operating speed. Normal starts took from five to six minutes. Fast starts (warmups eliminated) took only three and a half minutes.

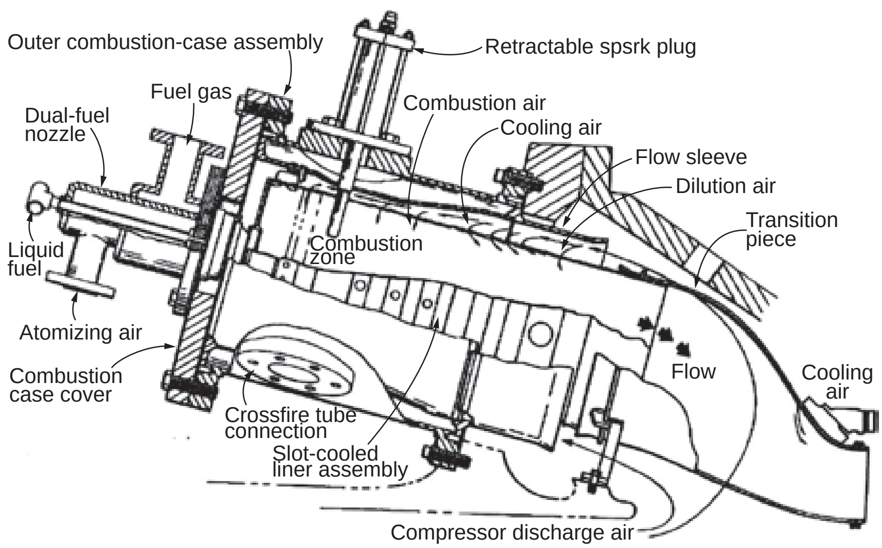
Synchronizing to the grid and slow loading should be the norm to extend the lives of internal parts. The times noted above were based on turbine inlet (a/k/a firing) temperature, which is calculated from measuring these two variables: turbine exhaust temperature (TXA) and compressor discharge pressure (CDP).

The actual output in megawatts depends on one or more of the following variables, among others:

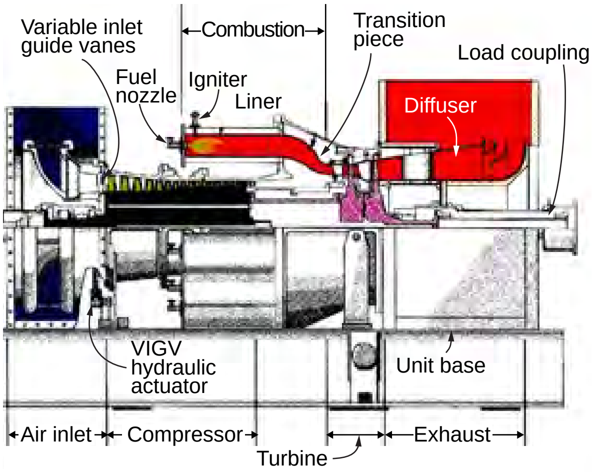
- Ambient temperature at the compressor inlet.
- Inlet-air pressure drop across the filters.
- Atmospheric pressure.
- Compressor discharge pressure.

Gas turbines can suffer significant life penalty if fast starts are initiated too often. A starting regimen that eliminates warmup periods is permitted, but discouraged, particularly when starting from a cold, standby condition. It is akin to loading the unit to "peak," if allowed at all, because "overfiring" the turbine reduces parts life.

Of most interest in Fig 1 is the center of the graph. There is a normal starting rate built into the Speedtronic control system. If the rate of rise in exhaust temperature is faster than 5 deg F/sec, fuel flow (VCE) will take command. If the rate of acceleration (speed exponential change) exceeds 1%/sec, this subsystem takes control of fuel flow. All three rates are built

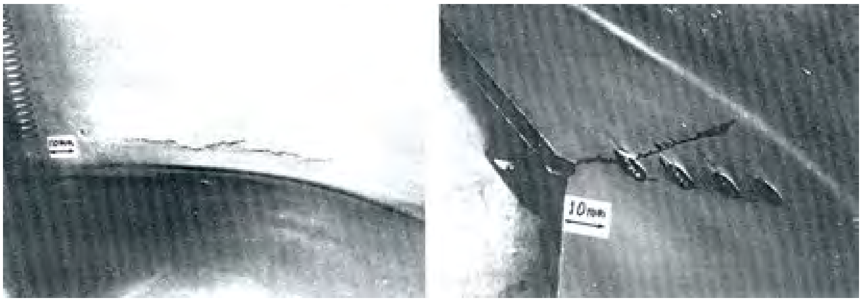


2. Typical combustion system for legacy GE engines



3. Frame 5 cross section

4. Hot gas path: Turbine buckets, nozzles, and shroud blocks



5. First-stage-nozzle partition cracking

into the control system and have and established relationship to protect the turbine.

The lives of combustion-section parts (Fig 2) decrease significantly if the turbine components do not have a reasonable amount of time to "heat soak." This is particularly true of combustion liners, crossfire tubes, and transition pieces for each of the 10 combustion chambers on the GE Frame 5P, 6B, and 7B-EA engines of interest here.

The hot-gas-path (HGP) parts shown in Figs 3-5 will be prone to cracking and distortion if fast starts are used too often. This is particularly true of the first-stage turbine-nozzle partitions and turbine buckets. The OEM says rapid heating without the recommended warmup period may shorten the lives of internal parts by a factor of five.

This means HGP inspection inspections will be required more frequently and the cost of repairs or replacement parts will be significant. Particularly vulnerable to cracking are the trailing edges and sidewalls of the nozzle partitions. Recall that the most expensive parts in the turbine are in the HGP because they are made with the most sophisticated materials and require precise heat treatment.

In Fig 5, consider that if the nozzle partition cracks propagate to connect in a way that material liberation could occur, repairs or a replacement nozzle is highly recommended. You don't want liberated material traveling downstream and damaging rotating or stationary components in the flow path.

In conclusion, keep in mind that while fast starts are permitted by the OEM for most package power plants, internal components may suffer cracking and degradation, and the practice should be avoided except for true emergency situations.

End note: Dave Lucier, author of the Turbine Tips series that has appeared regularly in CCJ for the last five years, has closed the doors of his Pond and Lucier LLC shop in Amsterdam, NY. Dave's career in gas turbine services and training began at GE in 1968. In the 55 years since he has worked in 20 countries, 31 states, Puerto Rico, and the Virgin Islands. There isn't much he hasn't experienced concerning legacy GE frames and their control systems going back to pre-Speedtronic days.

Although the shop doors are closed, Dave still has some premium parts available for sale—typically pre-1980 fuel pumps, flow dividers, fuel regulators, and unused Speedtronic Mark II circuit boards. Contact him at dlucier@pondlucier.com if interested.

Finally, Dave will continue to help clients and consult in his areas of expertise without getting his fingernails dirty. Contact him by email.

NERC CIP-003-9: What you need to know and how to comply

NERC CIP-003-9 is a set of cybersecurity requirements designed to protect the critical cyber assets of power generation facilities. Compliance with these standards is considered essential for ensuring the security and reliability of the North American power grid. All "responsible entities" (as identified by NERC) must comply by Apr 1, 2026.

NAES Corp, well known to CCJ readers, collaborated with Network Perception (www.network-perception.com) and the ABS Group of Companies (www.abs-group.com) in the development of a three-part webinar series to help owner/operators understand CIP-003-9 and its requirements (sidebar). Read on to learn more.

Webinar 1. Latest NERC CIP addresses control-system supply chain

Just as plant owner/operators should "be prepared for an ever-changing cybersecurity attack surface, they should also plan to control their own destinies with respect to regulatory compliance," noted a panel of experts representing the webinar developers in the first segment of the program. Scan NAES 1 to access the recording.

If you are one of the 72% of organizations that don't have full visibility into their control-system supply chains, the 47% of organizations that don't have the internal resources to manage operational technology (OT)/industrial cybersecurity (ICS) incidents, or the 75% of ICS networks successfully attacked by malicious external actors, don't fret. Listen to this and the two follow-on webinars.

For those of you whose plants are categorized as "low-impact" BES (bulk electricity system) assets and don't think this latest standard affects you, think again. "NERC is coming for you," these experts stressed.

One of the major implications of CIP-003-9 is that "plants should no longer rely on their control system OEMs for compliance or security [two different things]. There are limits to risk transfer," the experts say. Owner/operators and other responsible entities must now seek full supply-chain visibility.

Why? For one, a malicious actor can attack *all* users of a specific plant software (that is, many BES assets) by infiltrating the third-party vendor supplying or servicing that software. This looms large when you consider that the vast majority of combined-cycle control systems in America are sourced from only a few gas-turbine vendors and one or two control-system OEMs (along with the skids and subsystems with PLCs and other devices from a variety of vendors networked into the control system).

"You'd be surprised how frequently control-system vendors traffic through their remote access points, and how unaware plant staff are," observed one expert. Section 6.3 of the new standard, approved by FERC in March, requires one or more methods for detecting known or suspected in/outbound malicious communications through vendor electronic remote access points.

NAES 1

NAES 2

NAES 3

> **The webinar developers**
>
> **NAES Corp** is an independent services company dedicated to optimizing the performance of power generation facilities. Its deep experience in operations, maintenance, construction, engineering, and technical support enable the company to operate and maintain plants that run safely, reliably, and cost-effectively.
>
> **Network Perception** proactively protects industrial control systems by ensuring network security as the first line of perimeter defense. Its monitoring software provides network transparency and continuous mapping to better support cybersecurity compliance and enable greater cyber resiliency.
>
> **ABS Group** provides technical advisory and certification services to support the safety and reliability of high-performance assets and operations in power-generation and other industries.

This means plants need comprehensive remote access solutions, and perhaps a full network model. "If two hosts *haven't* communicated," you can't know whether they *could have* communicated or not." A model helps you understand what could happen, not what did happen, these experts stressed.

Webinar 2. Low-impact assets and CIP-003-9: Should dos versus must dos

Perhaps the best way to think about how to respond to NERC-CIP-9, which seeks to protect the bulk electric system from a coordinated attack on smaller, low-impact assets that can result in a catastrophic event on the interconnected system, is this: Rather than think in terms of *complying* with the new standard, think about *defending yourself in court* after a malicious attack through your facility.

The panel of specialists in the second of three NAES webinars on the subject put it a bit more gingerly: What you should do versus what you must do. Example: Regarding remote access by vendors, a site must determine who, how, and where vendors access devices and have a program to document its methodology for remote access controls.

What should you do? Suggests the panel, automate the detection of vendor access, alarm occurrences of such access (to the control room, for example), and log and record all sessions in which vendors made changes to the system.

That might not sound so terrible until you realize that some of your primary vendors might have 50 people authorized to access equipment on your site remotely.

Here's another example: A site must have procedures to disable access to the network boundary (not the device) and physical or electronic methods for removing access. What you should do is:

- Have granular controls per vendor.

- Test and validate controls per vendor and cyber asset.
- Have methods for terminating a previously authorized session (even mid-session).
- Form a global access management team with a two-person rule.

There are several of these examples available in the recording of the webinar (scan NAES 2).

The panel concedes that some of the key language in the draft is fuzzy, but NERC will be making modifications during the 18 months owner/operators have to comply. The term asset, for example, is not explicitly defined in 003 (unlike in 002); thus, it is difficult to define the scope of site implementation. Another term, the asset boundary, which experts call a "term of art," is not a NERC-defined term.

What should sites do know? That's difficult to say, but be prepared for today's "shoulds" to become tomorrow's "musts."

Webinar 3. What now? Response requirements

While the NERC standard is still subject to revisions and tweaks in the coming months, there is enough "writing on the wall" for low-impact bulk electric system (LIBES) sites to begin the long slog towards compliance and security. It begins with a comprehensive inventory of any and all vendors who have electronic access to your site, along with *all possible devices, pathways, and equipment they can access.*

The third webinar (scan NAES 3) hammers home the point that it's all about your site's supply chain. The opening salvo were words of caution and advice not to apply your processes and procedures for medium- and high-impact BES to your low-impact ones, and think of cybersecurity like safety—that is, you need to have a culture of cyber-vigilance. "Responsibilities cannot be assigned, they have to be accepted," one panelist said.

Rgarding what clearly is the big challenge, vendor electronic remote access (VERA), sites need to be able to document all network paths that vendors could use, and develop and document methods to authorize, monitor, alert/alarm, and record all remote vendor access.

"All network paths possibly available to a 'bad actor' need to be exposed and understood in terms of who is connected, what can they do, when do they connect, where can they go, how do I know, and what can I do (for example, disconnect them if necessary). For one thing, this means that all firewall rules need to be re-assessed, though not restricted to the point that normal plant operations are impacted if vendors are cut off.

Section 6.2, for example, requires the site to be able to disable VERA if necessary, disable inbound and outbound communications, and remove physical-layer connectivity. It also requires that you collect evidence that you can do, and have done, these actions.

Section 6.3 requires that you document anti-malware technologies and how they are updated and configured; and document intrusion detection/prevention software, use of automated or manual log reviews, and automated and/or manual alerting.

6.3 also requires that you detect known or suspected malicious communications, which begs the question: How do you define malicious code for specific systems?

Consistency in your processes, procedures, and responses is the key to avoiding trouble should you face an audit or an RFI (request for information), the panelists stressed. At the end, the panel noted that Network Perceptions has software, NP View, capable of generating a model, or network topology, of a site's electronic devices, monitoring multiple vendors, and producing consistent documentation. It is said to be "basically what's used by the auditors." CCJ

Anomaly detection: Small deviations can mean big bucks

Primex, the latest entrant into the field of operational anomaly detection and machine-learning (ML) services for gas-turbine-based plants, introduced its technology to the wider combined-cycle (CC) community through a series of four webinars held in June and July 2023 (access via the nearby QR codes). The legacy application of the technology has been for SO_2 scrubber and BOP performance at coal-fired plants.

The firm lists several big owner/operators as customers, several of which apply the service to CC units, and considers itself a services provider, not a software supplier.

ML, in its basic configuration, harnesses computing power to recognize patterns in large data sets, in this case the input and outputs of an operating system, either the entire plant, or its subsystems. ML first "trains" on the system to develop the baseline, or *normal,* operating patterns among the variables important to the system.

Primex 1

Primex 2

Primex 3

Primex 4

Real-time data going forward are compared to the baseline to detect anomalies.

The technology is system agnostic—that is, it doesn't care what the system is, just its streams of input and output data. However, deep domain expertise with the operating system is necessary to convert the ML results into actionable insights. For this and other reasons, the Primex team stresses that ML is not a substitute for human expertise. The technology pulls the data from the plant-wide data network, such as PI.

The webinars make a clear distinction between machine learning (ML) and artificial intelligence (AI) and they answer other questions commonly asked by powerplant managers. Many more questions remain and interested parties should contact Primex for additional information. This is typical for virtually all ML technology firms. The one requirement in ML pattern recognition is a stable baseline for comparisons, which may be difficult for CC units that start and stop frequently and cycle up and down in load.

Stewart Nicholson, founder, believes that the software offers more granularity and a deeper level of precision and confidence over traditional methods of analyzing performance–such as vendor performance curves. One example cited: An additional megawatt of output could have been worth nearly half a million dollars over 12 months (2021-2022) in the PJM market.

Use cases presented in the webinars include generation monitoring and diagnostics (for example, fault detection), performance optimization, predictive maintenance (for example, early warning of unusual degradation), performance comparison (such as before and after a major outage, or unit event like a GT water wash or HRSG chemical clean), generation and resource demand forecasting (improving bidding strategies and fuel procurement), and regional supply and demand forecasting.

"The service helps you make better decisions and make them sooner," the experts conclude. Visit www.primex-process.com for details. CCJ

Ammonia-system maintenance considerations

By Vaughn Watson, Vector Systems Inc

1. Common root causes of SCR performance include poor reagent quality, inadequate maintenance, catalyst bypass, fouling of the ammonia injection grid, and AIG maldistribution

The long-term performance of an SCR system depends on the efficiency of its critical components (Fig 1). While the catalyst often gets all the credit, and all the blame when performance *declines,* proper maintenance and routine inspection of the ammonia system can alleviate and prevent many factors that contribute to SCR issues in your plant.

It starts with ammonia supply. It is important to work with a reputable and accountable chemical supplier to ensure you are getting the ammonia purity necessary for your system. One way to avoid ammonia contamination is to require dedicated trucks for each haul. Also, requiring certificates and test reports before offload is important for keeping the system free of contaminants like chlorides and calcium, which can damage and plug various ammonia-system components.

Specifying the correct purity grade of ammonia is critical. For aqueous ammonia systems, reagent-grade ammonia (99.95% NH_3 diluted by weight with deionized water) is the best option. The key differentiation is the purity of the water content of the solution, which if not deionized could contain soluble minerals that can plug, foul, erode, and damage SCR equipment. Impurities in the reagent solution can lead to vaporizer fouling, ammonia-injection-grid (AIG) plugging, and potential catalyst performance problems. It only takes one bad load of ammonia to experience the headaches associated with ammonia impurity.

For ammonia vaporizers, impurities can plug the spray nozzles or drip rings. They also can cause calcification that hinders vaporization efficiency and can lead to liquid reagent carryover. Channeling and plugging of the vaporizer can lead to NO_x exceedances and excess ammonia usage.

For electric vaporization systems, inspections of the heater-panel components should be done to ensure all circuits and protective devices are functioning. Inspect the electric heater as well to ensure there is no water intrusion, which can affect heater resistance.

On hot-gas recirculation systems, rotate idle fans weekly, by hand or electrical bump of the motor, thereby ensuring all bearing parts are properly lubricated. Change bearing oil semiannually using the specified lubricant and check oil levels regularly. Grease bearing seals annually (two or three pumps maximum) using the specified product. Do not use synthetic grease and do not over-grease. Too much grease can leak into the static oil lubricant. Open the coupling cover and regrease the coupling approximately every other month with the product specified.

2. How exhaust gas can bypass SCR catalyst: elements shifted, packing lost (A) and gaps between catalyst elements (B, C, D)

Inspect the AIG for proper ammonia distribution every outage. Plugging of reagent ports can have a major adverse impact on catalyst performance. If plugging is found, the AIG should be cleaned and its root cause investigated. Note that AIG design can be improved to mitigate plugging and achieve better performance.

For example, specify Type 304 stainless steel for your AIG and eliminate burrs in drilled lances where chips might collect and salt could accumulate.

Catalyst should be inspected every outage to ensure its face is not blocked by rust or insulation. This can majorly affect catalyst performance by masking its active pore sites.

The catalyst frame also should be inspected for any areas that may allow exhaust gas and ammonia bypass, which can greatly affect NO_x and ammonia slip (Fig 2).

Ensuring these key maintenance and inspections are done regularly, and addressing problems when they are discovered, are essential to an efficient SCR system. CCJ

Best Practices Awards

Six plants earn Best of the Best honors

The COMBINED CYCLE Journal and the steering committees of the industry's leading gas-turbine user groups collaborate to expand the sharing of best practices and lessons learned among owner/operators of large frame and aeroderivative gas turbines.

Six plants participating in the 2023 Best Practices Awards program were selected by industry experts for Best of the Best honors:

Amman East Power Plant
Owned by AES Corp, Mitsui, and Neberas Power
Operated by AES Corp

Broad River Energy Center
Onward Energy

H O Clarke, Topaz, and Braes Bayou
Owned by WattBridge
Operated by ProEnergy

Exira Station
Owned by Western Minnesota Municipal Power Agency
Operated by Missouri River Energy Services

River Road Generating Plant
Owned by Clark Public Utilities
Operated by General Electric Gas Power

Ventanilla Combined Cycle
ENEL Generacíon Perú

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

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


Wartbridge


Amman East


River Road

COMBINED CYCLE Journal CCJ No. 75 (2023)

Index to advertisers

River Road

River Road Generating Plant

Owned by Clark Public Utilities
Operated by GE Gas Power

248 MW, gas-fired 1 ×1 7FA.02-powered combined cycle equipped with a Foster Wheeler HRSG, and a GE A12 steam turbine, located in Vancouver, Wash

Plant manager: Robert Mash

HP steam drum leak repairs

Challenge. The HRSG high-pressure drum doors had a history of leaking. Some leaks caused forced outages; all leaks represented safety hazards for employees.

During annual outages, the drum doors were a challenge to close and seat properly for several reasons, including these:

- Bent and worn drum-door hinge hardware, which often caused misalignment of the door-to-drum connection.
- Pitted drum and door seating surfaces allowed a pathway for steam to leak.
- Worn drum-door bolts and strongbacks resulted in over-tightening (over torque).
- The heavy weight of the doors required personnel to use pry bars and wood blocks to center the drum doors in the drum opening (the existing drum-door leveling blocks did not perform well).

Solution. River Road is a baseload facility with very little downtime. Thus, all remedies listed below were implemented at the same time:

- Performed "phonograph-groove" machining on drum manway and door gasket sealing surfaces (Fig 1).
- Replaced the drum-door internal hinge assemblies.
- Replaced drum-door strongbacks (Fig 2).
- Replaced drum-door bolting with Superbolt™ and nut design.
- Replaced existing drum-door leveling blocks with an improved style (Fig 3).
- Completed machining and installing all parts during a single annual outage.

Results:

- Performed several startups and shutdowns post-outage with zero leaks to date.
- Project provided the opportunity for team participation and collaboration to identify all related issues and research potential solutions.
- The new drum-door leveling system works perfectly.
- The Superbolt system ensures proper torque is applied to drum doors and can be accomplished with a small ratchet torque wrench.
- Enhanced safety was achieved for all personnel working near or passing through the vicinity of the drum doors.
- The physical effort and time required for opening and closing drum doors was reduced significantly.

Project participants:
Ken Roach, maintenance manager
Mike Buhman, mechanic

Operators receive reverse-osmosis specialist certification

Challenge. River Road relies on a twin, double-pass reverse-osmosis system to provide ultrapure water for HRSG makeup, gas-turbine water wash, and the hydrogen generator. Over time, the operators most familiar with operating and maintaining the RO units have moved on. Only one outside operator remained who had been trained and certified in RO O&M.

Solution. The operations manager

1. Phonograph groove machining contributes better sealing

2. Drum-door strongbacks and bolting were replaced

3. Drum-door leveling blocks were replaced with those of a new style recognized the value the one certified operator brought to the table and decided to expand the knowledge base of the whole team. All operators attended a Reverse Osmosis Specialist Certification Course.

Results. The site now has a full team of certified operators who provide system knowledge and take ownership of it. The additional training has increased reliability and efficiency: The operations team is now able to quickly identify potential issues before they have a negative impact on plant operations.

Project participants:
Jake Sanderson, Micah Wild, Mark Todd, Allen Barnes, and Jesse Robinson are now certified in RO O&M.

'Operator in Training' program proves its value

Challenge. Proper staffing is a core requirement for a well-functioning powerplant. Filling a vacant position with the right person is very time-consuming. Additions to the team, even members with years of industry experience, require several months of training to acquire competency in site-specific policies, procedures, regulations, and system operation.

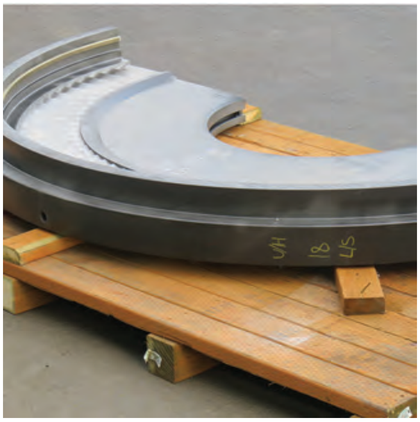
When a position opens, there is an immediate staffing shortage until the lengthy hiring process is complete. This increases the need for overtime and places an additional burden on the remaining operators as they work to cover shifts.

Promoting personnel internally provides opportunities for advancement.

Solution. River Road created a new position to help reduce staffing shortages: "Operator in Training," a/k/a OIT, a full-time entry-level job. This position allows the plant to hire local personnel who have potential but minimal power-industry experience. It provides an opportunity for the OIT to move to the next available operator position.

River Road's OIT program is comprised of the following three parts:

- *A. Employee orientation* introduces the new hire to plant administration and corporate and site policies.
- *B. EHS training and restricted work authorization* is designed to familiarize the employee with all hazards present at the facility and how to safely work with them. The training also introduces the employee to all environmental, health, and safety practices at the facility. Successful completion of this part of the OIT program allows the employee to work and navigate the facility unattended.
- *C. System qualification program.* The final section of the program provides a basic understanding of plant equipment, systems, and shift routines. This includes gas turbine, steam turbine, HRSG, water chemistry, thermodynamics, and balance-of-plant fundamentals.



4. Pallets are not ideal for maneuvering diaphragms

After completing Parts A, B, and C, the trainee is required to successfully complete both written and oral exams. After passing the OIT qualification program, the operator can begin training for the next level: "Outside Operator Qualification Program." Depending on the individual, the OIT program takes approximately one year to complete.

Results. Because the position is entry-level, there is a large pool of candidates to choose from. The candidates may have talent and aptitude, but lack industry experience.

Employees in the OIT program are often nearly qualified to stand watch when the next advancement opportunity arises. Staffing shortages during these periods have been greatly reduced. Since beginning the program, several OITs have advanced to outside operators.

In sum, the qualified OIT program provides the following:

- A staffing buffer.
- An operator-ready team member familiar with the plant.
- The ability to hire locally.
- The ability to train a new person from the start and introduce the OIT to the plant's culture.

Project participants:
Justin Hartsoch, operations manager
Robert Brown, shift supervisor
Steve Ellsworth, shift supervisor

Racks simplify diaphragm handling, transport

Challenge. River Road has a GE A12 steam turbine with 21 sets of diaphragms. During major inspections, handling all 42 diaphragm halves safely requires a lot of time—particularly when they are loaded onto pallets (Fig 4). In order to complete inspections, sandblasting, and repairs, each diaphragm must be handled several times when loaded on pallets.

5. Engineered racks facilitate handling of diaphragms

Solution. Construct steel diaphragm racks that can hold multiple stages (Fig 5).

All diaphragm weights and sizes were confirmed by a steam-turbine engineer to ensure the racks have adequate structural strength and provide adequate diaphragm support. For safety, ease of handling, and identification, each rack has the following:

- ID labels indicating which diaphragms are to be held in each rack.
- Maximum allowable weight label for each loaded rack.
- Empty weight label on the rack when unloaded.

- Lifting eyes for rack movement by crane.
- Heavy-duty wheels on each rack for movement with a forklift.
- Mounted keeper tabs to secure each section of the diaphragm in place during rack movement.
- Reflective tape on racks for safe movement during low-light operations.

6. **Diaphragm racks** have been loaned to neighboring plants.

Results. Construction of the diaphragm racks has resulted in several positive results, including the following:

- Time savings
  - Racks can be transported to the turbine deck during diaphragm removal.
  - Multiple diaphragms can be loaded onto a rack quickly once removed from the turbine casing.
  - Bridge-crane time is reduced.
  - Diaphragms can be inspected easily on the racks.
  - Minor repairs can be made to a diaphragm when it is on the rack.
  - Sandblasting can be done on the racks.
- Handling and transport
  - Both sides of the diaphragm can be seen and serviced while on the rack.
  - Large caster wheels installed on the racks facilitate their movement. Small racks can be manually pushed to new locations; larger racks can be moved using forklifts.
- The results have been so beneficial that other plants have borrowed the racks for use during their outages (Fig 6).

Project participants: The entire plant staff

Exira Station

Freeze-protection improvements assure high availability, reliable starts in winter

Exira Station

Owned by Western Minnesota Municipal Power Agency

Operated by Missouri River Energy Services

140 MW, 3 × 0 gas-fired peaking facility with diesel-oil backup, located in Brayton, Iowa. The LM6000PC engines are equipped with Sprint

Plant manager: Ed Jackson

Background. Exira Station's design minimum operating temperature is –26F. Plant often is called on to run at sub-zero temperatures and has operated as low as –30F.

Operating in extreme cold always is challenging. To ensure the facility is prepared to run in all conditions, plant personnel developed a winterization checklist. The four-page 56-step document lists everything necessary to prepare the plant for wintertime operation. Some steps are quick and simple and only require a couple of minutes or so to complete. Others are more involved and could take days.

While the checklist addresses the more obvious and general things the plant must do to prepare for winter, Exira had several other challenges requiring unique solutions. The list below highlights some of those problems along with their solutions.

Challenge 1. Package heat tracing was unable to keep up with sub-zero temperatures if fans are on. This caused water lines in the package to freeze unless water was flowing in the lines and created a "race" to get water flowing when operating in sub-zero temperatures before lines freeze.

Water injection starts at 5 MW, so the time it takes to push start buttons and fans start, until purge, warm up, and load to 5 MW are complete, is crucial; bad things can happen quickly. If there is a failed start for any reason during this time and another start is needed, there might not be enough heat in the package to prevent a line from freezing before water injection starts.

1. **Start supplemental inlet** heaters during the start sequence when the ambient temperature drops below 0F

2. **Insulation** between the bottom of the package and foundation helps keep heat where it's needed

Solution 1A. Buy more time by operating the supplemental inlet heaters in Fig 1 (which normally don't start unless the ambient temperature is less than –20F) during the start sequence when the ambient drops below zero. This adds a little more heat and helps prevent freeze-up. You can return to auto operation after water-injection flow starts.

Solution 1B. Keep as much heat in the enclosure as possible. MRES and other Midwest operators, have insulated their package bases to do this (Fig 2).

Challenge 2. Failed starts are extremely problematic in cold weather: You may not get another start attempt if the water lines freeze. It's critical to reduce or eliminate failed starts.

Solution 2A. It's important to eliminate inconsistent light-offs attributed to low fuel-oil temperatures by setting the fuel-oil-tank immersion heaters to maintain the oil at 60F.

Solution 2B. Starting on fuel oil takes longer to reach the 400F lite-off temperature than starting on gas. To reach 400F faster, within 40 seconds, increase the fuel-oil-valve lite-off percent from 12% to 14%.

Challenge 3. After a stop and subsequent cooldown period with the fans running, the package is cold. A restart would start fans and purge again. Since components already are cold from fans running during the previous cooldown, things could freeze faster than previously. You may not be able to start again because of freeze issues.

Solution 3A. Shared solutions with Solution 1 above.

Solution 3B. Give the package time to warm back up after a start. Exira has adjusted its offer parameters to the RTO to limit restarts in winter to every four hours, giving the packages time to heat back up. If the RTO wants to shut down and restart, and the time between stop and start is minimal, plant has sometimes self-scheduled to "bridge" the runs to prevent restarts as noted above. Bear in mind that starts are fickle in sub-zero temps and a failed start cannot be afforded.

Challenge 4. Cooldown times can be longer than necessary during sub-zero temps. Fans running longer than necessary can increase the time it takes for the package to warm up, or could freeze pipes.

Exira added logic to stop a cooldown if (1) it has been running for at least 15 minutes, (2) the zero speed detected is true, and (3) the enclosure temperature is less than 32F.

Challenge 5. Fans can run for reasons other than package cooling—gas-sensor drift, for example. If fans start when water is not flowing, the piping and water valves can freeze-up. Consider buying a new valve if you freeze-up the one in service. The bottom line: Prevent fans from running if water is not flowing or going to flow.

Solution 5. Logic was added to stop fans if the unit is *not* in a sequence (that is start, stop, cooldown, crank, etc) *and* enclosure temperature is less than 32F. There is still protection against gas leaks, as the gas valve will close if LEL continues to drift up. The operator can still take action to run fans from the DCS if needed to purge.

Challenge 6. Fuel-oil filters can wax-up faster than the operators can change them. Exira's oil terminals are over 90 minutes away and the fuel must be trucked in. During extreme cold, by the time oil gets to the plant it is less than 20F—possibly as low as 5F.

Oil-tanker capacity is about 7500 gallons, but the plant can burn much more than that hourly. In fact, oil often burned faster than Exira can receive it. Problem is that when filling a tank as you draw from it, the cold oil sinks to the bottom of the tank and is immediately pumped to the operating units. The cold oil waxes up all the filters and creates differential pressures high enough to trip the units if plant personnel don't respond quickly.

The tankers line up and are offloaded continuously, filling the tanks with cold oil faster than the tank immersion heaters can keep up, and the fuel-oil temperature drops.

Solution 6A. Keep storage tanks at their maximum levels at all times. This way the fuel has enough time in the tank to warm up to 60F and if the plant must operate on oil hopefully there's sufficient volume to get it through the run.

Solution 6B. Exira installed a bypass to allow fuel oil to flow through a prefilter and back to the tank (Fig 3). This permits the plant to circulate fuel when the unit is shut down—circulating it through the filter and cleaning it continuously, thereby preventing filter plugging when producing power. Operators are busy enough during oil runs and extending the time between filter changes makes a huge difference.

Solution 6C. Exira is installing a fuel receiving and conditioning system, soon to be commercial. It will have two 160-kW inline fuel-oil heaters, and filters, in the line from the tankers to the storage tanks. This will help prevent waxing by heating the fuel before it gets to the tank.

Plus, when fuel is not being received from the tanker, the system can switch to recirculating oil in the storage tank to help the immersion heater get the temperature back to where it needs to be, while filtering the oil.

It will be possible to recirculate, heat, and filter one of the plant's two tanks while filling the other. A 4-in. articulating unloading nozzle also is being added, giving Exira the ability to quickly connect to tankers. An Allen Bradley Flex I/O rack will bring the unloading system into the plant control system for better monitoring and control.

Challenge 7. The legacy cement pad used to park trailers was dished for containment, making it dangerous to use when the sloping sides were covered by ice.

Solution 7. The original pad was removed and a new one poured, eliminating the problematic slope. This pad has a redesigned drain for containment to increase safety.

Challenge 8. The demineralized-water trailer sits outside on a cement pad with fire hoses to connect to plant piping that send raw water to the trailer,

3. Bypass installed allows Exira to circulate fuel when the unit is shut down to clean the oil

4. When complete, building will protect demin trailers from the elements

and demin water from the trailer to the plant. This creates many problems—including freeze-up of access doors preventing operators from gaining access to the trailer, and the need to handle hoses in sub-zero temperatures. Staff cannot leave the hoses outside overnight and when needed in the morning must pull them out, connect them, and get water flowing before it freezes.

When finished making water for the day, staff must shut down the demin system and disconnect the hoses and pull them into a heated building before they freeze-up. If the demin system shuts down automatically because of a system upset, personnel must rush to get hoses pulled inside before the water in them freezes.

It's almost impossible to handle a frozen 2.5-in.-diam water hose. At times, personnel had to abandon the hoses in place and run new ones to keep water flowing. Also, trailers have been frozen in place with large ice dams preventing staff from replacing the trailers.

Solution 8. Exira is enclosing the demin-trailer pad and making it a heated building (Fig 4). When complete, it will accommodate two trailers side by side. A 26- × 18-ft roll-up door is being installed to close the building. This will greatly increase safety by preventing ice in the demin-trailer area and not having to handle water hoses during extreme cold conditions. Also, it will increase reliability by allowing access to the trailer and hoses at any time.

Project participants:
Ed Jackson, plant manager
Tyler Furgeson
Tony Knapp
Devon Meyer
Baker Group (contractor)

Broad River

Rigorous planning significantly improves outage results

Broad River Energy Center

Owned and operated by Onward Energy

865 MW, dual-fuel facility in Gaffney, SC, with five 7FA.03 simple-cycle units, each equipped with an IST once-through steam generator

Plant manager: Malcolm Hubbard

Background. Having five GT/HRSG trains, each consisting of a 7FA.03 and a once-through steam generator, managing outages at Broad River Energy Center can be challenging, depending on work scope, available time, available contract support, and other factors. Outages are among the top three or four expense entries on the plant's balance sheet, thereby demanding attention to detail and taxing the efforts of plant personnel to optimize and organize tasks.

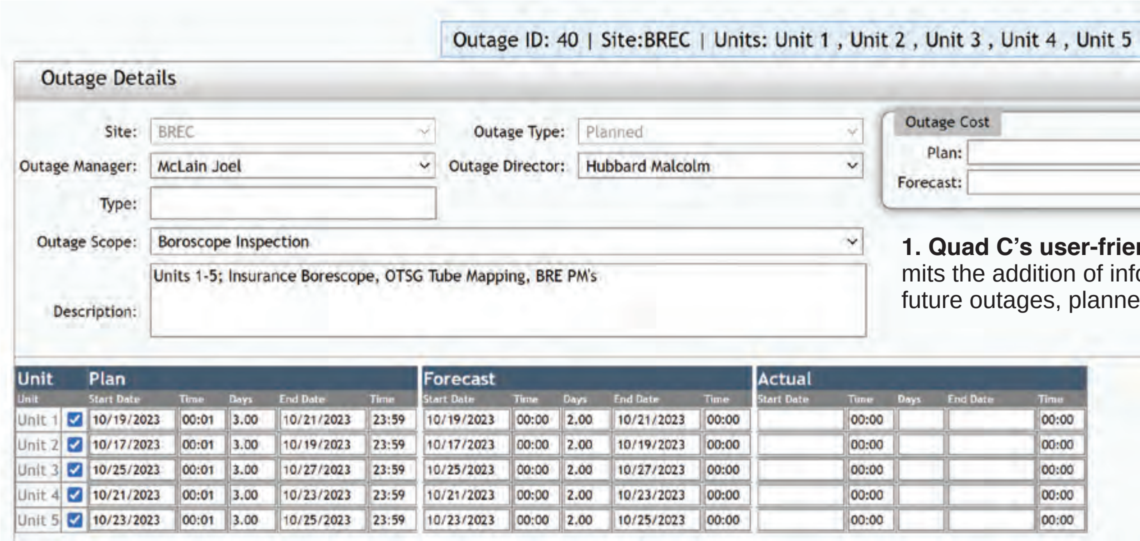
Past outages often fell victim to schedule and cost overruns. Quality of workmanship was another concern given the amount of rework often required and availability impacts caused by contractor quality oversight.

The current staff has been challenged by ownership to reduce outage cost and duration, and improve quality control, compared to past practices with different owners and operators.

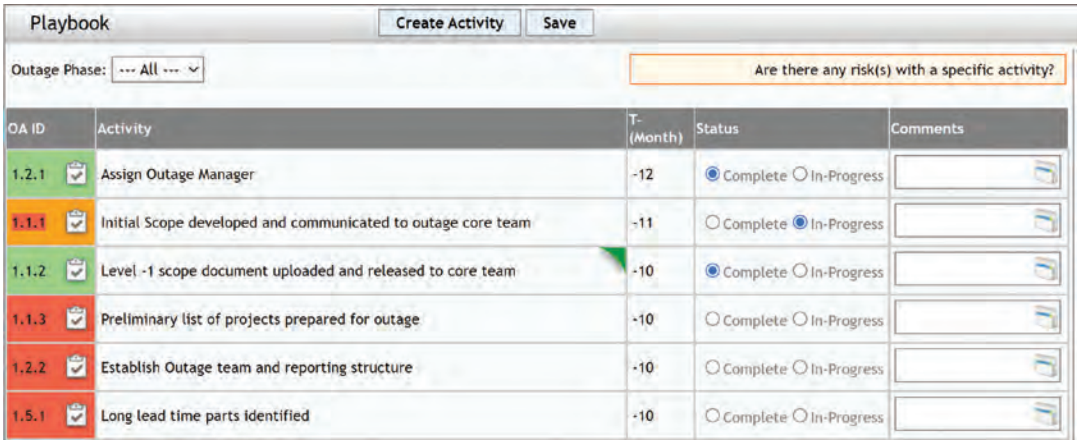
Challenge. A new manager was hired for Broad River with outage planning a high priority and goals of reducing outage expenses, increasing reliability, and improving customer relations. These strategic objectives were a focus with quality improvements being a dependency of each.

While outage philosophies are similar across the industry, the mechanics of how to prepare and optimize is highly dependent on staffing levels, knowledge and experience of personnel, and tools used to make the tasks and work packages more manageable to team members.

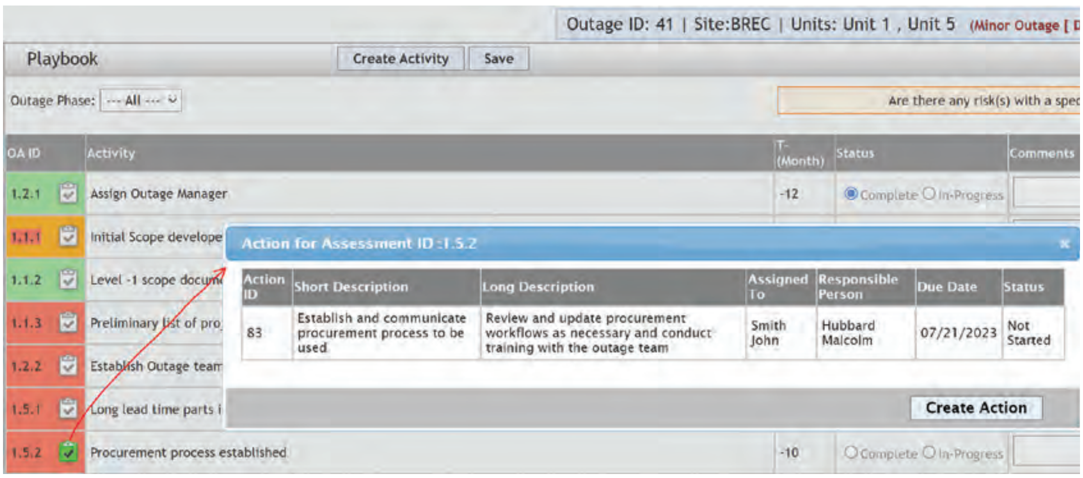
Solution. Broad River deployed Quad C®, a software tool to assist in outage planning, believing it would help improve coordination, enable earlier discovery of challenges, promote better communications with vendor and owners, and build a foundation for optimal outage oversight. One of the key objectives was to create a continuous-improvement plan that



1. Quad C's user-friendly menu permits the addition of information from future outages, planned or unplanned



2. New tasks can be added to the Playbook for future outages without having to go back and review notes



3. Action assignments can be managed through the Playbook, optimizing time and creating an automated work flow

would efficiently allow the facility to mature the planning and execution process over time.

Plan goals included the following:

- Consistency across the entire team.
- Standard reporting.
- Easy to use.
- Better oversight of risks and lessons.
- Reduce outage cost.
- Shorten outage duration.
- Provide a single location for outage files.
- Improve accountability and engagement.

Quad C provides a simple and user-friendly menu of modules that allow the addition of future outages, planned or unplanned, for ease of tracking fleetwide (Fig 1). The cornerstone module is the "Playbook" which is easy to follow, provides quick status indicators, and manages key tasks. New tasks can be added to the Playbook easily to help plan upcoming outages, without having to go back and review notes (Fig 2).

Action assignments can be managed through the Playbook, optimizing time, effectiveness, and creating an automated work flow (Fig 3).

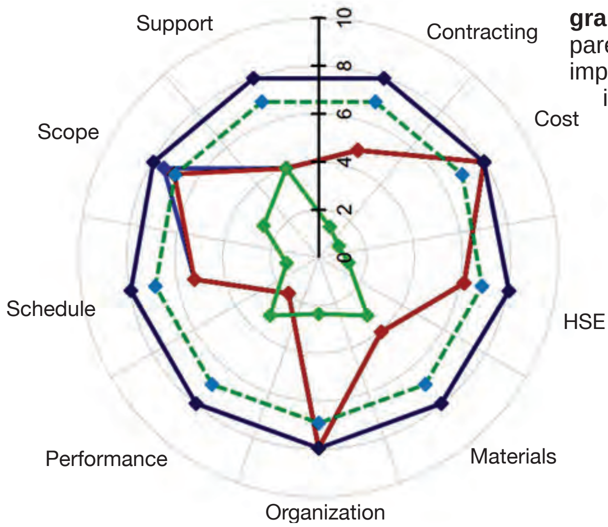
Numerous status reports and indicators are available to assess and communicate with others, improving planning support needs. A planning indicator shows status compared to the target, based on the phase and timing. The sample of status metrics in Fig 4 illustrates a simple status report of Playbook activities (Fig 4).

As one matures with planning, a dynamic readiness graph allows staff to compare outages and easily identify improvement areas, impacts, and risks that best support an owner's

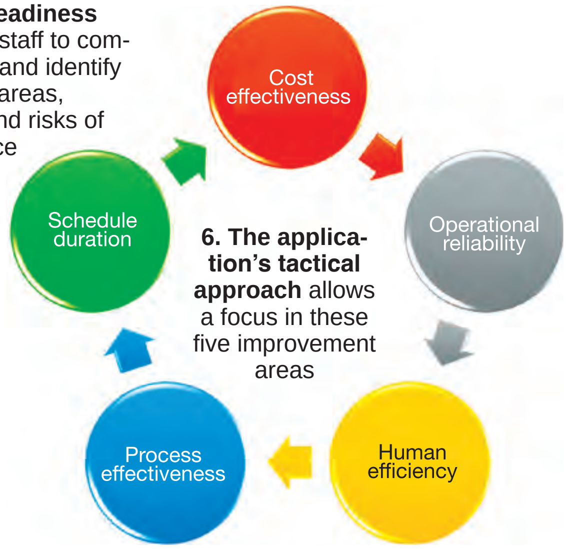
Playbook Metrics for Outage : 12 **Current Month**

OA ID	Playbook Activity	Target Months -12	-11	-10	-9	-8	-7	-6	-
1.2.1	Assign Outage Manager	✔							
1.1.1	Initial Scope developed and communicated to outage core team		✔						
1.1.2	Level -1 scope document uploaded and released to core team			✔					
1.1.3	Preliminary list of projects prepared for outage			✔					
1.2.2	Establish Outage team and reporting structure			✔					
1.5.1	Long lead time parts identified			✔					
1.5.2	Procurement process established			✔					
1.7.1	Outside Contract services identified			✔					
2.5.1	Special Tools, equipment needed for outage identified				✔				
2.6.1	Initial HSE program and communication plan established and communicated				✔				
2.7.1	Contracting Management Strategy established				✔				
2.1.1	Scope committee identifies required vs. elective work items					✔			
2.2.1	Pre-Outage meetings established and scheduled					✔			

4. Sampling of status metrics illustrates how these activities are reported for plant use



5. Dynamic readiness graph allows staff to compare outages and identify improvement areas, impacts, and risks of importance



6. The application's tactical approach allows a focus in these five improvement areas

strategy of continuous improvement, cost reductions, and quality elements for the plant (Fig 5).

The application's tactical approach has allowed for a focus in the five key areas of improvement highlighted in Fig 6.

Results:

1. Durations of outages have been reduced by about 11% when comparing similar schedule scope items.
2. Savings have been recorded from about $115k to more than $400k, depending on comparative data.
3. A positive annual reliability impact exceeding $275k.
4. A reduction of outage-related work orders resulting from quality issues and reduced trips/forced outages because of outage quality concerns.

End notes. Takeaways from Broad River's experience in outage planning include the following:

- Use a tool that allows the outage team to communicate easily and track progress–one that isn't overly complicated and/or burdensome for a small staff.
- Do not reduce scope items to meet a deadline and call the outage "successful."
- Collect data from the software that helps manage future outages better with the use of lessons learned, opportunities, and collaboration.
- Openly communicate to the owners and key contractors through a process that improves support, coordination, and results.

Project participants:
Malcolm Hubbard, plant manager
Joel McLain
Kevin Whitney

Starting reliability on oil improves with filtration

Challenge. Broad River Energy Center is a dual-fuel gas-turbine facility. Reliability when starting on distillate, or switching to it from gas, was historically lower than expected. The root cause for many of the reliability issues was contamination of oil in the plant's 4-million-gal storage tank.

Plants monitoring the condition of their backup fuel sometimes are surprised by the poor quality of oil at the bottom of their tanks—say the last 5 ft or so.

This generally is not problematic given the floating suction systems typically in use today—that is, until you have to burn the dregs. It doesn't take much sludge-type material to cause a failure to start or to trip a high-performance gas turbine. The financial penalties could be significant.

Solution. The first step to a solution was to take grab samples and have a certified lab analyze the fuel to identify the reasons for the trips, fired shutdowns, and failed transfers. Evidence in hand, a complete inspection and recommissioning of turbine fuel-system components—including flow dividers, purge valves, check valves—was conducted. A strategy to install a filtration system was developed to maintain the fuel in ready-for-service condition.

The filtration skid was installed in the fuel-oil offload area and equipped to take suction from the tank's sump area and from its floating suction strainer. Filtered oil is returned to the top of the tank to maximize agitation and turnover of the oil.

The filtration system selected, from C C Jensen, is similar to that used in lube oil systems at many powerplants. In the first four weeks of operation more than 340 lb of contaminants was removed. Note that a vacuum truck was used to remove settled contaminants from the system before commissioning the filtration system.

Water removed in the second stage of the two-stage filtration system is discharged directly to the oily water separator sump. A differential-pressure gage enables plant personnel to monitor the condition of the filter elements and proactively plan for filter changes.

Results. The system is meeting expectations. No hard numbers on starting reliability improvement were available prior to publication.

Project participants:
Joel McLain
Travis Haynes
Eddie Mustin
Scott Bostwick

H O Clarke, Topaz, and Braes Bayou

Owned by WattBridge

Operated by ProEnergy

1248 MW (Clark and Braes Bayou each have eight 48-MW LM6000PC engines; Topaz, ten 48-MW LM6000PC machines). All are gas-fired peaking units located in the Houston area

Plant manager: Kevin Chaffin

Modeling for successful proactive remote monitoring and diagnostics

Challenge. By their nature, peaking units must have high availability. As a result, O&M teams are challenged to maintain LM6000 units based on broad life-limit calendars, scheduled inspections, and experienced intuition. They are blind to the actual condition of equipment between inspections and must operate reactively to alarms. This approach risks reliability and availability during peak load times, as even a few hours downtime at the wrong point in a season can wreak havoc on plant economics for the year.

Solution. Create proactive remote monitoring and diagnostics (RM&D) models to detect incremental changes in equipment operation not identifiable with standard monitoring techniques. When identified, these changes should be reported via easy-to-understand advisories that include recommended actions.

The technology behind RM&D—predictive analytics—gives valuable insights into the actual condition of equipment and its performance. Result: Users can avoid outages during peak run times, proactively schedule maintenance, source equipment ahead of time, and adjust how and when to operate units. This solution has proven successful with various components—including fuel nozzles, bearings, and gearboxes.

Results. ProEnergy's O&M team provides recommendations to promptly rectify a given issue, with a view toward operational availability. This strategy provides a real-time view of equipment condition and protects operational strategy, saving time and money. Below are two case studies from WattBridge and a third-party RM&D user:

Case Study 1: Zero lost time through early detection. A user in the West received an advisory regarding an accessory gearbox before an alarm activated. An increase in bearing temperatures indicated a drop in lube-oil pressure. Plant was advised to closely watch the equipment during operations and to replace the lube-oil pump during regularly scheduled downtime. Upon replacement, operational values returned to normal with no loss of operating time.

Case Study 2: Catastrophe avoided with operational adjustments. During a peak runtime, a WattBridge site received an advisory of impending bearing failure, which could have catastrophic consequences for the turbine. The onsite team was advised adjust operating parameters to accommodate the damaged part, and a full-time remote operating center (ROC) watch was set for the unit. A replacement engine was sent to the site, which resulted in no additional damage to the original unit and a minor loss of productivity during peak load time.

Project participants:
Kevin Chaffin and the ProEnergy O&M organization

Seasonal shelters protect plant equipment in winter

Challenge. Climatic stress has no geographic boundary. As more-frequent extreme-cold events strain supply capacity, the challenge is keeping powerplants online. Virtually any facility in the world is susceptible to icing issues considering that turbine icing begins at 40F and air compression begins freezing at 34F.

Solution. Traditionally overlooked in warm climates, winterization solutions can ensure sustained cold-weather operation. To winterize balance-of-plant (BOP) equipment, O&M teams must balance operational strategies and procedures with costs.

What started at ProEnergy (PE) as an emergency effort—creating temporary, home-built structures in advance of a record freeze—resulted in effective, low-cost, and simple-to-use removable shelters as standard practice across all of the company's plants. In 2022, PE operated four peaking power facilities in the greater Houston area comprised of 30 LM6000PC gas turbines.

Rather than building costly, hardened shelters, PE worked with a vendor to create custom weatherization shelters installed and uninstalled via zippers. These shelters apply to the water-spray injection skids, the NO_x skids, and the plant instrument air compressors. An insulated covering is also used for the instrument panel on the turbine package.

Results. A temporary, urgently needed solution for one location has now grown to a permanent, inexpensive solution across an entire fleet. The ProEnergy O&M team conceived of this best practice even before related NERC compliance goals were instituted and now apply it to every new plant that comes online for improved energy security.

Though located in the warm Gulf Coast, the H O Clarke Generating Station—the first WattBridge facility, the world's largest LM6000 owner and operator—was prepared for the unprecedented. The station came online just a week and a half before Winter Storm Uri, a historic ice event that disabled more than half of the Texas power grid.

Recognizing that preparations were in order, the PE O&M team executed creative, low-cost solutions by erecting scaffolding around NO_x, water spray, and water pumps. Also ordered were 36 electric heaters (two per structure), built wind breaks for air compressors, and staffed the plant 24/7 for periodic rounds.

Weather shelters are installed and uninstalled via zippers

When the storm came, H O Clarke proved resilient with its newly innovated winterization strategy in place. The Ercot market reflected an extreme need for generation, and the station remained 100% available, running 141 uninterrupted hours with enough power for 200,000 homes. By the time Ercot revoked its emergency order, it had run for six days.

After that, ProEnergy explored options to make this successful short-term solution into a long-lasting one. The team explored a variety of structures, including permanent shelters and a wide variety of temporary, seasonal structures, and selected the zipper-based structures shown in the photo.

Applied at the second facility to come online, Topaz Generating Station, the O&M team deploys these structures starting in December each year and removes them in spring. In addition, WattBridge sites institute 24/7 plant staffing when expecting temperatures under 28F. These structures will be available at all of the company's sites in 2023—including H O Clarke, Topaz, Braes Bayou, Mark One, and Brotman.

Project participants:
Kevin Chaffin and the ProEnergy O&M organization

Roving work crews effectively support small onsite staffs

Challenge. Today's O&M environment faces a triple challenge: First, staff shortages abound and filling these roles with skilled, trained, and experienced technicians is difficult nationwide. Second, training inexperienced yet promising staff puts additional stress on the existing staff and tends to be site-specific and difficult to repeat at scale. Third, because O&M services at plants typically operate on razor-thin margins, additional investment for recruiting and training compounds the first two challenges.

Solution. ProEnergy O&M services leveraged geography to alleviate staff shortages and centralize training new staff. In 2022, the company operated four peaking-power facilities with a total of 30 LM6000PC gas turbines in the greater Houston area. The company embraced the small-team concept and embarked on a mission to streamline work management through standards and automation.

Each site is staffed with a small contingent of technicians. A roving services crew supports each site for major work items, can work on multiple turbines, and visits on an as-needed basis. In addition, all sites leverage technology from the 24/7 remote operations center (ROC) and remote monitoring and diagnostics (RM&D) support from the ProEnergy ROC in Houston and Sedalia, Mo.

Staffing. Each eight-unit plant site is staffed by one (each) instrumentation and electrical (I&E) technician, mechanic, auxiliary operator, and site supervisor. Staffing is the same for 10-plant sites, except they have two I&E techs. Roving plant services teams each have two I&E techs and two mechanics.

Results. Leveraging the geographic density of plants in the Houston area, creating an effective shared-services team, and streamlining work processes enables ProEnergy to thrive with a small O&M team. Based on 2022 performance, the company operates peaking-power facilities with industry-leading reliability and availability.

In 2022, the WattBridge fleet was dispatched for more than 1.3 million MWh of much-needed power throughout the year at an average starting reliability of 99%. Furthermore, as Texas endured record heat during the hottest July in 128 years, the H O Clarke and Topaz facilities met energy security needs with starting reliabilities of 99.6% and 99.7%, respectively.

Project participants:
Kevin Chaffin and the ProEnergy O&M organization

Amman East

Amman East Power Plant

Owned by AES Corp, Mitsui, and Neberas Power

Operated by AES Jordan PSC

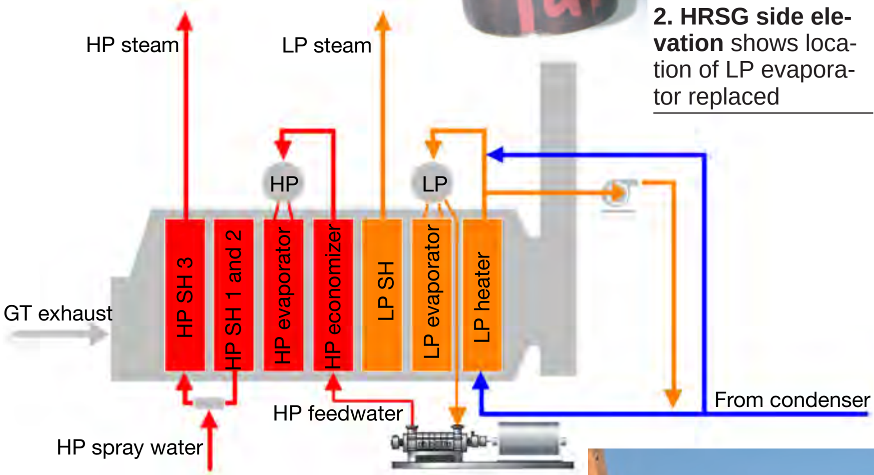
400 MW, gas-fired with diesel-oil backup, 2 × 1 combined cycle powered by AE94.2 gas turbines, located in Al Manakher, Jordan. COD was September 2009

Plant manager: Feras Hammad

FAC encourages replacement of LP evaporator

Background. Amman East's gas turbines are each connected to a dedicated heat-recovery steam generator through a diverter damper, allowing the plant to run simple- or combined-cycle. Steam produced by the HRSGs drives a single-casing, condensing, non-reheat turbine. The steam cycle is dual pressure.

1. FAC, flow-accelerated corrosion, was the underlying reason for replacing Amman East's LP evaporators



2. HRSG side elevation shows location of LP evaporator replaced

Challenge. LP evaporator sections in both HRSGs suffered from flow-accelerated corrosion (Fig 1). Investigations undertaken with the goal of preventing FAC or minimizing its consequences on plant productivity were not fruitful and management opted to replace the affected heat-transfer surface (Fig 2).

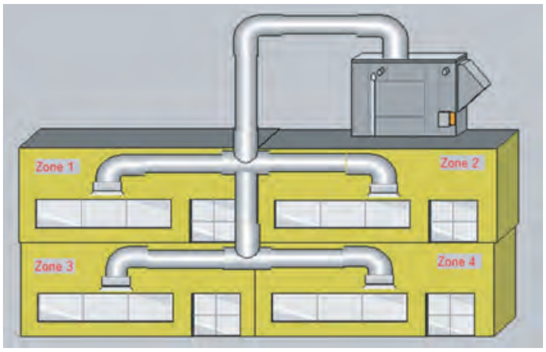
Solution. Each LP evaporator consists of three sections connected in parallel; each section has two harps. The harps weigh a nominal 28 t and measure approximately 21 × 4 × 0.4 m deep. The harp-replacement project began in 2021. The new modules are made with SA213-T11 tubes and SA335-P11 headers to minimize the possibility of FAC attack one might expect with carbon steel.

Preparation for replacement included removing a portion of the casing and installing the monorail shown in Fig 3 to extract the old panels and insert the new ones. While this work was ongoing, the new panels were transported to the site and stacked in the order they would be picked by the crane. The damaged panels were trucked offsite (Fig 4).

Final steps included installing the new harps and interconnection piping, non-destructive testing, leak testing, and flushing. Next, the HRSG casing was reinstalled with new insulation and high-temperature piping was insulated. Touch-up painting and verification that I&C and electrical circuits

3. Monorail was installed to extract/insert evaporator panels

4. Old harps being loaded for shipment offsite



5. Dividing building into four individually controlled zones made personnel more comfortable

were properly installed brought the project to a conclusion.

Results. Rehabilitation of each HRSG took about 30 days. All project goals were achieved. Access the project's 5-min time-lapse video produced by M AlRiachi by scanning the QR code; the editors give it two thumbs up.

Project participants:
Feras Hammad, plant manager
Sameer Ghanim, mechanical leader
Mohammad Thaher
Mohammad AlRiachi
Anas Diab, performance manager

Admin building HVAC operational improvement

Challenge. The climate-control system serving Amman East's administration building was not meeting expectations. There were many complaints by employees related to the failure to maintain building temperatures within desired ranges. Plus, noise on the top floor of the building was deemed excessive.

Solution. Divide the building into four zones for better temperature control (Fig 5). Install VFDs on air-handling motors.

Results. Goals achieved: easy and effective control of each zone by building inhabitants, eliminated the need for operators to deviate from their important duties to change the temperature setting, better working environment, less wear and tear on HVAC equipment, etc.

Project participants:
Sameer Ghanim, mechanical leader
Mohammad Yacoub, maintenance manager
Mohammad Al Ziq, I&E leader

Overhead-crane lift safer with load display

Challenge. Lift safety benefits from having the crane operator able to verify that load on his hook is known and free in all directions. In some cases, however, the object being lifted may have hidden corners or be of an unconfirmed weight, increasing the level of lift risk and possibly creating some operator discomfort.

Solution. Install a load display (Fig 6) to eliminate a possible unknown and improve the probability of lift success.

6. Highly visible crane load display took the guesswork out of lifting

Results. The load display provides the crane operator the information he or she needs to make a safe lift.

Project participants:
Sameer Ghanim, mechanical leader
Mohammad Yacoub, maintenance manager
Mohammad Al Ziq, I&E leader

ACC washing system changes promote safer operation, improved performance

Challenge. The washing system for cleaning Amman East's air-cooled condenser created high noise and vibration when operating—at times so severe that the discharge line would break.

Solution. These proposed solutions were investigated by plant personnel:
- Shifting the washing pump skid to the nearest adequate source.
- Changing the suction line to stainless steel and increasing its diameter.

Results. Problems solved: Cleaning performance improved, noise level reduced, repairs previously required eliminated.

Project participants:
Hussain Al-ajarmi
Ali Hamed

Meet the key participants in Amman East's 2023 plant improvement projects

Hammad Ghanim Thaher Yacoub Al-ajarmi Al Ziq Hamed