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CCJ COMBINED CYCLE Journal

POWER USERS Mega Event

2024 Combined Conference and Vendor Fair

Arizona Grand Resort (Phoenix) • August 26 – 29

Technical program overview begins on p 10, exhibitor list on p 16

2023 Combined Conference Report begins on p 20

COMBINED CYCLE USERS GROUP · GENERATOR USERS GROUP · STUG STEAM TURBINE USERS GROUP · POWER PLANT CONTROLS USERS GROUP · Low Carbon Peer Group

Best Practices Awards

INDEPENDENT VOICE OF THE GAS-TURBINE-BASED GENERATION SECTOR

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Sam Graham

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Nick Bohl

Garry Grimwade

Peter So

Jason Makansi

Bob Anderson, principal, Competitive Power Resources Corp

Bob Anderson joined CPS in 2005, following a 33-year career at Florida Power Corp/Progress Energy (now Duke Energy). The independent consulting firm, based in Palmetto, Fla, focuses on heat-recovery steam generators and their related auxiliaries for combined-cycle and cogen plants.

Recognized globally as an HRSG expert, Anderson has deep experience in powerplant design, operation, and maintenance. His positions at Progress included boiler engineer, steam-turbine engineer, plant manager, and director of gas-turbine major maintenance. As manager of PE's combined-cycle services section, he was involved in the procurement, design, and O&M of the utility's CC fleet.

Over the years, Anderson has participated in the installation of thousands of tube-temperature thermocouples in a variety of HRSGs and analysis of the resulting data. His expertise includes the optimization of boiler drain systems and attemperation systems. Plus, he has contributed to the development of startup/shutdown procedures for more than 70 combined-cycle and cogen plants around the globe. Results of his work have been published in many conference papers and the CCJ.

Anderson, chairman of the HRSG Forum (www.HRSGforum.com), is a skilled discussion leader well known both for his technical leadership in combined-cycle seminars and conferences and willingness to share his knowledge with users worldwide.

Nick Bohl, plant manager, St. Charles Energy Center

Nick Bohl as been plant manager at St. Charles, a 2 × 1 7F.05-powered combined cycle, since July 2018. Earlier, he was GM at Cogentrix Energy's Effingham County Power and held various leadership positions at CAMS from June 2007 to June 2015. He began his career in the energy industry as a technician for Mirant in 2001, migrating to Progress Energy in June 2005 as a production team leader.

Bohl's journey began in the US Marine Corps, where he served as an avionics technician for five years before going to Mirant.

Bohl and his present and former colleagues at St. Charles Energy and Effingham County Power continue share many of their valuable O&M experiences with the industry through CCJ's ongoing Best Practices program. The two plants have received more Best of the Best awards than any other facility since the program's inception 20 years ago.

Dr Barry Dooley, senior associate, Structural Integrity Associates (UK)

Barry Dooley, respected worldwide for his encyclopedic knowledge of powerplant materials and chemistry, has served the electric power industry for more than five decades. During that time, he has authored or co-authored more than 300 technical papers.

Dooley organizes and chairs boiler/HRSG and chemistry forums worldwide—including the Australasian Boiler and HRSG Users Group, European HRSG Users Group, Film Forming Substances conferences, and several others.

Prior to joining Structural Integrity, he was a technical executive at EPRI, specializing in cycle chemistry, materials, boilers, HRSGs, and steam turbines. Management of the research organization's boiler/HRSG tube-failure reduction/cycle-chemistry improvement and FAC programs was one of his responsibilities.

Earlier in his career, Dooley provided cycle chemistry and materials services for Ontario Hydro's fossil fleet and conducted oxidation research at the UK's Central

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Electricity Research Laboratories.

Dooley is well known today for his ongoing work as executive secretary at the International Association for the Properties of Water and Steam where he chairs the development of IAPWS Technical Guidance Documents so valuable to powerplant personnel, among others. Access the TGDs at no cost on www.iapws.org.

Sam Graham, plant manager, Tenaska Virginia Generating Station

Sam Graham was promoted from maintenance manager to plant manager at TVGS in fall 2017 with nearly two decades of experience in the power industry. His current responsibilities include facility operations, maintenance, and overall performance to ensure optimal efficiency and compliance with industry standards.

Graham came to Tenaska Virginia Partners in July 2005 after nearly a decade with Edison Mission Energy where his focus was instrumentation and controls. Responsibilities at Edison included maintaining and troubleshooting control systems, ensuring the accurate operation of instrumentation, and contributing to the overall efficiency of the power-generation process.

Graham has been stalwart in advancing and expanding the reach of industry user groups and championing the cause of owner/operators as long-time 7F Users Group steering committee member and instrumental in the development of many of the Power Users Group conferences like the Steam Turbine Users Group and Frame 5 Users Group.

Garry Grimwade, utilities generation technician, Riverside Public Utilities

Garry Grimwade is a seasoned powerplant operator and the only member of the Editorial Advisory Board with extensive aeroderivative O&M experience. He currently volunteers as vice president of the Western Turbine Users Inc, the world's largest organization of aeroderivative owner/operators, where he holds tremendous responsibility for organizing and managing its extensive technical program.

Grimwade has been with Riverside since May 2011 with responsibilities for an LM2500-powered combined cycle, four LM6000s, and four GE10 engines that include safely starting up and shutting down units, ensuring environmental compliance, maintaining logs and readings, adjusting plant water chemistry, providing safety training, and managing the plant's self-reporting ORAP® program.

Earlier, Grimwade was a CRO for GE Energy, attached to two 7H-powered single-shaft combined cycles. From August 2007 to January 2010 he was a powerplant operator for Dynegy at a 700-MW merchant facility with natural-gas-fired boilers and steam turbine/generators. His role included ensuring emissions compliance, performing and writing switching orders and LOTO, and troubleshooting faulty equipment.

From July 2003 to August 2007, Grimwade was at Duke Energy and Diamond Generating Corp. After mustering out of the US Navy in March 1999 with four years of experience as an engine mechanic, Grimwade joined the Pacific Gas Turbine Center as a rotor-balance team leader, supervising the overhaul of JT8-D engines.

Jason Makansi, president, Pearl Street

Jason Makansi, chairman of CCJ's Editorial Advisory Board, founded Pearl Street, an independent consulting firm, in 2001 and continues to serve as the firm's president. A chemical engineer by education, Makansi has spent the last four decades evaluating the global engineering, business, and regulatory issues governing advanced energy technologies, with a special focus on electricity production and delivery—including energy sources, electricity production, transmission, and distribution, customer-side energy services, and energy storage.

Earlier, he was employed as a process engineer for Heywood Robinson and as a chemical engineer for TVA.

Makansi is recognized worldwide as a thought leader in energy storage, clean-coal utilization technologies; environmental management; emissions control processes and carbon-footprint reduction; diagnostics, automation and information technologies, and knowledge management; powerplant asset optimization, gas-turbine and combined-cycle technologies, sustainable development, and industrial ecology.

A highly skilled communicator in energy technologies—verbal and written—Makansi has authored several books, including two for John Wiley, and hundreds of magazine articles on power generation technologies for CCJ and Power magazine, among others. Other credits include executive director of the Energy Storage Council and Coalition to Advance Renewable Energy through Bulk Storage, founder of Pearl Street Capital, and principal, Pearl Street Liquidity Advisors.

Bobby Noble, senior program manager for gas-turbine R&D, EPRI

Bobby Noble and his research team work on topics involving all aspects of the gas-turbine system, with a focus on combustion dyn amics, high-hydrogen and other alternative fuels, next-generation low-NO_x combustion architectures, and engine health and performance analytics—including digital twins.

Noble, an ASME Fellow with more than 20 years of GT experience, was awarded the 2024 Westinghouse Silver Medal for his work on behalf of the power industry. He holds five patents and has authored/co-authored/edited/co-edited more than 15 journal publications and more than 60 conference publications.

Peter So, project development/management director, Calpine Corp

Pete So currently manages technical development for Calpine projects in the West—including those involving carbon capture. He has been involved in powerplant development, operations, and maintenance for three decades and has a wealth of experience at facilities relying on traditional fossil fuels as well as leading-edge resources and technologies.

So's efforts have been rewarded with patents in the following areas:

- Inlet bleed heat and power augmentation.
- A method for providing off-gas to a combustion system.
- GT engine controls for minimizing combustion dynamics and emissions.

Among his many professional accomplishments, So led the software development of the first PSM LEC III retrofit on a 501D5 engine. Plus, he was the lead controls engineer for the company's Humid Air Injection project.

User-group credits include development of user-to-user discussion forums, serving on founding committees of Power Plant Controls User Group and Low Carbon Peer Group, as well as more than a dozen years on the steering committee for the 7F Users Group, where he contributed significantly to the group's growth and its transition to Power Users (www.powerusers.org), a 501c(6) organization. So remains involved with the not-for-profit organization as treasurer. CCJ

POWER USERS

2024 Annual Conference

Arizona Grand Resort, Phoenix, Ariz
August 26 – 29

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GENERATOR USERS GROUP

Low Carbon Peer Group

STUG STEAM TURBINE USERS GROUP

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TOSHIBA

Technical program highlights

DAYS	CCUG	GUG	STUG
Mon, Aug 26	AM: Baseload to cycling, condenser performance, lubrication basics PM: Safety, steam-drum door leak, terrorism, electrical testing	AM: Protective relaying workshop PM: Winterization, vibration case history, epoxy resin systems	AM: Navigating power trends, open forum and discussion PM: KN rotor cracking, EHC system issues, chemical excursion
Tue, Aug 27 Vendor Fair 8-9 a.m. 12-2 p.m.	AM: AIG tuning, attemperator replacement, HEP reliability, CUI PM: Cold-weather operation, ST case histories, metal-enclosed bus	AM: Stator condition assessment, EMI testing, vibration, overheating PM: Main-lead copper damage, end winding concerns, 324 failures	AM: Safety, advanced sealing, valve outage prep, solutions for aging fleets PM: Blade life extension, ST modernization, implications of carbon capture
Wed, Aug 28 Vendor Fair 8-9 a.m. 12-2 p.m.	AM: Forced-outage drivers, life extension, transformer inspection PM: SCR performance, ST modernization, outage management	AM: GE topics PM: Siemens Energy topics	AM: EPRI ST workshop, TILs/top issues, bolting, turning gear PM: Interval extension, casing replacement, outage execution improvement
Thu, Aug 29	AM: Insurance requirements, risk management, drones, safety valves PM: No sessions scheduled	AM: Recent EPRI projects, rotor ground faults, rewind case history PM: No sessions scheduled	AM: Cracked LP rotor, crossover tie-rod solution, D11, HP/IP replacement PM: No sessions scheduled

PPCUG	Low Carbon Peer Group
AM: Third-party integrator ensures controls project success PM: Technical training, Emerson update	AM: No sessions scheduled PM: No sessions scheduled
AM: Controls 101, GE program PM: GE program	AM: Integrated resource planning, EPA 111 rule discussion PM: CCS modeling, CCS pilot and DOE project updates
AM: Ergonomics, controls upgrades, cybersecurity PM: Changing NERC CIP standards, cybersecurity panel	AM: Hydrogen presentations by PSM, GE, Siemens, plus DeBary update PM: Nuclear, fusion, and grid-enhancement updates
AM: Effective control-system project management panel PM: No sessions scheduled	AM: Long-duration energy storage (NYPA, Duke, Dominion, Xcel, Southern) PM: No sessions scheduled

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.

2024 Combined Conference overview

The 2024 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 days away (August 26-29) at the Arizona Grand Resort, in Phoenix.

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.

The organizers expect more than 300 users at the Phoenix conference, plus a slightly higher number of vendor representatives.

Bear in mind that registering for any one of these user-group meetings gives you access to all.

The five groups come together for meals, the vendor fairs on Tuesday and Wednesday, August 27 and 28, from 7-8 a.m. and 12-2 p.m., and the Wednesday evening offsite event sponsored by Diamond Sponsors GE Vernova, MD&A, and Rexroth.

Keep up on program developments, both prior to and during the meeting, by visiting www.powerusers.com.

Another plus for attendees: All conferences associated with Power Users now offer PDH certificates.

The technical program for each user-group 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 26 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 2023 and earlier meetings already are accessible to registered users. If you are not registered, sign up now at www.powerusers.org; there's no charge.

COMBINED CYCLE USERS GROUP

Monday, August 26. The CCUG technical program begins at 8 a.m. with a two-hour workshop conducted by Babcock Power on (1) HRSG issues to be aware of when transitioning from baseload to cycling service—including component replacement, and (2) condenser performance—including the effects of water treatment on these heat exchangers.

In the second half of the morning's program, Shell Oil Products hosts a workshop on the fundamentals of lubrication.

The afternoon program kicks off at 1 p.m. with the presentation of CCUG's annual Individual Achievement Award, which recognizes industry professionals who have demonstrated excellence throughout their careers in the design, construction, management, operation, and/or maintenance of generating facilities powered by gas turbines.

The Turbine Inlet Cooling Association follows with the presentation of its annual award recognizing plants using innovative inlet cooling technologies.

Committee member Steve Hilger, plant manager, Dogwood Energy, gets the afternoon technical program rolling in high gear as moderator of the Safety Roundtable. CCUG Vice Chair Robert Mash, plant manager, River Road, retains the safety theme with his presentation on HRSG steam-drum door leak remedies.

Dealing with terrorism and its possible impacts, which would not have been a power-industry program topic only a few years ago, is addressed by the FBI following the afternoon break. The day concludes with presentations on the importance of testing and cycling your electric system and learning proactively about safety.

Tuesday, August 27. First topic after the morning session of the vendor fair from 7 to 8 a.m. (breakfast included) is AIG cleaning, tuning, and upgrades, covered by Andy Toback of Environex and Christina Suarez of Groome. Case studies on attemperator replacements, presented by Bill Kitterman of SVI Bremco, is next.

Remainder of the morning program: HRST's Jordan Bartol on corrosion under insulation; Emerson's (Flexim GmbH) Dennis Funk on attemperator leak detection; and Tetra Engineering's Peter Jackson with case histories concerning the reliability of high-energy piping.

Hilger chairs a roundtable on cold-weather operation, including lessons learned, following lunch and the two-hour afternoon session of the vendor fair. Next, Scott Cavendish of Independent Turbine Consulting shares steam-turbine case studies and best practices, with EBI's Mohsen Tarassoly bringing attendees up to date on what they need to know (and why) about IEEE's standard for metal-enclosed bus.

Wednesday, August 28. Jeff Chann, GE Vernova, launches the morning program (following breakfast and the vendor fair from 7 to 8 a.m.) with his thought-provoking presentation, "Unraveling the Forces Reshaping the Evolution of the Power Industry." GE Vernova speakers hold the podium for the remainder of the morning with these topics:

- Combined-cycle forced-outage drivers.
- Powerplant lifetime extension:

CCUG steering committee, 2024

Chair: Brian Fretwell, director of mechanical services—engineering and construction, *Calpine*
Vice Chair: Robert Mash, plant manager, River Road Generating Plant, *GE Power Services*
Phyllis Gassert, program director, operations excellence, *Talen Energy*
Steven Hilger, PE, plant manager, Dogwood Energy Facility, *NAES Corp*
Jason Jauregui, production lead, Woodbridge Energy Center, *CAMS*
Aaron Kitzmiller, principal engineer, Fayette Power Co, *Luminant*
Jonathan Miller, maintenance manager, Arcadia Power Station, *CLECO*
Jon Mongold, maintenance manager, Hill Top Energy Center, *NAES Corp*
Ben Stanley, VP operations, CPV Valley Energy, *DGC Operations*

Running your plant for the next 20 years.

- Transformer inspection and testing.

GE Vernova continues after lunch and the afternoon session of the vendor fair with "Turbine to Generator Alignment."

Remainder of the afternoon features these half-hour presentations:

- Top-Five SCR performance issues on combined-cycle units, Vaughn Watson, Vector Systems.
- Generator fleet update, Colleen Crawford, Siemens-Energy.
- Full element steam-turbine modernization approaches for existing combined cycles, Michael Smiarowski, Siemens-Energy.
- Generator outage management: What's your contingency plan? Jamie Clark, AGT Services.

Thursday, August 29. Power Users' Combined Conference concludes after the morning session's seven half-hour presentations:

- Outage management, planning, and execution, Jon Mongold, CCUG steering committee.
- Testing motive steam drain-pot valves and level indicators as required by ASME TDP-1, Chris Black, Lockton Companies.
- Manage or shut down? Brady Parscale, NAES.
- Establishing a drone program for your company, Aaron Kitzmiller, GUG steering committee.
- How to keep inlets running during extreme events, Bob Reinhardt, Donaldson.
- Roundtable moderated by members of the CCUG steering committee: How to temporarily deal with plant failures while you work on permanent solutions.
- Safety-valve testing, inspection, and maintenance, Jonathan Miller, CCUG steering committee.

Monday, August 26. The GUG technical program begins at 8 a.m. with a morning-long training program on generator protective relaying, presented by Doug Weisz, Hubbell Power Systems/Beckwith Electric.

The afternoon program, incomplete at press time (July 25), includes the following:

- Generator winterization, Eric Graftaas, PE, Midwest Reliability Organization.
- Generator core and parallel ring exchange, Sam Boshell, Calpine.

GUG steering committee, 2024

Chair: Jeff Phelps, system generator SME, *Southern Company*
Vice Chair: Craig Spencer, director of outage services, *Calpine*
Doug Coleman, generator engineer, *Duke Energy*
Dave Fischli, director of engineering and programs, *Duke Energy*
Andres Oliveres, generator specialist, outage services, *Calpine*
Joe Riebau, senior manager, electrical engineering and NERC, *Constellation Power*
Jagadeesh Srirama, senior electrical engineer, *NV Energy*

- Generator vibration case history, Juan Green, Duke Energy.
- Demystifying epoxy resin systems, Chris Klein, Astro Chemical.

Tuesday, August 27. Jamie Clark of AGT Services kicks off the technical program after breakfast and the morning session of the vendor fair from 7 to 8 a.m. with a presentation on condition assessments of GE hydrogen-cooled generator stators and related decision-making. Former GUG chairman, Kent Smith, follows with case studies on electromagnetic interference monitoring for his client, Cutsforth. Chris Breslin of EOne takes attendees to the morning break with "Generator Overheating Detection and Response with a GCM-X."

Three more presentations bring the group to lunch and the opportunity to visit the vendor fair for two more hours. The presos:

- Rotating rectifier redundant protection overview, series versus parallel, Jacques Leger, WEG.
- Importance of testing and cycling your electrical system, Nathaniel Smith, TEMS.
- Identify and resolve vibration caused by resonance, Danny Besmer, WEG.

The Tuesday afternoon program featured the following presentations:

- Safety differently: How your organization could learn proactively, Matt Barnes, MD&A.
- Generator failure discoveries, Howard Moudy, NEC.
- Generator fields: Common issues that can extend your outage, Jamie Clark, AGT Services.
- Damaged main-lead field copper with multiple main-lead styles, James Joyce, MD&A.
- Stator endwinding concerns, Howard Moudy, NEC.

Wednesday, August 28. OEM Day. GE had the podium in the morning to discuss the following:

- 7FH2 fleet performance, operation, and improvements.
- 324 fleet performance, operation, and improvements.
- Impact of sub-synchronous resonance and torsional interaction on powerplants.
- Tutorial: Stator core electrical design.
- Latest communications impacting the GE fleet.

Siemens-Energy takes the podium following lunch and the afternoon session of the vendor fair to present on these topics:

- Fleet major findings.
- Importance of the grounding brush.
- Generator product line update.
- Retaining rings.
- Stator endwindings.

Thursday, August 29. Power Users' Combined Conference concludes after the morning session's seven half-hour presentations, the first by EPRI's Bill Moore and the remainder by members of the steering committee:

- Recent EPRI projects.
- 324 phase-strap failure.
- Rotor ground management and rewind.
- Generator FME.
- TLRI rotor ground faults.
- Rewind case history.
- Troubleshooting vibration.

Monday, August 26. Jeff Chann, GE Vernova, launches the morning program with his thought-provoking two-hour presentation, "Navigating Power Trends." The STUG steering committee convenes an open forum and discussion session after the break; it is scheduled to take the remainder

STUG steering committee, 2024

Chair: Mark Johnson, *Florida Power & Light*
Vice Chair: Brandon Stewart, Plant Wansley, *Southern Company*
Jake English, *Duke Energy*
Jared Harrell, Taft Cogeneration, *OxyChem*
Jay Hoffman, *Tenaska*
Connor Hurst, Bayside Power Station, *TECO*
John McQuerry, *Calpine*
Jeremy Pou, *Tennessee Valley Authority*
Matt Radcliff, *Dominion Energy*
Seth Story, *Luminant*

of the morning.

The afternoon program, incomplete at press time (July 25), includes the following presentations by members of the steering committee:

- KN rotor cracking.
- EHC system issues.
- Alstom unit chemical excursion.

Tuesday, August 27. MD&A has the podium for the first half of the morning, following breakfast and the vendor fair from 7 to 8 a.m. Presentations by its experts are the following:

- Safety differently: How your organization could learn proactively.
- Advanced steam-turbine sealing technology.
- Valve outage preparation, fundamentals, and repair scopes.

After the break:

- HP inner block, Dave Cox, Power Services Group.
- ST case studies and best practices, Scott Cavendish, Independent Turbine Consultants.
- Out-of-the-box solutions from Allied Power Group for aging fleets.

Sam Drinkwater of EthosEnergy is first up following lunch and the two-hour afternoon session of the vendor fair with "Extending the Operational Life of Steam-Turbine Blades." Siemens-Energy closes out the day with these three presentations:

- Steam turbine fleet experiences.
- Full-element ST modernization approaches for existing combined cycles.
- Steam-turbine implications of carbon capture.

Wednesday, August 28. EPRI will share its steam-turbine experience after breakfast and the morning vendor-fair session. No information on content was available at press time.

The second half of the morning program and the entire afternoon (except for lunch and the two-hour vendor-fair session) is reserved for the following GE presentations:

- TILs and top issues.
- Bolting and turning-gear best practices.
- Interval extension with NGV—including NGV experience update.
- ASP with casing replacement experience.
- Update on improvement in outage execution for combined cycles.

PPCUG steering committee, 2024

Chair: David Martorana, *Tenaska*
Vice Chair: Richard Chiafolo, *Dominion Energy*
Brian Hall, *TECO*
Jason Justice, *Southern Company*
Peter So, *Calpine*

Thursday, August 29. Power Users' Combined Conference concludes after the morning session's presentations by members of the steering committee and colleagues:

- D5 cracked LP rotor and 10-month outage, Steven Weaver and Durane Bitsilly, SRP.
- 573-MW ST crossover tie-rod solution.
- D11 valve presentation, Brandon Stewart, Southern Company.
- D11 HP/IP replacement strategy, Steven Weaver and Gilbert Shupe, SRP.
- BB43 HP/IP retrofit lessons learned.

POWER PLANT CONTROLS USERS GROUP

Monday, August 26. No details on Monday's program were available at press time (July 25).

Tuesday, August 27. This is GE Day. No program details were available at press time (July 25). The vendor fair, including breakfast, is open from 7 to 8 a.m. and from 12 to 2 p.m., including lunch.

Wednesday, August 28. ABB is presenting the first half of the morning, following the vendor fair and breakfast from 7 to 8 a.m. The topics:

- Optimizing operator performance via a combination of control-room ergonomics and high-performance HMI.
- Optimizing steam-turbine performance by way of advanced hydraulic and mechanical control upgrades.

Following the coffee break, AP4 presents on "OT Cybersecurity: Is your Plant Protected?" Siemens-Energy is on tap for the last presentation before lunch and most of afternoon (after the vendor fair). Its lineup includes:

- Intelligent electrohydraulic redundant valve actuators.
- Navigating the changing NERC CIP standards.

LCPG steering committee, 2024

Dan Connors, *American Electric Power*
Todd Flowers, director of business development, *Dominion Energy*
Jess Kincaid, *Bonneville Power Administration*
Adam Reichenbach, lead engineer, *Duke Energy*
Bin Taddase, manager of plant performance, *DTE Energy*

A panel of experts representing GE Vernova, Siemens-Energy, AP4, and ABB addresses user questions to close out the Wednesday program.

Thursday, August 29. No details on Thursday's program were available at press time (July 25).

Low Carbon Peer Group

Monday, August 26. The Low Carbon Peer Group has not scheduled any events on Monday.

Tuesday, August 27. The day begins with breakfast and the first vendor-fair session from 7 to 8 a.m. Introductions and R&D strategy launch the group's technical program at 8:30 with an open discussion on integrated resource planning starting at 9:15.

After the break there's an open discussion on EPA's 111 rule and policy. Collaborative pilot opportunities and "other technologies" (including combined heat and power) close the morning program.

Following lunch and visit to the exhibit hall from 12 to 2 p.m., the focus is on carbon capture and sequestration—including a CCS modeling discussion and GE presentation. Pilot and DOE project updates complete the day.

Wednesday, August 28. PSM opens the technical program with a presentation on hydrogen after breakfast and the exhibit hall from 7 to 8 a.m. The hydrogen theme continues with an update on Duke Energy's DeBary project (green H_2) followed by GE's thinking on that fuel and an update on relevant pilot projects. Siemens-Energy's thoughts on hydrogen are next and a review of DOE's hydrogen hubs program takes the group to lunch and the final opportunity to visit the exhibit hall.

Forward-looking technology assessments dominate the afternoon, with discussions on the nuclear option, fusion, and grid enhancing technologies, plus plans for a transmission subgroup.

Thursday, August 29. The forward-looking technology assessments theme continues with a focus on long-duration energy storage. Updates on projects supported by DTE, NYPA, Duke Energy, Dominion Energy, Xcel Energy, and Southern Company dominate the program. An open discussion on LDES modeling completes the program.

Vendor Fair

Tuesday, August 27, 7 – 8 a.m. and 12 – 2 p.m.

Alphabetical order

Company	Booth no.
Advanced Turbine Support	14
Advanced Valve Solutions USA Inc	63
AGT Services Inc	44
AP4 Group	61
APG	60
ARNOLD Group	4
Astro Chemical	31
Avail Infrastructure Solutions	24
Baker Hughes	58
Baseload Power	5
Bosch Rexroth	54
Camfil Power Systems	34
Chevron	40
CUST-O-FAB	8
Cutsforth	6
DEKOMTE de Temple LLC	3
Donaldson	43
Doosan Turbomachinery Services Inc	22
Electric Machinery - WEG	20
Electrical Builders Inc (EBI)	46
EME Associates	32
Emerson	48
Engineered Pump Services	2
Environex Inc	12
Environment One Corp	53
EthosEnergy	45
Filter-Doc Corp	17
Fluitec International Inc	51
Gas Path Solutions	25
GE Vernova	1
Groome Industrial Service Group	19
Hargrove	42
HILCO Filtration	47
HRST Inc	16
Industrial Air Flow Dynamics Inc	57
Marioff NA	62
MD&A	21
Millennium Power Services	50
MSHS	23
National Electric Coil	39
Parker Hannifin	52
PESS	37
Power House Resources	56
Power Services Group	33
Precision Iceblast Corp	15
Projectile	35
PSM	7
Reliability Testing Services	27
Robeck Fluid Power	26
Shell Oil Products	64
Siemens Energy	30
ST Cotter Turbine Services Inc	49
STAR Turbine Inc	59
Sulzer Turbo Services Houston Inc	55
SVI BREMCO	41
Taylor's Industrial Coatings Inc	18
Technical Training Professionals	9
TEMS Inc	38
Tetra Engineering Group Inc	10
TOPS Field Services LLC	28
Toshiba America Energy Systems Corp	29
Vector Systems Inc	11
Viking Turbine Services Inc	13
Vogt Power	36

Booth number order

Booth no.	Company
1	GE Vernova
2	Engineered Pump Services
3	DEKOMTE de Temple LLC
4	ARNOLD Group
5	Baseload Power
6	Cutsforth
7	PSM
8	CUST-O-FAB
9	Technical Training Professionals
10	Tetra Engineering Group Inc
11	Vector Systems Inc
12	Environex Inc
13	Viking Turbine Services Inc
14	Advanced Turbine Support
15	Precision Iceblast Corp
16	HRST Inc
17	Filter-Doc Corp
18	Taylor's Industrial Coatings Inc
19	Groome Industrial Service Group
20	Electric Machinery - WEG
21	MD&A
22	Doosan Turbomachinery Services Inc
23	MSHS
24	Avail Infrastructure Solutions
25	Gas Path Solutions
26	Robeck Fluid Power
27	Reliability Testing Services
28	TOPS Field Services LLC
29	Toshiba America Energy Systems Corp
30	Siemens Energy
31	Astro Chemical
32	EME Associates
33	Power Services Group
34	Camfil Power Systems
35	Projectile
36	Vogt Power
37	PESS
38	TEMS Inc
39	National Electric Coil
40	Chevron
41	SVI BREMCO
42	Hargrove
43	Donaldson
44	AGT Services Inc
45	EthosEnergy
46	Electrical Builders Inc (EBI)
47	HILCO Filtration
48	Emerson
49	ST Cotter Turbine Services Inc
50	Millennium Power Services
51	Fluitec International Inc
52	Parker Hannifin
53	Environment One Corp
54	Bosch Rexroth
55	Sulzer Turbo Services Houston Inc
56	Power House Resources
57	Industrial Air Flow Dynamics Inc
58	Baker Hughes
59	STAR Turbine Inc
60	APG
61	AP4 Group
62	Marioff NA
63	Advanced Valve Solutions USA Inc
64	Shell Oil Products

Wednesday, August 28, 7 – 8 a.m. and 12 – 2 p.m.

Alphabetical order

Company	Booth no.
ABB Inc	19
Advanced Turbine Support	14
AGT Services Inc	44
Alta Solutions Inc	43
American Thermal Solutions	12
AP4 Group	61
APG	60
ARNOLD Group	4
Avail Infrastructure Solutions	24
Baseload Power	5
Beamex Inc	63
Bosch Rexroth	54
Camfil Power Systems	34
Catalytic Combustion	8
CC Jensen	10
Chevron	40
CleanAir Engineering	53
Cormetech Inc	20
DEKOMTE de Temple LLC	3
Deltak Inc	9
Doble Engineering Company	62
Doosan Turbomachinery Services Inc	22
Engineered Pump Services	2
EthosEnergy	45
Freudenberg Filtration Technologies	17
Gas Path Solutions	25
GE Vernova	1
Gulf Turbine Services	7
HPC Technical Services	32
Independent Turbine Consulting LLC	46
InServ	11
K Machine	58
Lectrodryer LLC	52

Company	Booth no.
Macemore Inc	16
MD&A	21
Millennium Power Services	50
MSHS	23
National Electric Coil	39
Nord-Lock Group	31
ORR Protection Systems Inc	38
Peening Technologies	56
Power Services Group	33
PowerFlow Engineering Inc	47
Precision Iceblast Corp	15
Premium Plant Services	6
Projectile	35
Rayker Mechanical	57
Robeck Fluid Power	26
Rochem Fyrewash Ltd	27
Shell Oil Products	64
Siemens Energy	30
ST Cotter Turbine Services Inc	49
STAR Turbine Inc	59
Sulzer Turbo Services Houston Inc	55
TesTex Inc	18
Tex Tenn Design & Consulting	37
Thompson Pipe Group	41
TOPS Field Services LLC	28
Toshiba America Energy Systems Corp	29
Veracity Technology Solutions	48
Viking Turbine Services Inc	13
Webster Associates	42
Young and Franklin	51

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14	Advanced Turbine Support
15	Precision Iceblast Corp
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18	TesTex Inc
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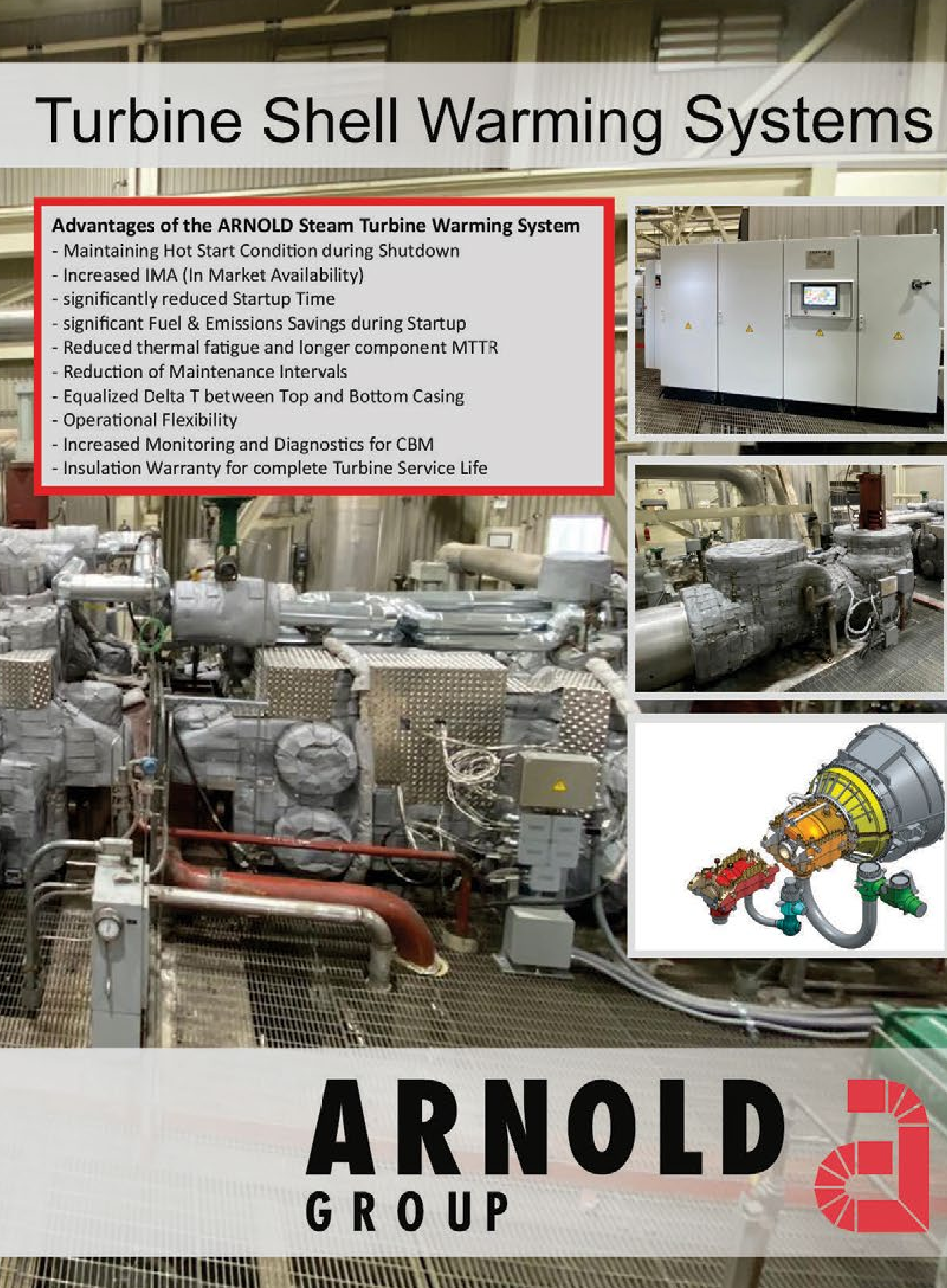
55	Sulzer Turbo Services Houston Inc
56	Peening Technologies
57	Rayker Mechanical
58	K Machine
59	STAR Turbine Inc
60	APG
61	AP4 Group
62	Doble Engineering Company
63	Beamex Inc
64	Shell Oil Products


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
ARNOLD
GROUP

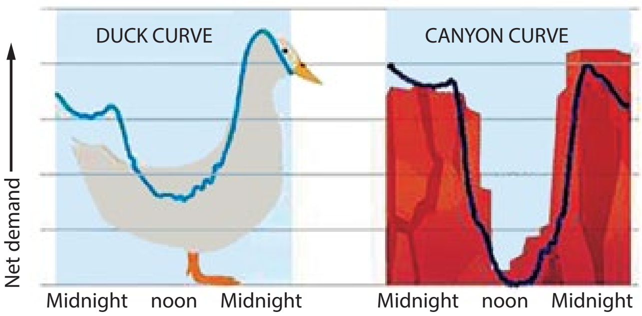
2023 Combined Conference report

Quality of work, changing missions challenge aging plants

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 year's event and to reflect on the positive impacts these user groups have had on plant operations and maintenance industry-wide. The knowledge, experience, and expertise shared on how to keep the nation's aging gas-turbine-powered generating facilities operating reliably and efficiently in the face of shoestring budgets, supply-chain disruptions, and labor shortages, is perhaps unprecedented.

Two broad themes stood out at the 2023 Combined Conference. The first: How aging plants adapt to changing, sometimes radically different, operating missions. The second: Continuing issues with supply chains, both labor and materiel, especially in terms of quality of work.

For more than a decade, combined-cycle plants have been following wind and solar with greater load cycling and more starts and stops. Today, many of those plants are cycling more frequently for even shorter periods with as much capacity as they can muster. One reason: The well-worn "duck curve" has become a "canyon," referring to the changes in dispatch curves where more gas capacity is "in the money" during daytime hours (the canyon floor) compared to five years ago (Fig 1).



1. The image of a duck, oft used to describe a typical ISO load dispatch curve, can look more like a "canyon" on certain days, with more gas-fired capacity needed during daytime hours. Data used to make the left-hand figure are from California, mid 2018; at right, California in spring 2023

But if three of the facilities highlighted in the user-driven presentations last year are representative, some plants are having to adapt to *radically changing missions,* like being scheduled for shutdown in a few years, but then suddenly being called upon to run for years more—if not one or two decades. This presents obvious challenges in many areas, including safety, obsolescence, staff knowledge, and others.

Even the newest, most efficient H-class machines installed over the last five years or so are not running baseload and are "cycling all over the place," said an OEM rep, who also noted that earlier model gas turbines expected to be retired in 2045 are now having to plan on operating another 20 years.

Supply chain issues take many forms, but quality of work continues to dominate discussions in many industry forums. There was a time, when competitive power supply emerged as a counter to regulated-rate-of-return utilities, industry soothsayers anticipated that OEMs and/or contract service providers would be responsible for the major plant subsystems—like the gas turbine, steam turbine, HRSG, condensers, etc—while onsite staff was reduced. While this indeed had been a major trend over the last two decades, it may have run its course.

Several presentations made last year suggest that owner/operators are re-asserting responsibilities for onsite work, or at least acknowledging that OEMs and contractors require much greater oversight. Other speakers noted that equipment commissioned recently is failing prematurely, or exhibiting unexpected downtime and repair needs.

A seasoned expert from a major owner/operator reported on implementing a broad fleet-centric borescope inspection strategy for its turbines to respond to "narrow grid margins and cost pressure on lower-priority units."

A steam-turbine expert for a large fleet concluded that two D11s of similar vintage can exhibit vastly different first- and second-major outage characteristics. Somewhat surprisingly, the one with 1000 starts and 20+ years of operation required few repairs, while the one with 70+ starts and eight years of operation required significant repairs during its first major. The two units were procured around the same time but one remained in long-term storage for seven years.

In one session on NERC compliance, there appeared to be audience consensus around the statement, "Don't trust the equipment OEM or the control system OEM to do any of this [verify models, capabilities, data, etc] for you." An expert in a session on severe-service valves noted "make sure your vendor has QA/QC processes you can refer to after the fact." A presenter on a BOP subsystem replacement noted "major communication issues," referring to a non-responsive vendor.

Some of the comments in a "generator quality roundtable" echo these sentiments:

- Experience has dropped over the last decade across the industry.
- One-third of events in 2022 are accounted for by quality issues.
- Cannot rely on contractors: Owners must force accountability.
- Be wary of vendors "preferred by management," which may not be best for the job at hand.

Finally, the CCUG conference presented its traditional share of deep discussions in broad areas affecting all plants all the time, like safety and lockout tag-out (LOTO), hot and cold weather ops and associated regulatory compliance, as well as unique equipment events and failures which may seem like "one-offs" but offer warnings, guidance, and lessons learned which can often be broadly applied in similar or other situations.

New lease on life

Consider this situation: Your cogen plant is facing the end of its steam contract, and you experience a brushless exciter loss-of-field trip. During the repair period, the steam contract is extended several years. Soon after, the contract is extended another five years. Now you need a different strategy, one that ensures exciter reliability at least through the end of the contract. On top of that, the outage dates have been moved up by two years.

The source of the failure, and subsequent damage described as "carnage," was excessive moisture in the exciter enclosure. Source of the water was steam leaks from the main stop valve and extraction flange channeling from the steam-turbine enclosure along the generator to the exciter. The full story, and some of the breathtaking details, is captured in the slides but the lessons learned are generically applicable:

- Steam can flow through flashing and skirting and get into very unwanted places.
- Keep a stock of brushless exciter parts.
- Double check planned power ratings versus existing equipment.
- Variable-frequency drives may not be suitable to replace the permanent magnet generator.
- Consider a subject matter expert (SME) to oversee such a project.
- Take advantage of redundancy if necessary (this unit has "double double redundancy," parallel and series circuits).

Where do you start?

A presentation on a DCS replacement, prompted by lack of spare parts for the original, began with the subhead question. Commercial operating date for the plant was 1997, and it still runs baseload. A new Mark VIe was incompatible with the original RS3 technology, given its old networking protocol, lack of OEM support and cybersecurity protection, and reliability/spare-parts issues. Plant selected Ovation to be installed at the same time as an ST/G major, a 30-day outage. Note that the equipment has to be operating and LOTOs removed to perform the DCS functional checks.

During process startup, 124 variances were identified, and all but 11 were completed with the plant online. The remainder were completed during an outage three months later. Generic lessons learned include:

- Onsite training needs to be site-specific.
- Pay attention to establishing links with existing software, including PI links.
- Data links between Mark VIe and Ovation presented problems for the ST/G.
- Make sure there is access to the portal for transferring data to/from the plant.
- Budget contingency funds for additional IC&E technicians.

Although not listed in the lessons learned, perhaps the most important one is that the plant withheld 10% of the contract funds until all variances were addressed.

From "hardly on" to baseload

Imagine how many challenges a more than 40-year-old simple-cycle plant might face going from peaking, which is "hardly ever run," to baseload ops. This presentation focused on the H_2 purge system for the 501D5 generators, proving that even the replacement of a relatively minor subsystem

2. New H_2 purge control system and dryer for a peaker (right) replaced one which had the controls cabinet (left) hanging off of the unit—just one facet of taking a gas turbine that "hardly runs" to one now running baseload can lead to major headaches (Fig 2).

When your H_2 purge dryer breaks as a peaker, maybe you can get away with leaving it and locking it out and continuing to suffer from the control cabinet hung onto the unit which had presented many problems over the years (for example, vibration). Also, the skid was located outside. Solution for baseload service was to replace it with a new purge control system, dryer included, and change all the lines to stainless steel.

Project challenges included failure modes resulting from an OEM design disagreement between a fail-open or fail-safe valve; integrating the new equipment with an old, not optimized, CO_2 system; lots of wires to be pulled and P&IDs to update; islands of automation and "heartburn" over PLCs and HMI; infant mortality; cabinet purge; regulator issues; and components not designed for outdoor service and requiring heat tracing. Many others are discussed in the slides. Thankfully, the plant arranged payments based on engineering deliverables, rather than lump sum.

Generic lessons learned include:

- Involve the controls staff early in the process and make sure to check design against engineering standards.
- Identify equipment supply from the vendor before finalizing the contract.
- Demand (or ensure) that operating manuals are adapted to your site.
- Decide whether failure modes for valves are specced for safety or reliability.
- Make sure your skid is designed for the right service—for example, simple cycle, combined cycle, etc.

Another 25 years? Aye aye, sir! Limping along with a 1967-vintage excitation system (controls were upgraded in 2012) is fine if you're planning to be shut down in a few years. Things change when management says it'll be running for another 25 years. Check out the slides if you want to know why the outage for the excitation system upgrade (it's an old coal unit) had to be extended from 27 days to 49 (then extended again because of issues with the ST valves). Three of the lessons learned are: Collect all drawings and files well ahead of project start, get the structural study done early, and use a variation of the old adage, "measure twice, cut once" when it comes to clearances.

Newer units, unexpected events

The slides for the presentation referenced earlier, comparing two similar D11s with very different operating histories, have an incredible amount of detail on design, predicted versus actual diaphragm dishing, casing disassembly, opening clearances and alignment, packing, N1 and N3 offsets performed, and inlet-bowl cracks and weld repairs. Diaphragm dishing is described as "a base scope item on these units" and is the focus of the material.

Regarding new diaphragms ordered for Stages 12-14 for this heavily cycled unit, they were specified with 0.125 in. extra stock and the OEM was required (1) "to provide a matrix of the material/weld/profile changes for each possible diaphragm ordered," and (2) that the component adhere to TIL385A1598.

Generator maladies. After less than four years operation, a generator at a 2 × 1 1100-MW site tripped on phase-phase and phase-ground targets. Initial inspection revealed that the "inner nozzle shield directing cooling gas toward the stator end caps had liberated, fallen across the endwindings, and eventually cut through the insulation, creating the fault."

The failure led the owner/operator to shut down and inspect the other GT and ST generators at this site and at a sister site (six total) of similar design and start date. During "extent of condition" inspections, cracks and epoxy voids with dowel pins were discovered. The OEM issued TIL-2323 after inner-nozzle shields were removed on all the units. Further inspection results and shop repairs are described and illustrated in the slides. One end result was that the OEM issued TIL-2337 for potential field coil migration on H65 and H84 units.

The owner/operator decided to send another generator from the sister site to the OEM shop to address blocking replacement and sliding-surface length changes. There was significant evidence of coil movement, a number of blocks on the underside of the winding fell out, the winding had shifted from the turbine end toward the exciter end (unlike the first unit), and significant distortion was present on the exciter end of the winding. Full-scope repairs were not possible within the outage window.

Temporary repairs were made, and the plant is monitoring vibration and flux-probe readings in anticipation of a partial rewind in 2025.

Cracked and broken through-bolts (TB) on the MBH model generator are believed to be a fleetwide issue (fleet here referring to the owner/operator's units). Presenter reported on units placed in service between 2009 and 2011. One broken TB was discovered during a minor inspection in 2018. Crack-like indications discovered through NDE were found on bolts in two other units. No conclusion was reached on root cause (OEM elected not to perform a root-cause analysis). Short-term solution was to encapsulate both ends with epoxy resin, but the user is seeking a solution that can get them to a rewind outage several years from now.

An arcing incident in a water-cooled generator (different OEM and model) outlet manifold pipe is also reviewed in these slides.

Solid particle erosion (SPE) is one of the issues plaguing the steam valves for D11 units (and its variants from other OEMs), according to several presentations which took much of the STUG conference's first day.

One user said, "We are struggling to control SPE." One piece of evidence is that a main steam valve incurred 30% loss of material after less than 12,000 operating hours. A "Next Gen" valve installed in spring 2020 showed dramatic improvement after around 20,000 hours. However, pins had migrated out of the stem and stem nuts, causing damage downstream. A user from the audience noted that their valves have had so much erosion, they question the material choice.

Another user presenter reported that they cut maintenance intervals on D11 main steam valves from three to four years to one to two years because of SPE and noted that this was "true for most users." Replacing with a "Next Gen" valve also posed a new set of issues with large coupling actuator bolts, pressure seal head jacking-plate bolts, broken balance-chamber bolting, and out-of-spec valve-disc seal rings. A non-OEM "solution" was able to reduce the erosion rate by around 35%.

Needless to say, if you are experiencing SPE or other problems, or suspect such, this group of slide decks is a must-view.

Generator borescope inspections "can provide more and higher-quality information than a traditional minor," said an expert from one of the largest GT/CC-fleet owner/operators in a GUG session, and require a minimal level of disassembly, and help identify issues especially after protective-relay operating events. His company has expanded a formalized borescope inspection program initially applied to gas turbines as a way to reduce costs for low-priority units. The inspections are generally performed every 25,000 EOH or "for cause"; planning documents are delivered to the plants so equipment can be properly prepped.

The list of generator components subject to the inspections, descriptions of guidance documents, examples of findings, and program statistics are all available in the slides. Since 2021, five major issues were identified through 59 inspections, 45 planned and 14 emergent. One finding was loose stator wedging on three units, which prevented a failure and potential stator rewind, valued at $6-million per unit.

Limitations to the program include the following: Some generators cannot be inspected, borescopes can't reach all target areas, and inspection capabilities and experience have to be nurtured internally.

Old standbys: LOTO and NERC

For the best of reasons, safety is always a popular topic at the CCUG, and this year was no exception. The LOTO Roundtable Discussion on best practices included a detailed discussion of what should be subjected to LOTO (or enhanced safety procedures) during outages. An example included how a seasoned maintenance worker caught a gloved finger in a fan that typically only runs during high humidity. Digital solutions for LOTO and safety were discussed; some plants have completely automated these processes using hand-helds and commercially available software, others have hardly automated at all, based on the ensuing discussion.

LOTO "traps" listed include electronic inlet-guide-vane (IGV) actuators, electronic fuel-gas valve actuators, and peripheral equipment like ventilation vans, blowers/heaters, 480-V element space heaters, injectors, and fire protection equipment. Users noted that they "struggle with electrical" and that "electrical is not as easy [in terms of LOTO] as mechanical equipment."

Some of the best practices include:

- Fostering a learning culture where blame is absent and communication is high.
- Daily face-to-face meetings before work begins.
- Mandatory plant walkdowns before starting up or outages begin.
- Having a trailer dedicated to LOTO outside of the control room.
- Having systems experts at the plant during major work and updating P&IDs.
- Having one person dedicated to the LOTO program at the plant.
- Making sure LOTO tags are secure against wind and weather.

NERC and ISO regulations have plants laser-focused on hot and cold weather prep, a topic of another CCUG roundtable. One plant manager illustrated how much has changed in this area by stating that his plant (central Midwest facility) was originally designed as a plus-8F facility (above zero) and now it is a minus-23F facility. Some of the best practices for hot-weather work which arose from this session include these:

- Use the 40/20 rule—40 minutes work, 20 minutes rest—and force contractors to take breaks.

  Provide cooling vests (and make sure employees wear them), hydration stations, tents, and even salty beverages (for example, pickle juice) or just salt.
- Make sure air conditioners (AC) are covered under annual PM and inventory replacement parts. Also, cross train a tech to work on ACs so you aren't waiting for a repair when everyone's ACs in the area are hiccuping.
- Wire cabinet temperatures into the control room.

For cold weather:

- Verify that your HRSGs are, in fact, drained and drain valves are not plugged (such as with magnetite).
- Verify electrical draw on heaters.
- Cycle valves to make sure they start in cold weather.
- Be prepared to drain an HRSG quickly, such as when you only have fuel gas for one unit and the other won't be running.
- Give staff guidance on making sure

3. Through-wall crack in turbine steam chest, 48 in. long, was one of the more dramatic "indications" causing the presenter to ask, "How much longer can this unit run?"

4. Collector-brush flashover (at right in left photo) was caused by inadequate maintenance. Repaired rigging is at right

the cooling tower doesn't turn into an "ice palace."

Other user presentations with valuable content covered a range of important topics, that didn't "fit" conveniently into the foregoing narrative, which was based mostly on content from the CCUG meeting. That additional material is presented below by user group.

Steam Turbine Users Group

"IP to LP Turbine Crossover Failure" for a 1974-vintage coal/gas-fired unit makes the point that units with a welded tie-rod configuration on the crossovers (as opposed to a solid bar) are susceptible to the same failure mechanism described here, where the tee balance end plate liberated from the piping (60 in.).

Importantly, the crossover bellows was replaced in 2018. One key point in the post-mortem evaluation is that the vendor for the bellows replacement could not verify that Loctite was applied to the fasteners during reassembly. Outage incurred was more than 60 days.

"ST Casing and Valve Body Indications Strategy" addresses the questions of how long and at what capacities can a unit run with multiple indications in the main-steam valve chest, HP and IP inlet leads, and HP-to-IP packing head fits. A 48-in.-long crack in a steam chest wall is particularly notable (Fig 3).

"Combined Cycle A10 HP Turbine Shell Issues" traces inspection, analysis, repair, and monitoring of a crack discovered in a HP bowl crack (caused by low-cycle thermal fatigue) during the first major outage for a 2003-vintage unit, along with operating strategies (for example, potentially altering the cold-start ramp rate) to avoid a casing replacement.

"Know Your Fleet" reviews a large owner/operator's steam-turbine units from the perspective of informing a fleetwide O&M strategy.

"Major Outage Findings on BB-43 Uprated Turbine" takes you through major outage activities for a 324-MW combined-cycle steam turbine—including replacement of all HP/IP rotating blade rows and sealing components, high-speed balancing, replacement of LP rotor seals, bore inspection, and low-speed balancing. Cracked L-2 wheel steeple and blade dovetail (leading blade in a group of six) was discovered and addressed with titanium blade replacements.

"LP Bucket/Blade Removal—The Good, The Bad, and the Ugly" is a pictorial review of findings (the majority ugly) on various L-0 blades (mostly titanium) in the owner/operator's fleet discovered between 2011 and 2023.

"HP16 and KA24 Issues and OOEM Partnerships" reviews inspections focused on TILs 2052 (cracking in IP/LP rotor) and 2010 (radax cracking) for the KA24. Plus, barrel extraction and refurbishment, upgrades, and process improvement for the HP 16.

"D11 Lift Oil Leak" investigates an oil leak discovered at the left-side housing connecting joint (threaded) at bearing 5 and posits risk scenarios for the technique implemented to arrest the leak.

"Replacing HP First Stage on D11 Due to FOD" covers damage and repair to diaphragms and blades from parts missing from the main stop and control valve seats, caused by lack of bonding between the Stellite® and base material, as per TIL1629-R1. As a result, *all* control-valve seats are now UT-inspected during minor and major outages.

"LP Gland Replacement on a Legacy Fossil Unit" covers the 1965-vintage coal unit configuration and history, air-inleakage and previous inspections, and shop surveillance over repairs. Among the last with respect to lessons learned: Owner/operator will insist on ultrasonic testing of the rough machined castings before they ship from the foundry, along with renewed emphasis on vendor surveillance—including technical and schedule considerations.

Generator Users Group

"Generator SFRA Testing" answers these questions: "What is sweep frequency response analysis" and "What is it good for?" Details of this owner/operator's test standard, numerous examples of insight offered through the test, and tips for successful SFRA testing are included.

"Modern Tool for Managing a Large Fleet's Electrical Issues" (listed on the Power Users website as "Generator Inspection/Data App") covers the

5. Harmonic filter for grounding transformer almost doubled in size after being redesigned based on actual startup data

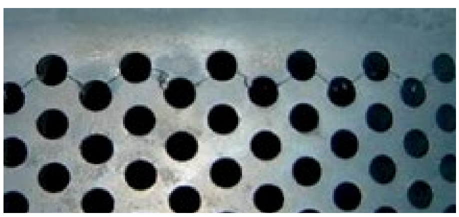
Cracked probe body

Liner damage

Branch-to-nozzle weld crack

NDE of nozzle head

Cracked pipe



Valve trim damage

Wet steam erosion (turbine bypass)

6. Component failures associated with desuperheating and attemperation processes in combined-cycle systems are relatively common. Typical problems are shown in the montage

use of a mobile-device software called Power DB to organize data sheets for hundreds of generators, transformers, and exciters for maintenance, outage scoping, and most importantly, NERC compliance. Screens essentially replicate the look and feel of paper technical data sheets and checklists, but data across units is searchable, queryable, and navigable.

"Aeropac I—Main Lead Failures" reviews a three-phase-fault trip event occurring during heavy rainfall, which according to initial engineering reports "didn't look good." Water ingress and flashover were the culprits. Photos of before and after, damage evidence, disassembly, and repair are included. Second similar event is also described.

"Rotor Slot Filler Migration" (listed on the Power Users website as "Blocked Rotor Cooling Holes") covers a generator failure from a stator ground fault in 2009, a subsequent stator ground-fault failure with the replacement used generator in 2011, modifications, and findings during a 2019 outage. Core hot spots, rotor core filler migration, and blocked cooling slots are some of the maladies. Slides conclude with OEM recommendations and owner/operator actions and follow-up.

"Turbine Generator Shaft Grounding Case History" begins with the sources, detrimental effects, and ways intended to control shaft voltage and resulting damage, then goes into the case history of ineffective shaft grounding on an old generator for which the solution was a simple braid assembly retrofitted around the machine.

"Collector Brush Flashover Case History" pertains to a trip of a 148-MVA unit (critical to the grid) attached to a steam turbine after which inspection of the collector house indicated brush rigging failure (Fig 4) was caused by inadequate maintenance. Inspection, repairs, recovery, and subsequent shop repair of the rotor main leads during a scheduled outage are covered.

Power Plant Controls Users Group

"Battery Storage Energy System (BESS) Black Start" describes in remarkable detail a BESS added to a site with a 2 × 1 combined cycle and one simple-cycle unit but one section notes that the BESS harmonic filter design, which was based on the Load Commutated Inverter (LCI) load for the simple-cycle GT (BESS is used to start the GT), had to be doubled in size based on actual startup data.

If a BESS for similar duty is under consideration for your site, this is a must-read (Fig 5).

COMBINED CYCLE USERS GROUP

Vendor presentations

"Mastering Desuperheating and Attemperation," *Ory Selzer, IMI Insyt*

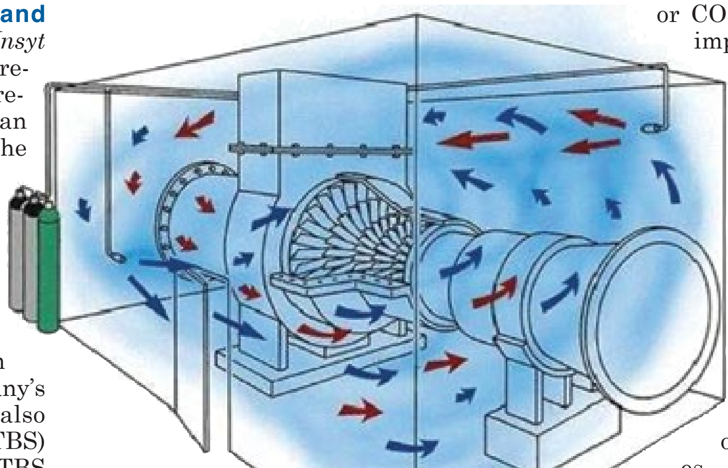
Almost 200 slides long, this presentation could serve as a comprehensive training course on what can and does go wrong with two of the most vexing subsystems in the steam cycle, as well as solutions. Instructor sets the stage with numerous photos of component failures (Fig 6), then reviews function, theory, and fundamentals; available designs; most challenging designs; impacts from unit cycling; and two of the company's attemperator solutions. Slides also cover turbine bypass systems (TBS) design, challenges, noise effects, TBS desuperheater applications, and solutions to common problems. Company has replaced over 400 attemperators in North America and supplies all the major HRSG vendors.

"LOTO Trap Roundtable Discussion," *Matt Barnes, MD&A*

Outage work at legacy gas-turbine installations can be more prone to safety incidents because precautions and procedures may not have been updated over the years. This presentation opens with detailed safety incident report (lacerated finger in a rotating fan blade) from a 1975-vintage 7B gas-turbine site, a time when fan-guard maximum spacings were not published and turbine heaters were not part of LOTO if work was not scheduled in the area. The incident is well worth reviewing as a means of forcing evaluation of other potential situations in older plants. List of other "LOTO traps" is included.

"Turndown or Shutdown? Combating the Effects of Increased CCGT Cycling," *Jeff Schleis, EthosEnergy*

Macro trends in renewable energy growth, electricity pricing, and CCGT capacity factors are reviewed, along with options and investments to extend turndown range and plant profitability. Results from a case study in Germany is included.



7. High-pressure water mist fire suppression cools the environment, prevents reignition, protects personnel, and puts out the fire fast

"Hydrogen as a Fuel for Gas Turbines in the Power Industry," *Gus Graham, CRDX-Carbon Reduction Systems*

A useful table is provided showing firing characteristics for hydrogen/natural gas blends from 0 to 100% assuming a 7F.04 machine, along with basic information on H_2 properties, the H_2 "color rainbow" (the different sources and environmental attributes), and H_2 value chain. One useful fact on experience: One vendor reports that more than 100 gas turbines worldwide are now operating on H_2 blends.

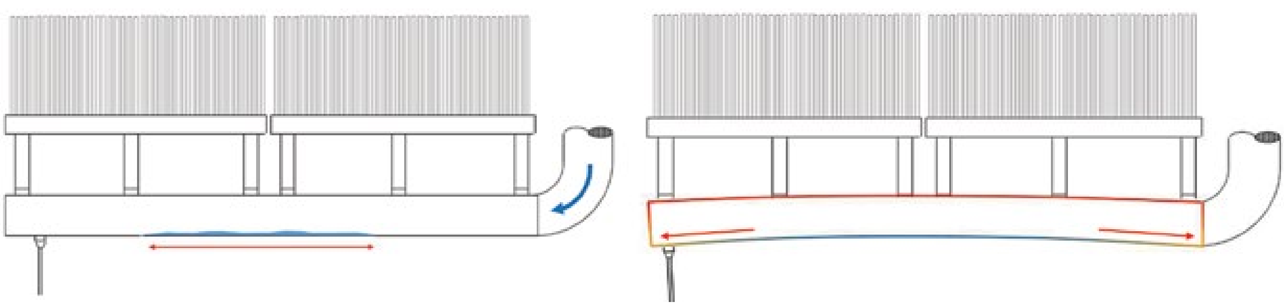
"Water Mist Fire Suppression System for Power Generation," *Jonathan Ingram, Marioff NA*

Most everything you need to know about high-pressure water mist systems (Fig 7) as an alternative to low-pressure water mist, Halon, CO_2, dry chemical, and other options. One statistic (from a leading insurer's technical report) that may may drive you to examine these slides closely: "A study of fire protection in gas-turbine installations reported a 49% failure rate for total flooding Halon or CO_2 systems…" One important advantage cited is that high-pressure mist is not compromised by an enclosure open door.

"Enhanced SCR and CO System Management for Today's Operational Challenges," *Andy Toback, Environex*

A variety of operating changes—among them high ammonia slip, CO catalyst behavior, turndown, and H_2 fuel blends—lead to high NO_x emissions at the turbine exhaust. Bulk of the presentation addresses the impacts of this on SCR and CO systems, as well as general maladies affecting performance. Presenter advocates for full system analysis, including an engineer onsite for inspection and sampling, testing multiple catalyst samples from each unit, and analyzing plant operating data.

"Process Chemistry in Combined Cycle Power Plants," *Andy Howell, EPRI*



8. Poor drainage causes manifolds to bow. In sketch at left, leak-by feedwater from the desuperheater slowly evaporates and creates a temperature differential in the header because the existing drain is no longer at the low spot for drainage. Righthand sketch shows the lower manifold initially "frowns." The bottom of the lower manifold is forced to grow longer as the upper part of the pipe expands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Textbook-like chapter in slides covers water chemistry and treatment for plants with water- and air-cooled condensers.

"Supply Chain Challenges 2023 and Beyond," *Bob Wasik, Voith US.*
Learn from company's challenges and solutions in servicing torque converters and maintaining an exchange program to address your supply-chain issues. Two software platforms mentioned in the slides as contributing to company's ability to manage supply are SAP and Microsoft Navision.

HRSG Duct Liner Design and Installation," *Samir Baydoun and Bill Kitterman, SVI Bremco*
Take a journey that includes a functional explanation of a duct liner, design parameters, failure mechanisms (replete with excellent photos), considerations for repair and replace decisions, and field construction (also with excellent photos).

"Gas Turbine SCR in the Changing World," *Dan Johnson, Cormetech*
If you don't need a primer in SCR function and design or gas-turbine market trends leading to increased cycling, start with slide 45, where you'll learn about new catalyst designs you can consider if you need to add catalyst to further reduce CO and/or NO_x or improve performance.

"Effects of Cycling Operation and Superheater and Reheater Link Piping and Manifolds," *Edgar Castro, HRST Inc*
Presentation specifically covers inspection, maintenance, and redesign for what is described in the title for the Aalborg reheater tube panel and desuperheater (DSH) manifold and the Alstom superheater and reheat "straight shot" interstage DSH. Slides include clear and concise diagrams and excellent photos of damaged components (Fig 8).

"Duct Burner Issues and Flame Monitoring—Lessons Learned," *Lester Stanley and Anand Kumar, HRST Inc*
Slides cover turbine exhaust-gas bypass affect on burners, structural failures in burners and potential retrofits, fuel-line corrosion and nozzle plugging, and flame-monitoring strategies and best practices. Regarding the latter, because burner problems can cause expensive, collateral damage, presenter advises you to "get familiar with your flames" by maintaining your viewports, correctly positioning them, replacing them with better designs, and/or mounting video cameras so flames can be monitored in the control room.

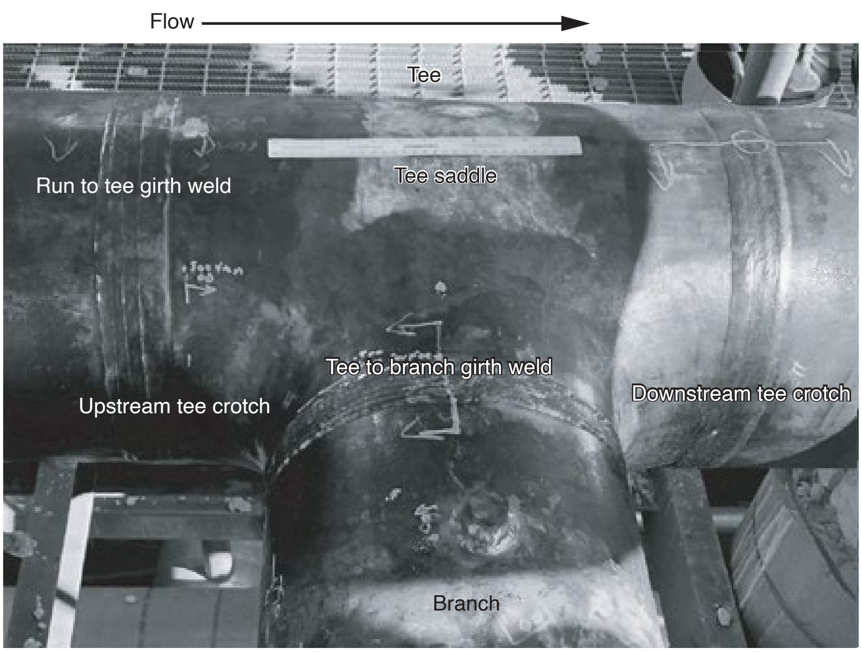
"Steam Drum Inspections," *Amy Sieben, consultant*
Everything you always wanted to know about steam drums, first in generic terms, then by individual vendors Aalborg/CMI, Alstom, Deltak, Foster Wheeler, Nooter Eriksen, and NEM.

"Moving Goal Posts—What Is Insurance Looking for Now? *Chris Black, Lockton Companies*
Presentations from insurers tend to sober you up but this one may get you to quit drinking. Costs and allocations are escalating; market conditions are terrible; equipment normally not on the insurer's radar, like steam turbine/generators and transformers, are experiencing more catastrophic failures; new gas-turbine models are problematic; business interruption is growing because of delivery delays; and climate change impacts are being priced in. And that's just for starters. Some insurers are even developing their own GT equivalent operating hours calculations. Conclusion: Plants must objectively differentiate themselves to enhance their insurability.

"Detecting and Mitigating Damage In Attemperators/Desuperheaters," *Tom Sambor and John Siefert, EPRI*
Relevant sections include diagnosing problems with historian data, attemperator diagnoses with additional instrumentation, mitigation strategies, and a bypass desuperheater case study including metallurgical analysis and findings, review of operating data, and recommendations. As routing data to the DCS/historian can be difficult, "EPRI has developed a low-cost solution for data collection and retrieval."

"Header End Cap Failure Case Studies," *John Siefert, EPRI*
Based on five failures occurring worldwide between 1991 and 2005 and a "recent" incident at a coal-fired plant, EPRI recommends that plants institute an integrated life-management plan for this component.

"Steam Leaks in High Temperature Intersections," *Tom Sambor and John Siefert, EPRI*
"The race to the bottom has created substantial uncertainty and financial exposure" so say the presenters, with respect to the inadequacies in documentation, fabrication, codes and standards, and materials development for tee piping intersections made of grades 22, 91, or 92 alloys. A single unit may have four to six "at-risk tees" (Fig 9). This "mandates an integrated approach to life management."



9. A unit may have four to six *at-risk tees*, mandating an integrated approach to life management

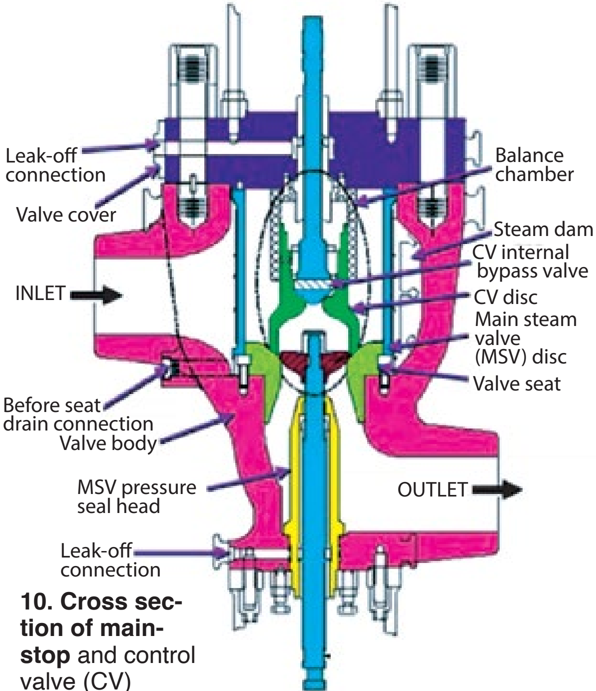
STUG
STEAM TURBINE USERS GROUP

"Energy Transitions: Evolving Electricity Resources, Challenges, and Opportunities," *Mike Caravagio, EPRI*
There's enough graphical material here for a landslide "best in show" win at the science fair. By reviewing EPRI's program priorities for its members' aggregate generating fleet, the viewer also gets a status report on the challenges facing combined

cycle owner/operators. One important underlying message is that "cold winter nights" (in Texas, for example) and "hot late summer evenings" (in California, for example) have become key risks at the margins. Those tired of hearing about the "duck curve" will be happy to know it's become a "canyon" (p 20).

"Steam Turbine Valves: Flexible Operation Damages and Testing/Monitoring Methods," *Constantin Chitic Foldi, EPRI*

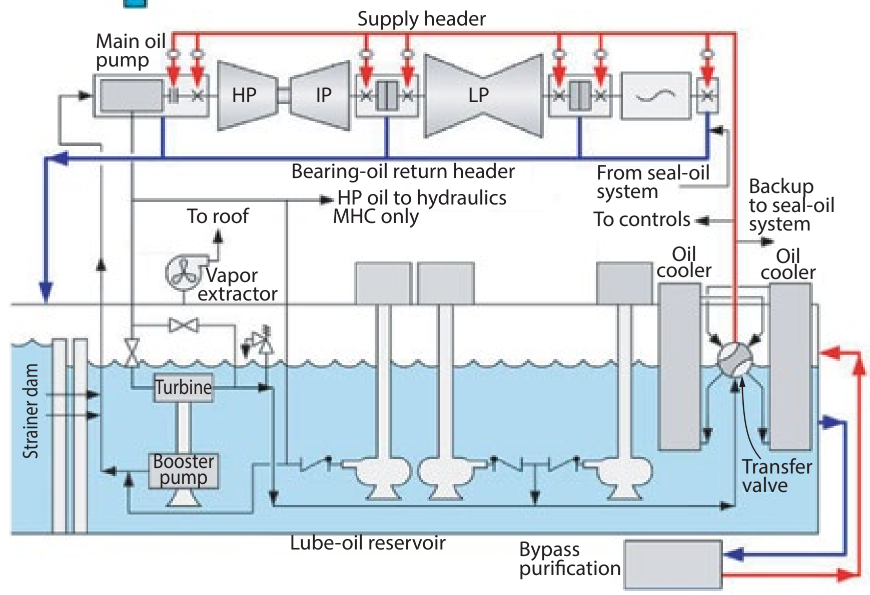
The throttling required of steam-turbine valves during load cycling poses additional stresses and risks. Slides review valve basics and functions, effects of cycling on specific components, condition monitoring and maintenance strategies, and the following online and offline tests: actuator spring pre-load and valve travel adjustment, hysteresis and ramp, hysteresis step response, stroke, seat tightness prior to startup and during scheduled shutdown, and steam leak-off (Fig 10).



10. Cross section of main-stop and control valve (CV)

"HP/IP Steam Turbine Rotor Bending—Contributing Factors and Lessons Learned, *Constantin Chitic Foldi, EPRI*

A significant number of D11-equipped combined cycles have experienced temporary or permanent rotor bending, some quite severe. Numerous potential contributing factors are reviewed here. Results of a utility survey revealed 22 affected units and the subsequent slides on the severity, causes, and best practices to manage rotor bending should be considered "must read" if you have a D11 at your plant.



11. Lube-oil-system equipment important to check on operator rounds

"Lube Oil System: Maintenance and Commissioning," *Randy Steele, EPRI*

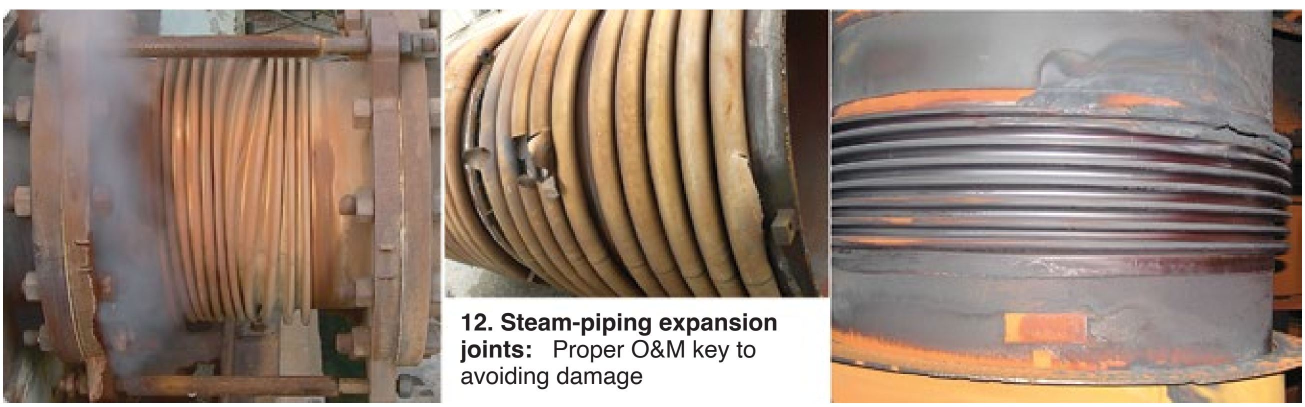
Essentially a summary of generic lube-oil-system (Fig 11) best practices, or what you'd find in a EPRI Report 1025331 (2012), "Turbine Generator Auxiliary Systems Volume 1: Lubrication System Maintenance Guide," and companion reports (all listed at the end).

"Steam Piping Metal Expansion Joints," *Eric Davis, Senior Flexonics Pathway*

If you (1) want to avoid what is illustrated in numerous "wreck on the highway" photos (Fig 12), (2) need a refresher on the types of metal expansion joints and how they behave under operational stress, (3) could use some guidance in developing a comprehensive inspection plan, or (4) are curious about "in-plane squirm, "loss of convolution parallelism," "pressure thrust," or column instability," you won't want to miss this slide deck.

"Return to Service Following Abnormal Operating Events," *Matthew Scoffone, TG Advisors/Entrust Solutions Group*

Abnormal events included here are



12. Steam-piping expansion joints: Proper O&M key to avoiding damage

13. Steam-turbine L-0 blade resonance causes high-cycle fatigue damage, leading to blade failure

loss of lube oil, shaft and gland oil coking and material loss (four separate incidents), and LP blade vibration. Analysis of the event, questions to ask, steps to return to operation, additional risk considerations, and/or lessons learned are provided for each.

"Boiler-Feed-Pump Steam Turbines: Recent Issues and Challenges," *Hector Delgado, EthosEnergy*

Should you worry if your boiler feed pump steam turbine (BFPT) is over 30 years old and your plant has undergone significant load cycling? Yes, says author, because the unit was designed for baseload ops, blades cannot be tuned to avoid resonance (unlike generator drives), alloy material naturally degrades over time, and blades are subject to low-, and high-cycle fatigue (Fig 13). Author reviews remedies and mods developed through testing programs from the '80s and '90s. Bonus section covers BFPT control system upgrades.

"Turbine Generator Coupling Bolt Solutions," *Peter Miranda, Superbolt/The Nord-Lock Group*

Advantages of company's expanding bolt technology (EZFit, HiFit) over fitted or through bolts, retrofit options, and numerous plant references are delineated. Split expanding sleeves ease installation and removal.

"Turbine Insulation and Warming Systems," *Pierre Ansmann, Arnold Group*

Company's technology, now applied to HRSGs in addition to steam turbines, can improve startup times by 75%, reduce turbine stresses (because unit remains above 300F during non-outage shutdowns) and lifecycle consumption by 25%, and save on fuel, emissions, demin water, and manpower. Steam-valve services round out company's "complete cycle solution."

14. One of several excitation retrofits identified in the slide deck. Specs for this unit: 158 kVA, 3600 rpm, 13.8 kV, 6600 amps, 0.85 pf

GENERATOR USERS GROUP™

"Generator Stator Endwinding Tutorial," *Howard Moudy, National Electric Coil*

Because endwinding reliability has been a source of concern for decades, the refresher offered here should never go out of style. Covered are function of endwindings; design, material, and process considerations and alternatives; sub-components; vibration and harmonics; bump testing; corona protection; and a case study of a harmonic-induced failure. Author stresses, the endwindings should "take a licking and keep on ticking."

"Generator Monitoring," *Bill Moore, EPRI*

"No other 'non-essential' sensor gives more information for so little effort and money" than the flux probe, insists author, who covers essential, "for-cause," and online monitoring options. EPRI's Generator Health Assessment Tool, which culminates in a weighted risk score for the unit, can assist with the latter.

"Stator Endwinding Impact (bump) Testing and Mode Shape Analysis,"

Jason Sinkhorn, EME Associates

Topics addressed include: Consequences of resonance in endwindings; fundamentals of vibration; forcing function and response; end turn, phase lead, and global end basket testing; and addressing undesirable test results.

"Brushless Excitation System Overview," *Jacques Leger and Danny Besmer, Electric Machinery/WEG Group*

Theory, design, construction techniques, failure modes, and testing metho ds are reviewed (Fig 14), with ample illustrations and graphs. Last twelve slides are a pictorial of excittion

Coil installation **Coils installed**

15. Coil installation for expediated rewind is at left, rewind complete at right

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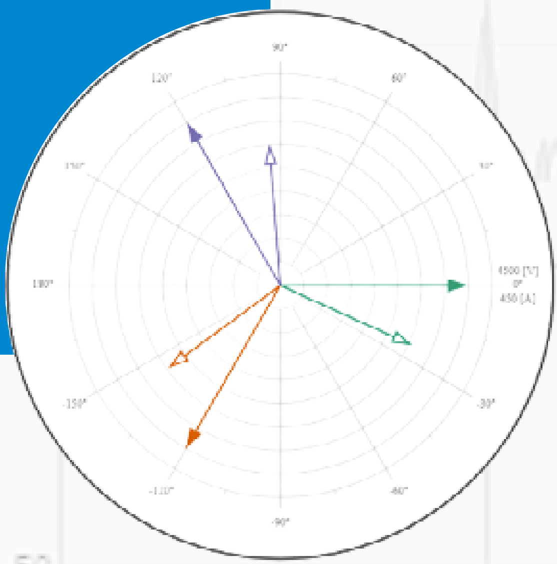

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- Bearing Faults
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16. Significant contamination was found under this unit's retaining ring

system retrofits and summary of benefits obtained.

"Advances and Case Studies on EMI Monitoring," *Kent Smith, Cutsforth*

After some basics on, and rules of thumb for, electromagnetic interference (EMI), heart of the presentation are a description of the legacy continuous EMI monitor, the Cutsforth EMI Versions 1 and 2 (the latter including InsightCM), latest innovations, and case studies for a generator/transformer and a generator/exciter cable.

"7A6 Field and Stator Expedited Repair Solutions," *James Joyce, MD&A*

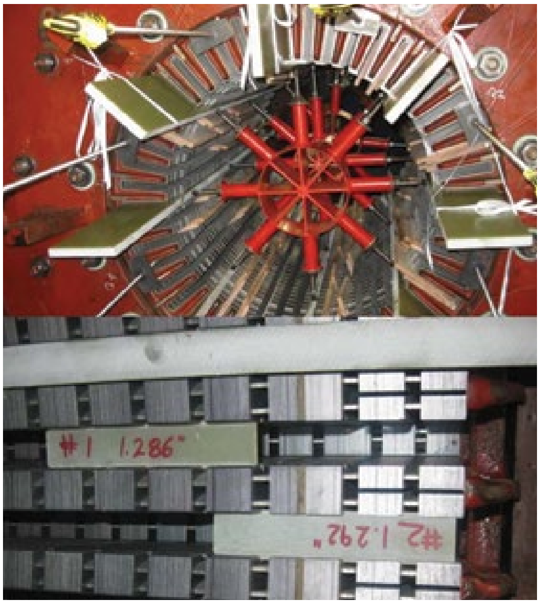
Meat of the presentation is an illustrated journey through the rewind of a generator (Fig 15) with dozens of shop photos.

"Turbo-Generator Rotor Rewinds: Maximize the Value of Maintenance," *Rob Rettler, Toshiba America Energy Systems*

Why rewind your generator? That's the question addressed to kick of this series of slides, which then covers considerations in project scope, NDE (especially rotor-coil retaining rings), conductors, insulation materials, and final testing and verification.

"Generator Field Issues: Thermal Sensitivity and 9A4 Bore Copper Looseness," *Jamie Clark, AGT Services*

Bulleted scope considerations for standard field and stator testing make up the first slides, followed by details for field vibration and thermal sensitivity indicators and testing; a case study involving a GE 6A2 unit—including rating info, O&M history, and photos of internals, ventilation provisions, shorted turn, contamination under retaining-ring insulation (Fig 16), block displacement, and other findings; and ending with dramatic photos of a field ground caused by loose bore copper connection and repair.



17. Horizontal restacking: With all laminations in place, final alignment tooling was installed along with the press plate; torquing followed. Note that slot wedges were installed to keep the wedge grooves aligned

"Generator High Speed Balancing Case Studies," *Keith Collins, MD&A*

Included here are general characteristics of balancing, component balancing (including the often-forgotten collector end balance cap), operational speed testing, and "the case [study] of the speed-induced short."

"Generator Rotor Concerns," *Howard Moudy, National Electric Coil*

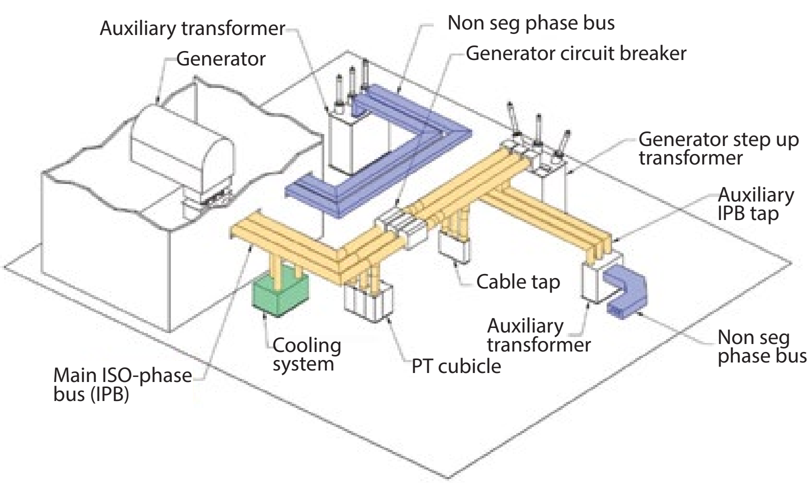
Contamination and moisture contamination are two of the concerns mentioned, but the slides' core material is focused on distress from speed and load cycling, with a photo-driven case study of damage areas and subsequent repair.

"Core Restacking in the Horizontal Position," *Antonio Flores, EthosEnergy Generator Services*

The original scope for a 38-MW Westinghouse air-cooled generator (outdoor unit) was testing and inspection, but after multiple hot spots were identified and corrective measures proved unsuccessful, decision was made to conduct an innovative full-core horizontal restacking. The photo journey comprises the balance of the slides. Notable are the new core-support tools manufactured to complete the project (Fig 17).

"Isolated Phase Bus Circulating Currents and Overheating Issues," *Mohsen Tarassoly, Electrical Builders Inc*

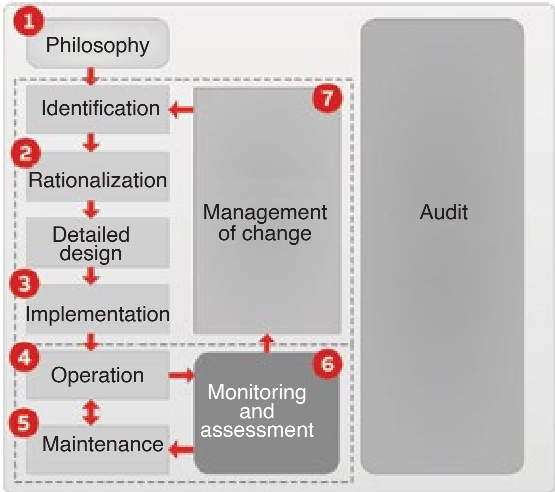
Isolated Phase Bus design and construction basics are reviewed, then causes for overheating are listed, especially for bolted connections at major equipment terminations. Circulating currents caused by damaged or degraded component also lead to overheating. Maintaining the integrity of the original design (Fig 18) and appropriate grounding are two good ways to avoid overheating.



18. Layout of isolated phase bus is useful for identifying connections that should be checked periodically for their integrity

"Using Metrology Fundamentals in Calibration to Drive Long Term Value," *Ned Espy, Beamex*

If you need a refresher on the gen-



1. Alarm philosophy development services: Geared towards delivering a tailored alarm philosophy
2. Alarm rationalization tool and master alarm database: Capture and manage alarm rationalization data
3. Alarm lists: Highly customizable; colors, filters, hierarchical structure; bubble-up/-drill-down capabilities, high-performance alarm symbols and faceplates
4. Online operator alarm response showing ISA 18.2 required fields like purpose, consequence, TTR, corrective actions
5. System backup: All alarm configuration data are backed up with system and always consistent
6. Alarm analysis KPI dashboard, periodic reports, email of reports, SMS with escalation for critical alarms
7. Alarm setpoints change management; baseline tracking; master alarm DB

19. Alarm-management products for complying with ISA Standard 18.2

eral fundamentals of measurement, calibration, standards, the various forms of uncertainty, and hysteresis, this set of slides is for you.

"Hands On Training: AVEVA PI Learning Lab 301," *Nick Thorson and Rebekah Atkinson, ProcessInnovations/ProcessPlugins™*

Two separate presentations with same title review PI basics such as what a PI system is, exception and compression, PI Data Link (an add-in to Microsoft Excel), PI Vision (which replaces Process Book), PI administration basics, asset framework, analysis, event frames, notifications, templates, accessing data, and third-party integration.

"Considerations for Combined Cycle Controls Upgrade," *Kevin Kochirka and Ralph Porfilio, ABB*

The reasons customers are considering control upgrades are reiterated (obsolescence, reliability, cyber vulnerabilities, performance improvement), then the presenters offer upgrade project drivers and benefits of high-performance HMI upgrades, integrated alarm analysis, addressing cybersecurity, and finally subsystem upgrades such as steam turbine, gas turbine, duct burner firing, and optimization opportunities throughout the plant.

"A Practical Approach to Alarm Management and Rationalization," *Liwei Huang, ABB*

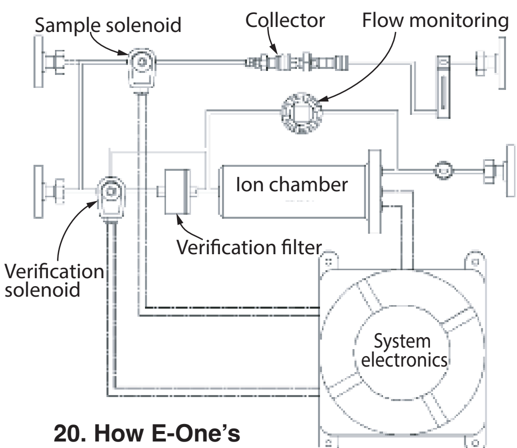
Before 1960, a plant operator had to monitor and respond to 100 alarms; Post 2000, that number is more like 4000, note authors. Hence, the keen interest in alarm rationalization, the creation of ISA 18.2, and this company's products for complying with the standard (Fig 19), the subject of most of these slides.

"Using Real Time Data Analytics to Improve Asset Reliability and Performance Across the Tenaska Combined Cycle Fleet," *Kelly Borgen, Black & Veatch, and David Martorana, Tenaska*

Company's software and services are used by owner/operator to "distill large data sets into meaningful and actionable issues." Examples of "catches" with meaningful value include desuperheater spray-water valve actuator failure, identifying condenser air inleakage, gas-turbine bearing temperature, and others.

"Hydrogen Injection in Natural Gas: Case Study at Long Ridge Energy," *Cory Marcon, Endress+Hauser*

Company's extensive global process industry experience worldwide opens this presentation. While "industrialized Raman spectroscopy" technology and other aspects for measurement of 5% H_2 blends at Long Ridge are amply covered, last few slides detail company's experience with many other H_2 blend situations. A comprehensive table comparing four other H_2 measurement solutions to Raman spectroscopy is worth noting.



20. How E-One's generator condition monitor is designed

"Lessons Learned During Industrial Steam Turbine Control Retrofit," *Mike Hovious, MD&A*

Simply put, the lessons are (1) create a control narrative, a document that contains a functional description of the control system programming and configuration; (2) don't overlook instrumentation; (3) check trip time; (4) assume nothing when troubleshooting.

"Remote Operator Initiated Purge," *Mike Williams, Environment One Corp*

Slides cover benefits of a remote-operator-initiated purge, what you need to know to get started, options for automating, connecting points, 7F automation kit, and CO_2 vaporizers.

"Why Do I Have a Core Monitor? Generator Condition Monitor (GCM-X)," *Christopher Breslin, Environment One Corp*

If you think your existing core monitor may be obsolete, the monitoring apparatus supplied by the OEM of your H_2-cooled generator is inadequate, or you just want additional assurance about protecting the asset, these slides will guide you through the company's GCM-X technology, how it works (Fig 20), and examples of alarms.

Several descriptions of "saves" and a recent success story are particularly salient.

"Performance, Reliability, and Instrument Calibration," *John Downing, AP4 Group*

There are an average of 3000 instrumentation-related reliability events per year with 7F machines, leading to 75,000 hours of downtime.

In 2022, there were 13 excitation forced outages between July 1 and September 30 with an average 30-hr recovery time. For these reasons, company advocates performance evaluations to determine performance baseline, monitor degradation, identify instrumentation affecting plant performance, and maintain critical equipment with proper service and calibration. CCJ

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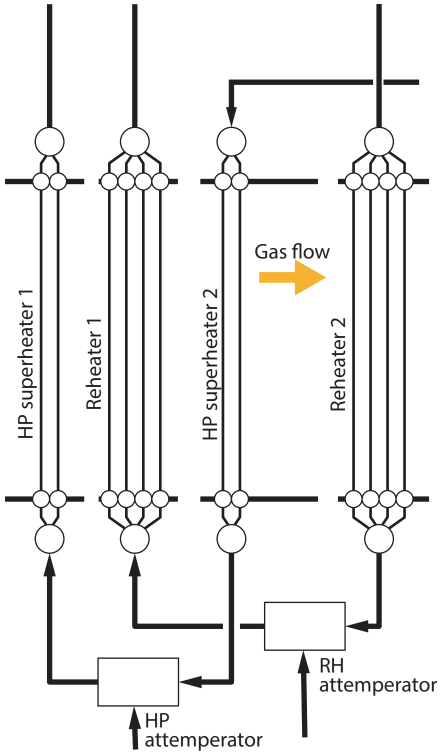


1. Kwinana tube module layout

2023 Conference Report

By Steven C Stultz, Consulting Editor

The Australasian Boiler and HRSG Users Group will conduct its 2024 meeting in Brisbane, December 3-5. Details will be available at www.ccj-online.com as they become available.

The IAPWS Australasian Boiler and HRSG Users Group (ABHUG) held its 2023 conference and workshops last November, in Brisbane, Australia. Participants joined from Australia, New Caledonia, New Zealand, Singapore, Switzerland, the UK, and the US. There were 26 technical presentations, two workshops, and 100 attendees.

Summarizing the annual event, Co-chair Barry Dooley, Structural Integrity, said: "The meeting provided a highly interactive forum for the presentation of new information and technology related to HRSGs and fossil boilers, case studies of plant issues and solutions, and for open discussion among plant users, equipment suppliers, and industry consultants. ABHUG provided a unique opportunity for plant users to discuss questions relating to all aspects of HRSGs and boiler operation with the industry's international experts."

Below are selected highlights.

Large-component replacement

Dan Gitsham, NewGen Power, updated attendees on its 330-MW combined cycle in Kwinana, Western Australia, providing power to the South West Interconnected System. This plant, commissioned in 2008, features a 180-MW Alstom gas turbine, 160-MW GE steam turbine, and Alstom triple-pressure HRSG with duct firing.

Gitsham focused on lessons learned from a major reheater module replacement in 2022.

Reheater (RH) tube breaks in 2016 led to tube inserts. Ongoing leaks called for tube plugging in 2017, and in 2018 a reheater tube row was disconnected. After Reheater 2 suffered a tube leak in 2020, plans were made for tube module replacement (Fig 1).

Modules were delivered in 2021 but the project was delayed because of Covid.

The 2022 outage was extensive in

Steering committee

ABHUG is chaired by Barry Dooley, Structural Integrity Associates, and Bob Anderson, Competitive Power Resources. Steering committee members in addition to Dooley and Anderson are the following:

David Addision, *Thermal Chemistry,* New Zealand*

Russell Coade, *HRL Technology Group,* Australia*

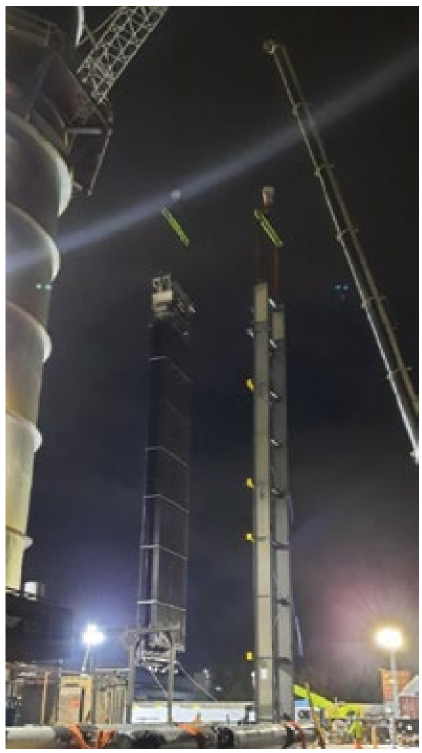
Ivan Currie, *EnergyAustralia,* Australia**

Stuart Mann, *AGL*, Victoria**

Ian Rawlings, *CS Energy,* Australia**

Charles Thomas, *Quest Integrity,* New Zealand**

* Consultant ** Energy provider


2. Kwinana tube module replacement

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3. Reheater tube removal

scope, including:

- HRSG tube module replacements (Fig 2).
- Partial replacement of RH2 module tubes (Fig 3).
- RH interstage attemperator spray loop redesign and replacement (Fig 4).
- Major inspection of high-energy piping (HEP).
- IP/LP steam turbine major.
- GT generator major.
- Replacement of generator rotor pole-to-pole connection.
- Modification of generator phase-ring connections.
- Main cooling-water pump replacement (seawater cooled).
- Major HV electrical protection testing.

Project complete, Kwinana returned to full operation.

This presentation highlighted factors that should be included in any major outage planning (learn from the experience of others). The outage was extended from a planned 38 to actual 85 days. Selected reasons: lack of experienced people, some people simply "not showing up for work," scaffolding contractor change needed two weeks into shutdown, difficulty finding quality welding supervisors, and rework with 22 nonconformances.

These details offer invaluable lessons and cautions for planning, with special thanks due for an honest project review—reinforcing the value of attending events like ABHUG 2023.

Thermal-transient updates

Co-chair Bob Anderson, Competitive Power Resources, provided updates on 68 combined-cycle plant surveys conducted globally over the past 15 years, plants of various configurations. Equipment covered 23 HRSG OEMs, five gas-turbine OEMs, 11 steam-turbine OEMs, various cooling systems, and "every possible type of cycle chemistry."

As Barry Dooley explained, "This presentation offered international updates on HRSG thermal transient aspects associated with attemperators, condensate generation, superheater/reheater drain management, and steam-turbine bypass operation, revealing common (global) HRSG problems and issues."

Anderson's key tube-failure observations included the following:

- Causes of tube failures are not associated with a particular HRSG OEM.
- Most causes identified in 2008 remain active today.
- The frequency and impact ranking of tube-failure causes has not changed.

Supporting observations included:

- Very few failures are caused by a single event.
- Very few failures are attributed to creep damage.
- Failures are primarily associated with low-cycle fatigue (startup and shutdown).

He then offered the basic actions necessary to avoid repeat failures:

- Look for early symptoms of known causes and take prompt corrective actions.
- Remove the failure site for metallurgical analysis of the mechanism.

- Conduct a complete root-cause analysis (RCA); "fatigue is not a root cause."

Only nine percent of the plants surveyed in 2023 (an increase from zero percent in 2009) had implemented a root-cause program. An important point: "Approval (time and money) to remove the failure location for analysis must be agreed by upper management before the failures occur." Approval is the most common stumbling block.

For attemperator issues, routine hardware inspection programs showed an increase from 11% to 21% of plants, which is positive. But leaking spraywater still causes cracks in thermal liners and steam pipework. This high rate of damage, Anderson explained, is aggravated by "incorrect spray-valve sequence logic" where incorrect use of master control/martyr block valve logic quickly causes leak-through in both valves.

4. Spray loop redesign before (left) and after (right)

Drain design and performance, along with data monitoring, also remain critical issues in most plants surveyed.

Anderson traditionally offers this update with details at all related HRSG events (CCJ No. 75, p 71; CCJ No. 71, p 54).

Attemperator control, procedures

Said Dooley post-conference, "Several presentations on improved attemperator control and startup procedures described situations where an understanding of the process variables, steam flow, temperature, and pressure were able to assist in determining the root cause of failures."

One primary presentation served as the opening technical discussion, namely *Improved attemperator control and startup procedure to avoid overspray and overshooting of HPSH and RH outlet temperatures.* This is the collective work of Anderson and Dave Buzza, American Electric Power (retired).

Content originated with a EPRI

5. Drain pot with forged tee

conference presentation by Buzza in 2018. Anderson and he drafted HRSG Fundamentals (Volume 4), *Optimizing startup procedures and control logic for HP and reheat steam attemperators*, for EPRI Program 218 in 2021 based on Buzza's work.

One basis is heating-surface design. "If there is too much surface downstream of the attemperator (secondary) relative to upstream (primary) it is difficult to avoid overspray and avoid overshooting HPSH/RH outlet steam temperatures," explained Anderson, adding that this design feature cannot be changed easily in existing units.

This foundation led to a suggested new startup procedure and case-study example. Maximizing steam flow during the startup is a key element of the procedure. A unique model-based attemperator control method developed by Buzza is also key to the procedure's success. For details, see the recap of the 2023 European HRSG Forum (ninth annual conference) in CCJ No. 75, p 67.

Key features of the improved process include, but are not limited to, the following:

1. Ensure HPSH and RH are properly drained.
2. Use exhaust-temperature matching (if using a GE gas turbine).
3. Maintain steam outlet temperature setpoint at unit rating.
4. Establish stable steam flow path before loading the gas turbine through the "Hot Zone."
5. Increase GT load in small steps.
6. Hold GT load steady for a few minutes until steam flow stabilizes.
7. Increase GT load in one-megawatt steps.
8. Hold GT load steady for a few minutes to allow steam flow to stabilize.
9. Unit is now ready to ramp GT load through the Hot Zone.

Drain issues

Two presentations addressed drain issues.

Derek Pang and Jenni Pang of APA Group presented *Recent learnings about erosion at APA*. This focused on the energy company's 244-MW Diamantina Power Complex in Queensland, the HP drains system, and problems associated with design and high-velocity erosion.

In one example, an incorrect valve installation was corrected to an isolation and shutoff arrangement and water accumulation was reduced by pipework changes.

Kalpesh Gharat, SRG Global, discussed *Piping drain attachment failures* associated with condensate from high-energy pipework. Inspections have centered around large branch welds and personnel safety concerns. Primary focus has been the pipe to drain pot branch weld.

Gharat reviewed all inspection techniques then zeroed-in on creep damage in the main branch attributed to stress, temperature, and time (geometric stress). "Creep voids accumulate until microcracking initiates," he explained. He also included examples of corrosion under insulation.

His summary:

- Drain-pot and drain-line repairs are relatively simple, provided there is no creep (Fig 5).
- Cut lines should be based on ultrasonic testing and thickness.
- Post-weld heat-treatment requirements depend on the material and its thickness.
- Depending on configuration and number of welds, repair may affect other areas of the drain pot.
  - Post-weld heat treatment may affect other welds already impacted by creep.
  - Bore cracking may impact the extent of repairs/replacement.
- Plants should stock billet material or pot sections for replacement if needed.

NDE/inspections workshop

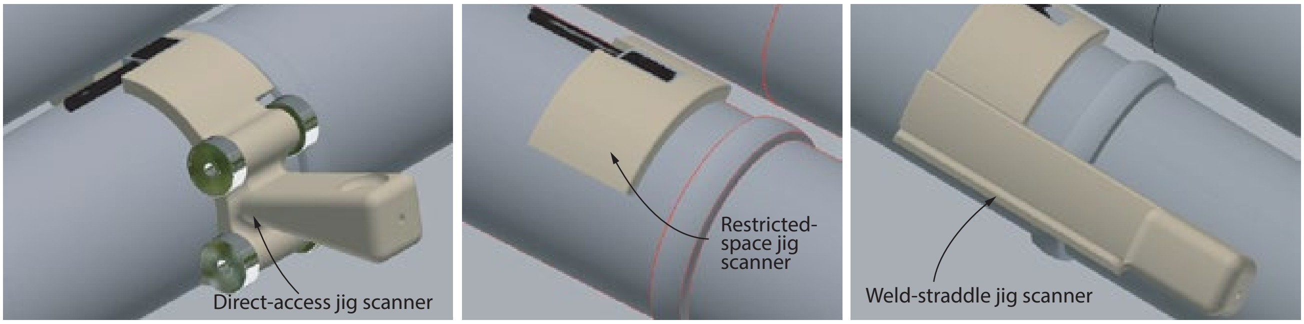
One case study showed how low-frequency electromagnetic testing (LFET) could rapidly screen reheater tubes for internal corrosion pitting.

Benji Rhead, IrisNDT, and Jason Cruickshank, AGL Australia, discussed *Inspection of reheater tubes using LFET to find standby corrosion.* Their example was an increasing trend of standby corrosion at Loy Yang, a multi-unit lignite-fired power station in southeastern Victoria, Australia. Tube repairs attributed to standby corrosion first appeared in 2020 and increased dramatically in 2021.

Rhead explained that standby corrosion generally occurs when condensate is trapped in the boiler tubes while the boiler is out of service, leading to oxygen pitting. The detection method shown was a variation of eddy current technology using ultra-low frequencies in the range of 5 to 10 Hz.

LFET can be used on tubing or pipe ranging from 2.4 to 36 in. OD. Testing is from the outer diameter of either ferrous or non-ferrous tube or pipe to identify inner-diameter corrosion. LFET also can identify generalized losses such as flow-accelerated corrosion.

This is a non-contact, couplant-free method that can be effective through thin coatings. Equipment is portable



6. UT probe jig designs

and requires little or no surface preparation. LFET is primarily a screening tool for follow-up ultrasonic testing.

Another case study described the ultrasonic inspection of superheater inlet stubs with a custom-made UT probe (Fig 6). Andrew van Niekerk (AGL Energy) and Aron Abolis (SRG Global) presented *Development of ultrasonic inspection for cracking in secondary superheater inlet stubs*. The subject was stub failures at Bayswater and other New South Wales power stations, primarily large fossil-fueled units.

Cycle-chemistry workshop

Barry Dooley and David Addison, both members of the steering committee, gave international updates on HRSG and fossil-plant cycle chemistry, instrumentation, internal deposition, and flow-accelerated corrosion (FAC) as well as on selected recent IAPWS Technical Guidance Documents (TGDs).

TGD discussions included an update on the *Application of film-forming substances (FFS)* and new IAPWS procedures for monitoring total iron in plants pursuing flexible operation.

The latest statistics on system-chemistry deficiencies again showed that the most important aspects relate to corrosion-product monitoring, assessment of internal heat-transfer deposition, and plant instrumentation. Flow-accelerated corrosion (FAC) remains a leading cause of failures in HRSGs.

ABHUG participants requested an FAC workshop during the 2024 event with a session on internal deposition and analysis.

Flow monitoring

Leaking attemperator spraywater is often responsible for cracking in attemperator thermal liners, steam pipework, and superheater/reheater tubes (Fig 7).

Claus Weihermueller, Flexim Singapore, presented *Attemperator leak detection to prevent steam tube damage*. To get more detail, access the summary of Flexim's Denis Funk presentation at the 2023 HRSG Forum (CCJ No. 77, p 73).

Weihermueller's update on this non-invasive flow monitoring solution highlighted the ease of attachment and accuracy of the meters.

One feature presented was its application on an HRSG spraywater line between the control and block valves (Fig 8), identified as "a challenging spot."

7. Damaged HP-attemperator spray liner

8. Flexim flow measurement between control and block valves

Monitoring equipment under pressure

Wayne Hill, Energy Australia, discussed *Implementation of a software package for tracking pressure equipment maintenance*, identified as an inspection-data management system (IDMS) for boiler tubing, HEP, and condensers.

The basics include tracking failure mechanisms with graphical maps, using data to help formulate future outage work, and centralizing and storing equipment history.

One result shown was a graphical boiler-tube inspection, failure, and repair database. The HEP module included inspections, repairs, and hanger surveys. The program's condenser module includes history, tube status, consistent tube numbering, and failure predictions.

Low-load operation

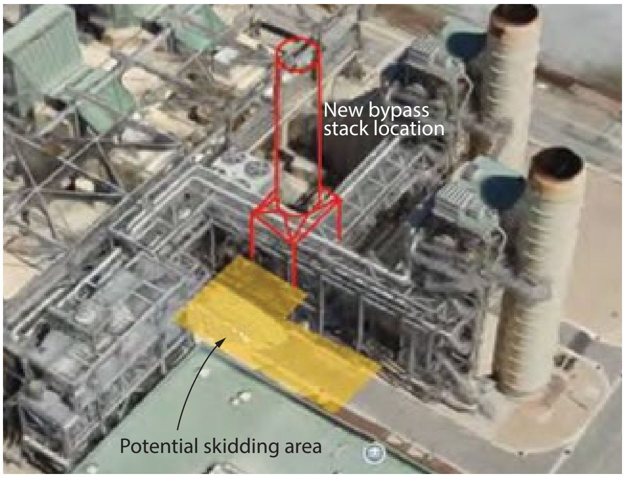
Alan Beveridge, Alinta Energy Australia, offered *The effects of boiler low-load operation on evaporator (waterwall) tubes and first-stage superheater tubes*, analyzing the impact of low-load operation on flow disturbances.

"Operation of [fossil] power boilers at low loads requires consideration of the effects of buoyancy and steam quality on flow stability, which in turn affects tube metal temperatures and tube life," he explained. Buoyancy is the ratio of steam volume to water volume, and steam quality is the ratio of steam to water. "These issues are complex and

9. Vertical transition-duct joint damage. North-end metal joint cracked again within two weeks

10. Economizer tube repair work and new access door

11. Main-steam slide support disengagement



12. New bypass stack location (red outline)

dependent on boiler design," he stated.

Beveridge covered tube temperature versus steam quality and heat flux and the influence of tube slope, among other specifics, including headers and distribution pipes.

The basic message, "Low-load operation increases the likelihood of flow instability and localized temperature changes. Analysis of flow patterns can assist in the optimization of inspection and repairs, and reduce failures."

Dooley added that "This may be applied to better understand overheating failure of sloping waterwall tubes at a corner door offset that has occurred in a conventional boiler."

Swanbank, Pelican Point

Swanbank E, discussed at previous ABHUG meetings, is a 385-MW combined cycle in Queensland with Alstom GT26 gas turbine and 145-MW steam turbine behind a triple-pressure HRSG. The aging HRSG was designed for baseload operation, but daily thermal cycling has led to degradation of insulation material, casing cracks in the transition duct and SH1 section, and general concerns with HRSG structural integrity because of its exposure to high temperature. Swanbank E, owned and operated by CleanCo Queensland, was commissioned in 2002.

Problem areas, presented by Brad Kreis and Flower Hua, include vertical transition duct-to-HRSG joints (Fig 9) and metal expansion joints (now replaced with fabric). Discussions centered around options and challenges including repair difficulties (both inside and outside), congested work areas, and excessive scaffolding needs. Participants shared their experiences and ideas.

Kevin Crowley, Engie, also discussed high cycling and HRSG inspections and findings at Pelican Point in Adelaide, South Australia, commissioned in 2001. This 485-MW station has two GT13E2 gas turbines, one steam turbine and two unfired HRSGs.

The station now serves morning and evening peak demands; gas-turbine starts are increasing annually. Monthly starts peaked in March 2023.

Some of the more graphic examples shown included economizer tube repair (Fig 10), main steam slide support disengagement (Fig 11), and a planned bypass stack installation to run a gas turbine in open cycle, reduce thermal stresses on an HRSG, and allow HRSG maintenance (Fig 12).

Rounding it out

Other technical presentations included these:

- Update on detecting and neutralizing hexavalent chromium, by David Addison, which will be revised again for the 2024 HRSG Forum, June 10 – 13, in St Louis, Mo.
- Boiler chemical cleaning (ALG Australia).
- Improving reliability of degassed conductivity and cation exchange measurement using EDI technology (Swan).
- Tube rupture on a 40-MW boiler (PEI New Zealand).
- FAC in a 50-year-old boiler (HRL).
- Creep fatigue life assessment and weld risk ranking of P91 HP piping system (Quest Integrity).
- HRSG tube failures in superheater and evaporator circuits (Quest Integrity).
- Cycle-chemistry updates at Loy Yang B.
- Cycle chemistry at Kogan Creek (CS Energy).
- Mobile reporting (Intertek and TransAlta Canada).
- Updates on activities at IAPWS, AUSAPWS, and NZAPWS.

Exhibitors/service providers

The meeting featured six exhibitors/supporters: Duff and Macintosh with Sentry, Flotech, HRL, Intertek, Precision Iceblast Corp, and Swan.

The Duff & Macintosh/Sentry team, provides electronic and mechanical instrumentation to customers in Australia, New Zealand, Asia Pacific, and Antarctica for power stations, research facilities, pharmaceutical research, and defense organizations.

Flotech Controls supplies severe-service valves and instrumentation to all industry sectors throughout Australia, New Zealand, and the Asia Pacific Region.

HRL Technology Group is a leading energy consulting organization specialized in engineering, testing and laboratory services.

Intertek provides technical inspection services, asset-integrity management programs, and nondestructive testing to power generation, oil and gas, and other major industries.

Precision Iceblast Corp says it is the most experienced dry ice blasting company in the world. It specializes in HRSG deep-cleaning technologies.

Swan Analytical Instruments provides high-quality instrumentation for boiler and water system operation and analysis. CCJ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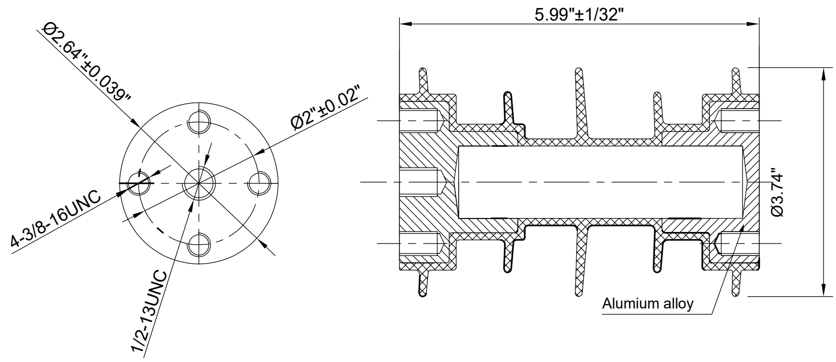

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ACGTUG

Advanced Class Gas Turbine Users Group

Next meeting: Nov 5-7, 2024 • EPRI Campus • Charlotte, NC
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EPRI brings together leading-edge turbine users to drive collaborative research, solutions

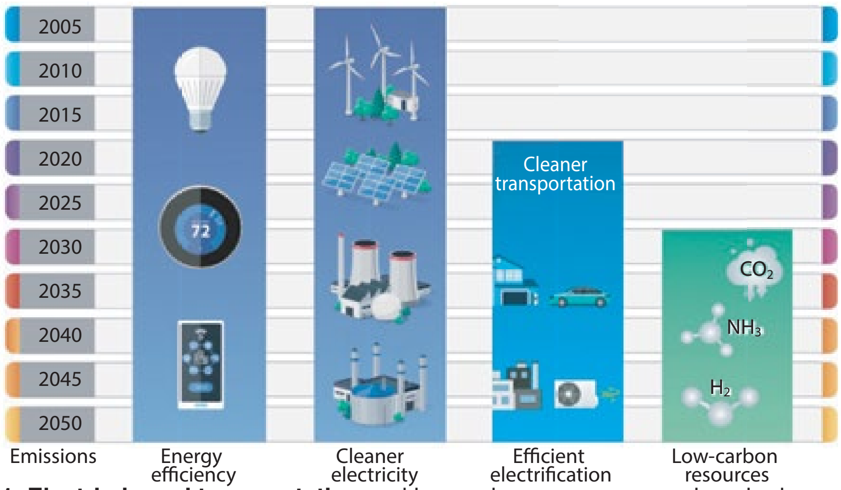
Welcome the latest addition to the worldwide gas-turbine user community: The Advanced Class Gas Turbine Users Group. It was formed by EPRI to focus on issues common to the M501G, M501J, SGT6-6000G, SGT6-8000H, SGT6-9000HL, and other advanced frames (Sidebar 1), and to develop collaborative responses and solutions. The group's inaugural conference was held Nov 14-15, 2023, in Charlotte, NC.

Sharing information is the hallmark of a users' conference, but that's no small feat for the owner/operators of these machines. They reside at the leading edge of technology, some would say the bleeding edge. Users and OEMs are bound together by long-term service and nondisclosure agreements. It takes years before third-party service firms can access the proprietary technology and reverse-engineer solutions, and before users will trust third parties with their machines.

As one user stated, "we are completely dependent on the OEM."

This is why a research-driven organization like EPRI, which has partnered with CCJ to launch this user group and conference, can help facilitate the necessary exchanges among the parties involved while identifying the best areas for collaborative programs.

One of the most illuminating sessions was a panel discussion among representatives from three leading insurance firms. As you'll read later, it is obvious that the need for information sharing is great, but so too are the challenges in doing so. Catastrophic



1. Electric-based transportation and low-carbon resources, such as hydrogen fuel for gas turbines, are two of the elements transforming the industry towards year 2050

2. Damaged 7F.05 combustor hardware sits on the grounds of a highly cycled plant serving a grid characterized by a "canyon" dispatch curve in the spring

and significant failures, learning opportunities for all, are also governed by NDAs as OEMs guard their proprietary design elements.

OEMs resist even sending technical information letters (TILs) and other documents to insurers. At the same time, insurance companies compete with each other for new business, even as they cooperate to reduce, underwrite, and spread the risks.

The relationship between user and insurer can also be sensitive. For new technology, insurers demand more information from plants regarding O&M practices, the implementation of TILs, operating data, etc. When a significant loss is experienced at one plant, insurers are quick to try to avoid such a loss at other client sites. Meanwhile, plants wonder why their premiums are never reduced when they implement the insurers' recommendations.

The symbiotic relationship among user, OEM, and insurer has always been delicate and fraught—like trying to dance with two partners and never quite receiving all the signals and gestures needed to know where and how to move next. It's just that everything is heightened when the technology is new and proceeding through its paces.

Setting the stage

Neva Esposito, EPRI VP energy supply and low carbon resources, kicked off the conference by offering a glimpse of the industry to 2050 (Fig 1). One of the more interesting forecasts was that electricity is anticipated to be between 43% and 59% of *final* energy in 2050. That figure was 20% in 2020. For per-

1. EPRI facilitates the implementation of advanced gas-turbine technologies

The Advanced Class Gas Turbine Users Group focuses primarily on G-, H-, and J-class engines with firing temperatures above 2600F. However, advanced technologies found in 7F.05 units, as an example, are also included because of their similarities in uniqueness. From materials and coatings to combustion systems and challenging operational profiles, these advanced units are ever pushing their operational limits and are a primary focus of ACGTUG discussions and experience-sharing.

EPRI's Gas Turbine Advanced Components and Technologies program (a/k/a Program 217) supports owner/operators of gas-turbine assets, especially those served by the ACGTUG. Research in the following areas assists users in procurement, operation, and maintenance:

- Combustor innovations and use of alternative fuels.
- Compressor durability and innovation.
- GT enhanced controls and monitoring technologies.
- Hot-section advances in alloys, coatings, and cooling.
- New gas turbines and experiences.
- QA: Component inspection and testing technologies.

Program 217 R&D projects for 2024 seek to broaden and strengthen research focused on new and next-generation components and technologies for gas turbine. In some cases, work is coordinated with Program 216, "Gas Turbine Lifecycle Management," and related generation programs sponsored by the research organization—including heat-recovery steam generators, materials, nondestructive evaluation, monitoring and instrumentation, controls, and flexibility.

REGISTER TODAY to attend ACGTUG 2024 on the EPRI campus in Charlotte, NC, Nov 5-7. Details are available at www.epri.com/events.

spective, it took the industry well over a century to achieve 20% final energy; now the percentage is expected to double in 25 years as electric vehicles (EV) displace fuel-powered vehicles, data centers suck up more and more electricity, and general electrification of society accelerates.

GT owner/operators don't need to be reminded how renewable resources are affecting their operations. So, it was almost astonishing to learn that in 2022, solar represented only 3% of electric production, and wind 10%. It's a case of the tail wagging the dog, but the tail is only expected to get fatter and bushier.

Several representatives of utility and non-utility power producers presented on their O&M experiences with advanced gas turbines on the second day of the meeting (Fig 2). The information shared with attendees was viewed as of considerable value to owner/operators, based on comments shared by attendees with the editors. Unfortunately, on-going investigations and pending litigation militated against CCJ's coverage of this material both here and online.

Suggestion: Attend ACGTUG 2024 at EPRI's facilities in Charlotte, NC, Nov 5-7, and take detailed notes to share with your management and colleagues. What you learn almost surely will have a positive impact on the operation and maintenance of your existing assets while providing guidance in the design of future generating units.

'We are the checkbook!'

The frustration in the room was palpable during the panel discussion with insurance-firm representatives, even as everyone maintained an outward spirit of learning and improving.

One insurance firm rep summed it all up as "You are the test stand, we are the checkbook!" It might be surprising to learn that insurers only hope to break even on insurance; all their money is made on investments.

More specifically illuminating for plant folks is how an insurance firm distinguishes proven from unproven technology. Thus, it was eye-opening to learn that one firm still considers the 7F.05 unproven. Why, asked a member of the audience, for an 11-year-old machine? The response from the rep was that they took it off the unproven list but then compressor problems persisted, components were redesigned, and so it was returned to unproven.

The rule one insurer uses is this: Proven means that the first two fleet leaders for the new technology both got through a major outage with no major issues and no component redesigns. If a critical component is redesigned, then the "clock" goes back to zero. Insurers also factor in whether they consider the OEM's response to fleet issues to be a "patch" or a long-term "solution."

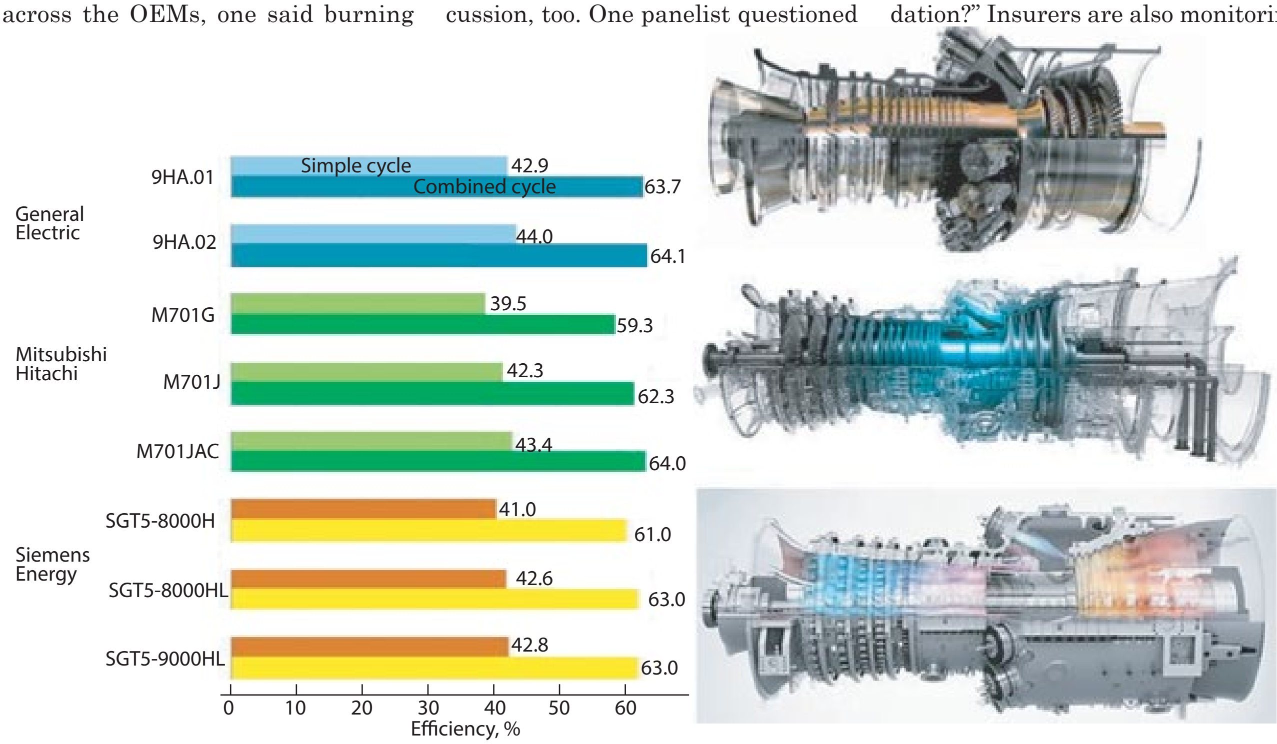
Eight years later, the HA series is still considered by some insurers to be unproven. According to one, although the OEM did "pretty well" managing the Gen I bucket issue, there are other persistent issues like the 0 spacer issue, the thrust bearing, and changes in the clutch design. "The ground is shaking around some of these HA units," one panelist said. That perhaps is one reason why one user's HA unit is considered unproven even with 32,000 operating hours.

Resolving issues with the technology is only one aspect of today's insurance challenges. Two of the others are the supply chain and inadequate quality of shop and repair work. An example of the latter is a first-stage blade failure resulting from the shop putting four times the amount of thermal barrier coating (TBC) on the blades. "Third party shops are hard to qualify," concluded one panelist.

Another issue mentioned is more fundamental. Design engineers are specialists in a specific turbine com-

ponent, lamented one insurer rep. "There's no longer 'one master machine engineer' like in the old days." When asked how they view insurability across the OEMs, one said burning holes through blades and nozzles is similar even if the causes are different.

TILs (Technical Information Letters) were the subject of robust discussion, too. One panelist questioned whether TILs actually address root causes or treat symptoms. Another asked, "What are the unintended consequences behind the TIL recommendation?" Insurers are also monitoring



3. The advanced-class gas turbine has evolved from predecessor machines in ways described as "minimize radical departures from previous designs," and "provide flexibility to inspect and repair" not only that TILs are implemented in a timely way but that the TIL was implemented in the best way possible for the particular site.

You couldn't be blamed if you came away from this session thinking that the owner/operator is between a rock and a hard place. Insurers conceded that many critical aspects of insurability are out of the user's control. When all of the fleet's blades are made in one factory worldwide, or all the clutches have to be sent to one location in England for repair, or the number of qualified forging shops is limited, these are all supply-chain bottlenecks. Parts scarcity is a huge issue for insurers.

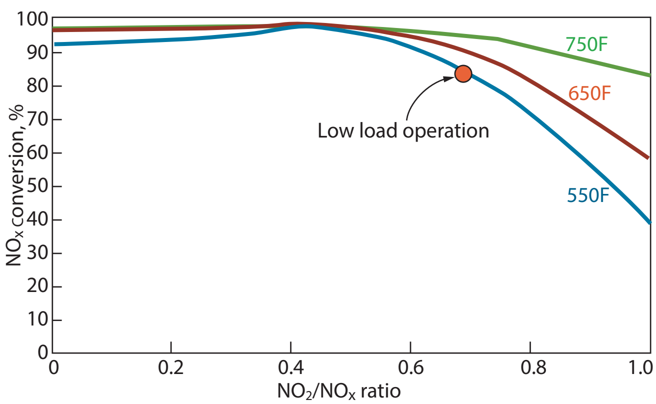
One attendee muttered that it's like we need to have a duplicate machine onsite just for spares. But even that strategy, expensive as it may be, may not be sound. One panelist noted that spare components become obsolete because six months later the design changes.

As much as users and insurers might want to share information, advanced frames are so proprietary "we can't even get a mass communication out to our clients," said one insurer rep. Units which are the subject of litigation between the OEM and user can't be talked about. Even the evaluation of a catastrophic loss event is governed by tight nondisclosures.

The sharing of information, such as TILs or technical bulletins, depends on the transparency of each OEM. While one panelist said that "some were better than others," another said, "all OEMs are bad about sharing." A third went further, saying they can't get one OEM to respond to requests for these critical docs. The suggestion was that the OEMs are more interested in hiding problems from the insurers. One audience member intimated hat they were afraid that underwriters will add an exclusion for a TIL component.

Insurance is, by its nature, collectively punitive. One panelist explained that what moves the needle on premiums is a catastrophic-loss event. The "Law of Large Numbers" dictates that the more bad actors there are in the fleet, the more everyone pays in premiums. Such a loss event also motivates everyone to get focused, not only on that particular risk but on machine risks generally.

Business interruption (BI) also drives premiums and the panelists encouraged the users to do what they can to minimize BI lost hours—such as emergency spare rotors, access to HGP components, etc.



4. NO_x conversion across the SCR significantly decreases as the concentration of NO_2 to NO_x rises above 50%, which can occur as machine output decreases

That '90s show. If all of this sounds familiar to seasoned industry veterans, that's because the industry went through a similar protracted "learning curve" with the original F-class GT technology. The first demonstration F machine was operating

2. Use PCRT to qualify metallurgy, identify manufacturing defects in turbine blades

During manufacturing and repair processes, industrial-gas-turbine (IGT) hot-section blades are subjected to a range of destructive and nondestructive (NDT) testing methods to assure structural integrity and uniform quality. Microstructure is an important characteristic of a component because it dictates overall strength and directly influences usable life via probability of defect initiation and propagation.

Thus, much effort is put into obtaining the optimal microstructure of turbine blades. Generally, one component from a given set is sacrificed to run a metallurgical analysis and determine the microstructural state of the remaining parts. This process is expensive, time consuming, and cannot capture the full-population variation. Nondestructive methods can provide full component-set inspection as opposed to the destructive sampling methods generally employed.

Several NDT methods are capable of some amount of metallurgical characterization—including x-ray diffraction and ultrasonic testing—but they are limited to surface or point-by-point inspections. Resonance inspection is an alternative method that has gained traction during the last two decades, particularly in the aerospace industry.

Resonance methods, such as Process Compensated Resonance Testing (PCRT) are full-body ultrasonic methods that rely on the modal response of a component and hence mechanically interact with the microstructure. The mode shapes and frequencies collected from a component serve as a resonance fingerprint and are dependent on the material, microstructure, geometry, and presence of defects.

PCRT uses a stepped-frequency sine-wave excitation to drive a part to resonate and then records the resonance spectrum. It applies advanced statistical analyses and machine learning to the resonance spectrum to assess components and identify parts with defective conditions, including defective metallurgy.

The capabilities of PCRT have been demonstrated in the lab, by modeling, and through operational inspection applications. PCRT has more than 10 years of proven success in the aerospace industry and is the only NDE method to be granted approval by the FAA to replace metallurgical cut-ups for the disposition of blades that have experienced-over temperature exposure.

The experience accumulated in aerospace PCRT applications is being leveraged for inspection of power-turbine components by Vibrant Corp, Albuquerque, NM, in partnership with EPRI.

Although PCRT analysis of IGT blades is in the nascent stage, it has already proven useful to multiple gas-turbine owner/operators by providing a quick and easy receiving inspection for evaluating a component's fitness for repair, and for assessing the consistency of material rejuvenation heat treatments.

Work to further quantify PCRT response to specific IGT blade defects and related quality standard characteristics is ongoing. Collaborative efforts in building an EPRI database for various IGT models has expedited the ability to use anonymized data for statistical analysis and population characterization. More than 20,000 components already have been scanned and incorporated into the database.

For more information on this valuable resource, contact Nick Smith (nsmith@epri.com), senior technical leader for EPRI Program 216, "Gas Turbine Lifecycle Management," and Program 217, "Gas Turbine Advanced Components and Technologies."

in the early 1990s. By the late 1990s, the OEM was airlifting machines from around the world to its shops for repair of critical components. Insurers were experiencing huge losses.

In fact, a conference was convened which brought together insurance companies, users, and OEMs to grapple with the emerging issues.

CCJ reported out the early operating experience with the HA machines from the first and second HA User Group meetings in 2018 and 2019 (Issue No. 58, p 24; No. 62, p 5).

If you join up that material with what's being reported here, you'll see how the trajectory from unproven to proven overlays with the experiences from the 1990s.

Rotor risk assessment

John Scheibel, EPRI technical executive, drilled down to risk assessments for the advanced-class rotors. He started by offering a generic description of the G, H, and J machines in terms of air flows, output, efficiency (Fig 3), turbine inlet temperature, cycle pressure ratios, and other parameters, then how the machines differ in four areas: construction, materials, assembly/disassembly, and turbine stages for power generation.

Request a copy of this presentation from EPRI if you are looking for a succinct review of the three major OEM designs, design philosophies, and willingness to push towards technology limits in the design. EPRI's work in this area includes identifying high-risk components, assessing the probabilities for users to reach the rotor life limits specified by the OEM, and rotor material testing. A brief explanation of EPRI's probabilistic risk assessment and FMEA ranking methodologies are also included in Scheibel's slides.

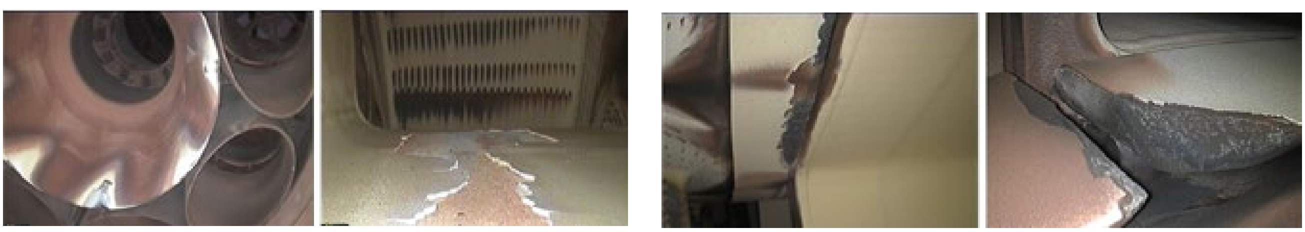
Earlier EPRI work, dating as early as 2000, identified 30 potential durability issues with the F-class machines, including a handful not associated with TILs. Surprisingly, many of the high-risk issues involve design *corrections,* harkening back to the earlier comments by the insurers on the unintended consequences of implementing TILs.

The relevant conclusion here is that independent assessment of rotor durability will assist users in making decisions which may differ from OEM recommendations or predictions. Durability testing has already ensued of Inconel 706 (a/k/a IN706), the HA rotor material, and other HA hot-section components.

Round-robin issues

Day Two of the conference involved more intimate conversations among users. Below are some of the gems most applicable to the user community, based on notes taken by the organizers:

- Some users consider sensors, such as haz gas, nuisance alarms since they can trip the unit, but they are



5, 6. Combustion coating loss and cracking (left) and transition-piece seal erosion (right) are two of several damage mechanisms identified in the 501G line of machines often required by insurers.

- One user mentioned that all of their advanced-class turbines use HEPA filters for inlet air filtration.
- Some HA users have experienced blockage of turbine-blade cooling holes because of debris originating in the compressor casing. The OEM offers a coating solution that does not require removing the rotor. Others have experimented with filters.
- Users with a coated compressor discharge casing are seeing oxidation in the rotating section—after Stage 6 in one case. One noted that, for their simple-cycle GT, they are coating anything that can be coated for oxidation resistance.
- The 501G may be on its seventh redesign to prevent rotor through-bolt fracturing, according to one user.
- The HA last-stage (14th) compressor blades are shifting such that there are gaps between the blade and the base.
- The combustion liner in the first SGT6-9000HL in the UK burned through, and the OEM is still in RCA.

Users opine on other issues

Several user presentations covered tangential subjects of general importance to the community, including the following:

Outage oversight. These post-outage findings might be familiar to readers: bolts not properly torqued, alignment changed after the last data sheet was submitted, transition-piece seals not installed correctly, flush plug left in, and thermocouple wires pinched. They occur because procedures and tooling for advanced-class-machine outage work are not fully developed and craft workers are inexperienced, said the presenter, representing a large fleet owner/operator.

However, also at fault may be inadequate supervision and oversight by the owner/operator and lack of a quality-control plan. The QCP should be agreed to in advance with the contractors, and include trained, experienced quality observers who identify witness points, hold points, and measurement techniques and data which will be reviewed by the affected parties. A QCP should also be developed for major shop work.

New tools in development by EPRI and its partners can help in identifying manufacturing defects and poor metallurgy that might be missed by QA/QC teams (Sidebar 2).

Aging workforce. Ask yourself, do you have one document that carefully charts the history of each unit in your plant? It should include commercial operating dates, implementation dates for each TIL, experience and details with the first and subsequent machine wrecks, fuel-nozzle upgrades, flashback incidents and liner replacements, exhaust-section replacements, and so on.

You should also have a policy for retaining and storing all email strings on specific machine O&M issues and resolutions as they arise. All of this is part of "tribal knowledge" which must be transferred as efficiently as possible to newly appointed responsible entities. Other forms of tribal knowledge include O&M procedures, operator aids, training videos, etc.

As the presenter stated up front, recapturing tribal knowledge lost when a seasoned veteran retires or quits is very costly. Searching for information and trying to retrieve it is wasted time. Storage devices and retrieval need to keep with available technology. Many engineers and technicians are loathe to write detailed reports, but capturing such knowledge must become part of the plant's culture—like safety, cybersecurity, and other objectives.

Lifecycle management. First, a plan or strategy should be in place from Day One of the machine's operating life. Sourcing today is a different ballgame. You may need to accept some risks, like buying and reserving slots at a shop or the manufacturing facility without a specific project in mind. This plan should reflect changes in the machine's operating profile over time and experience with earlier turbines in your fleet. Perhaps most important for dealing with your financial team: Consider ways to calculate the probability of failure versus the lead time required to obtain the components.

Vendor thoughts

Several consultants and suppliers were invited to share their expertise on the first day of the meeting. Here's what four had to say:

Environex on causes of SCR non-performance. The company's Andy Toback, a staple at user-group meetings, always is good at reminding users that the SCR is a chemical process and catalyst-driven chemical processes typically are optimized around temperature, pressure, catalyst surface characteristics, and concentration of reactants and their desired/undesired byproducts.

One important point: The CO catalyst design is driven by the types of higher-order hydrocarbons (propane, butane, hexane, formaldehyde) in the exhaust and their concentrations in the flow stream. In other words, other reactions are going on besides CO to CO_2. These other reactions complicate the process and the conversion of NO to NO_x.

Toback reported on a case study of elevated NO_x concentrations at an advanced GT plant (Fig 4). The plant was experiencing double the design ammonia flows at low loads, and temperature problems with the ammonia vaporizer at high flows. All of the catalyst samples tested showed excellent results so it wasn't a question of catalyst quality.

Here's a cause of non-performance which may not be as familiar as others: Exposed insulation upstream of the SCR affects performance because loose catalyst particles mask catalyst surfaces and plug ammonia injection grid (AIG) lances and ports.

Another common problem is that lower load operation, and lower temperature across the CO catalyst, induce more oxidation of NO into NO_x. Higher NO_x levels, in turn, require more "work" from the downstream NO_x catalyst. However, if you add catalyst to compensate for the higher NO_x, you increase the pressure drop. Catalyst performance drops when NO_2/NO_x is greater than 50%.

In the case study, the additional catalyst needed to compensate for high NO_x increased pressure drop by 0.6 in. H_2O. On the bright side, SCR performance improved considerably after the catalyst surfaces and the AIG nozzles were cleaned.

SI on rotor design evolution. Matthew Ferslew of Structural Integrity Associates (SI), covered the evolution of rotor design and the challenges imposed. Rotors have become lighter and lighter, even as megawatt output, efficiency, and the need for greater operating flexibility (that is, more starts and stops) have increased.

Lighter alloy steels have to operate at higher and higher temperatures which impose new creep, thermal-gradient, and fatigue regimes. Ferslew used the term "chaos of design" to describe how design objectives often conflict.

He emphasized the importance of lifecycle management, especially accurate condition monitoring and predictive analysis, to extend the life of these assets and prevent failures. He also suggested the intriguing concept that, in a high-starts world, perhaps the industry needs a rotor expressly designed to start three times daily and/or an effective thermal-gradient management methodology when 10-minute starts are required.

Advanced Turbine Support on M501G

7. Quality issues shown here were identified by an independent owners' engineer after field inspections by the responsible crews

observations. Advanced Turbine Support LLC trained its prodigious inspection capabilities on the M501G, GAC, and GAC enhanced-response machines. The photo-rich slides illustrate compressor icing damage, combustor coating loss and cracking, TP seal erosion, turbine-vane platform erosion, and turbine-section coating loss and base-metal cracking (Figs 5 and 6).

Regarding the last item, one user commented that they have also seen this level of cracking and as a result did not make their scheduled outage interval. The parts have to be replaced with newer versions but they aren't sure the OEM has determined the root cause or long-term solution. Clogging of cooling holes causes the problem. OEM is experimenting with filters to remove the debris.

Gas Turbine Specialists on outage oversight. The cost of quality (or lack thereof) in the utility sector was said to be 15% of revenue. Foreign material left in the turbine after an outage can cost up to $100-million when implicated in a catastrophic loss. With these and other alarming stats, Joe Mitchell of Gulf Turbine Specialists, stressed the importance of, and role for, an independent owners/engineer (O/E) during outages (Fig 7).

He showed a photo of a water bottle left in the generator discovered after the OEM field inspection had taken place. In another case, the O/E identified a dislodged end-turn block in the generator after the generator specialist was released from the site and the OEM field inspection team had completed its rounds.

Mitchell also reviewed some major projects his firm was responsible for—including a 7F.02 to 7F.03 flange-to-flange upgrade, 7FA.05 flange to flange upgrade, diverter-damper overhaul, and project management for a steam-turbine overhaul. CCJ

Towantic

CPV Towantic Energy Center

Owned by Competitive Power Ventures

Operated by NAES Corp

805 MW, gas-fired 2 × 1 7HA.01-powered combined cycle equipped with DLN2.6+ AFS combustion systems, located in Oxford, Conn

Plant manager: Larry Hawk

Reducing nuisance alarms

Challenge. Since commissioning, CPV Towantic personnel have identified an abundance of nuisance alarms, as well as other alarms whose priorities were improperly identified.

Primary concern was that there were several Priority-1 alarms that weren't as serious to Towantic operation as they were indicating. There also were alarms with priority locations that were easy to miss on the busy alarm screen and needed some sort of audible sound that wasn't available. This resulted in an increase of alarms, making it difficult to identify when action was needed, while nuisance alarms may have been given more attention.

Solution. First step in resolving the issue was to export all alarm-system points to Excel and begin the process of identification and remediation. There were 9490 points that had to be sorted through, verified, and prioritized.

Management divided the project among the plant's five control room operators with help from the lead CRO in reviewing the points and making changes/comments on the revised priority levels.

On the first run-through, the CROs identified 706 alarms that would benefit by changing their priority levels to reduce the number of nuisance alarms, and by making some low-priority alarms a higher priority. There was a large number of alarms that the CROs wanted audible alarms for, but they didn't necessarily meet the plant's Priority-1 definition.

Solution was to create a secondary audible sound for Priority-2 alarms, different from the Priority-1 tone, to help get the attention of operators and enable them respond appropriately without causing a nuisance.

Having a second audible alarm, Towantic was able to reduce the number of alarms earmarked for a priority change to 196. The operations manager and plant engineer compiled the final changes and during the spring 2022 outage, staff programmed a Priority-2 audible and changed the priority of 196 alarms.

Screen shots of an alarm workbook page and an alarm screen were provided with the entry but their resolutions in print were too poor for publication.

Results. Though alarms still are received in the control room, their organization, frequency, and urgency are better defined and appropriate for helping the CROs respond effectively. The changes also give the CROs confidence that they can take action and understand the true plant condition when issues arise—this while avoiding the stress of a nuisance alarm taking them away from other important duties.

While the bulk of the proposed changes have been made, plant personnel continue their remediation efforts in reducing nuisance alarms and making the alarm system more effective.

Project participants:
Ryan Earnheart, LCRO
Stosh Kozloski, control room operator
James Murray, control room operator
Michael Gilbert, control room operator
Jason Johnson, control room operator
Brandon Martin, control room operator

In-house fabrication of critical turbine transmitter enclosures

Challenge. The OEM-supplied turbine enclosures at this outdoor facility left critical gas-turbine transmitters exposed to ambient conditions without heat tracing, weather guarding, or insulation.

Towantic experienced trips attributed to instrumentation freeze-up and quickly put in place a foam-board insulation "stop gap" to help protect the transmitters (Fig 1). Temporary heat tracing also was installed as part of this impromptu freeze-protection effort. Insulation and heat tracing addressed most concerns, but equipment still was susceptible to the colder "polar vortex" days that the site might experience.

Several other improvements also were proposed and implemented to mitigate the effects of cold weather—such as capturing heat radiated from gas-turbine lube-oil lines (Fig 2).

Solution. Plant personnel wanted a more-permanent freeze-protection solution and invited several vendors to walk down the gas-turbine enclosures and share their expertise. But staff soon realized that an ideal solution was not available on the market, or at least for reasonable cost. Internal discussions resulted in a custom-designed, fabricated, and installed set of enclosures proposed by Plant Mechanic Brian Kennedy.

Having previously completed similar projects, Kennedy explained his design and provided a list of materials and tools needed to complete the project. The three-sided enclosures installed are of a shelled design consisting of 16-gauge Type-304 stainless-steel inner and outer shell walls with a high-temperature

1. Temporary transmitter enclosures with foam-board insulation, made by plant staff, mitigate freezing and other weather effects

2. Temporary enclosures were fabricated in a manner to capture heat from gas-turbine lube-oil lines

4. Self-regulating heater inside the plant-fabricated enclosure keeps temperature above recommended minimum

polyisocyanurate insulation embedded between them (Fig 3).

The stainless-steel walls were bent using purchased tooling and insulation was placed between the walls and stitch-welded along the seam to create an effective weather-tight barrier. The new enclosures also feature weather-sealed double doors of the same design for access to the transmitters and self-regulated heaters (Fig 4) specified and installed by IC&E Technician Matthew Trafficante. This design also allowed field fabrication for bulkhead penetrations and installation to be done without interrupting generation. The enclosures require no painting or maintenance.

Finally, the ambient indications available on the transmitters protected by these new enclosures were added to the DCS screens in the control room, thereby allowing remote monitoring (Fig 5). An alarm alerts the CRO when further attention is needed—such as when a heater fails.

5. Ambient temperature indication was added from a selected transmitter in each box to provide the control room real-time monitoring of freeze potential inside the new enclosures

Results. Towantic has eliminated, or severely reduced, the possibility of lost generation and equipment damage caused by transmitter freeze-up and other weather-related complications. Enclosures were installed for the cost of materials only (Fig 6) while the units were online (no downtime required). This amounts to a six-figure saving compared to the alternative of contracting out the project to a third party.

3. Six enclosureswere fabricated in-house for each gas turbine. The material: 16-gauge, Type-304 stainless-steel

6. New enclosures were field-fitted around existing permanent infrastructure, enabling plant personnel to fabricate and install them with no loss of generation

Project participants:
Brian Kennedy, plant mechanic
Matthew Trafficante, IC&E technician

Capital improvements to plant infrastructure focus on personnel safety

Challenge. Final plant design/construction upon turnover to the Towantic O&M team lacked capital infrastructure platforms, ladders, enclosures, etc. This required the erection of scaffolding to serve as "temporary" enclosures and platforms to perform routine plant operations.

While not ideal with respect to performance and safety, scaffolding also is costly to retain onsite and maintain its certification. Plant personnel have been very careful working around the temporary scaffolding and there have been no injuries or OSHA recordables since commissioning. However, the possibility remains.

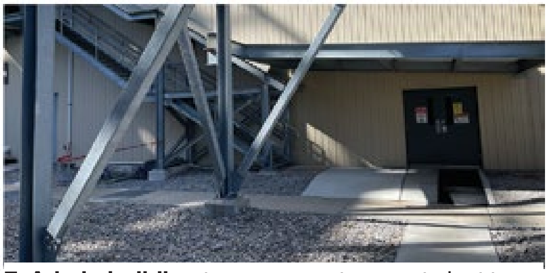
Solution. Plant management and Towantic's owners developed a prioritized capital improvements list to address the lack of infrastructure and the safety/operational concerns it creates. Owners have set aside money for capital investments every year since commissioning to complete permanent projects for safer and more reliable operations. Management works through the agreed upon capital-improvements list, completing projects through a prioritized and fiscally responsible program annually.

This list includes 27 identified areas that could benefit from capital improvements; the list is a living document undergoing continual updating both by the owners and plant management. To date, a dozen of the 27 areas identified for capital investments have been addressed.

Thumbnails of several projects completed through calendar year 2022 are described in Figs 7-13.

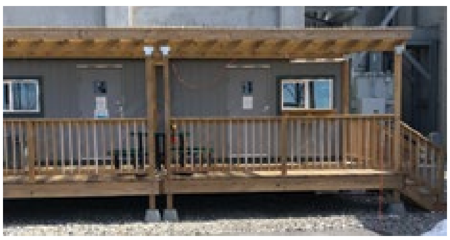
Results. CPV Towantic has eliminated safety concerns through engineering and installation of permanent structures, while simultaneously improving O&M reliability. This initiative continues as areas recommended for improvement are identified.

Project participants:
All plant O&M personnel

7. Admin building temporary entrance at plant turnover is at left. Upgraded entrance at right has vestibule to protect personnel from falling snow and ice

8. Temporary scaffolding was provided around HRSG blowdown tanks to access HP and IP blowdown valves (left). Permanent access was by way of guard rails fabricated around the tanks and other equipment (right)



9. A mobile LOTO trailer with modular deck was provided for outages. It is equipped with power, heat/AC, domain network cables for the LOTO officer's computer, plus shelving and organization for all LOTO job boxes. The trailer and deck can be moved easily to provide convenient access to the work effort. Also, the trailer keeps contractors out of the admin building. It is more effective than the original arrangement

10. Handrail system was installed on top of the auxiliary boiler building to provide safe access to the air-cooled condenser for routine maintenance


11. A plant-wide system of concrete walkways was designed and installed to avoid the slips, falls, and ankle injuries associated with traversing areas "finished" with crushed rock


12. LCI staircases enabled operators safer access for routine equipment checks than temporary scaffolding (left). A platform for service-water cartridge filter changeouts (right) was installed to eliminate the need for step ladders

Relocating sample cooling panel makes plant safer

Fairview Energy Center

Owned by Competitive Power Ventures, Osaka Gas, and DLE

Operated by NAES Corp

1050 MW, gas-fired 2 × 1 7HA.02-powered combined cycle located in Johnstown, Pa

Plant manager: Irvin Holes

Challenge. It didn't take long for O&M technicians at Fairview Energy Center to realize the difficulties that came with performing routine maintenance tasks on the steam sampling system. This system, which is in a 10 × 30-ft enclosure, is equipped with coolers, filters, flow meters, and analyzers used to monitor the steam quality and drum chemistry of both HRSGs.

The compact space with limited access posed several safety challenges—such as exposure to high temperature and pressure, hot surfaces, and hand traps. Of special concern was the building's limited egress given the amount of high-pressure/high-temperature piping squeezed into the small sampling-system enclosure. How would one quickly escape in the event of a major steam leak?

In addition to the hazards mentioned, the lack of double isolations on incoming sample lines presented a major hurdle when trying to isolate and lock-out equipment. To prepare for what should have been a simple maintenance task, an extensive LOTO was needed to isolate the entire system to ensure that adequate double-block-and-bleed protection was provided to protect technicians. Occasionally, a plant shutdown was required to adequately isolate the leaking components.

The resulting LOTO consisted of more than 50 isolation points located across various levels of each HRSG that took multiple personnel more than four hours to hang and verify—a daunting task for what should have been a simple maintenance task involving a single set of double-block-and-bleed isolations.

Solution. After talking through options with the sampling-panel manufacturer, it was decided to use an external panel to house the primary coolers and include a set of double-block-and-bleed isolation valves on each incoming sample line.

Moving this hazard to a remote panel located just outside the sample room (Fig 1) would eliminate the need to bring high-pressure/high-temperature fluid into the congested sampling room.

The insulated enclosure was equipped with two roll-up access doors and an electric heater for freeze protection. This option allowed locating the new panel close to the existing sample-line penetrations through the fixed enclosure, making for a quick and easy transition and allow the job scope to fit within the allotted outage window.

Results. With the primary coolers now located outside the sampling room, the temperature and pressure of samples entering the original enclosure are greatly reduced, thereby minimizing the risk to the technicians who routinely perform maintenance and take

1. Relocating the sample panel eliminated concerns associated with having high-pressure/high-temperature fluid in the space-confined sample room

2. New sample panel with primary coolers and double-block-and-bleed valves

3. Arrows for each route through Fairview are prominently displayed at intersections of plant roads (left)

4. Danger signage identifies hazardous areas of the plant (right)

chemistry samples. The noticeably lower ambient temperature inside the enclosure provides a more favorable environment for the analyzers with the added benefit of reducing the burden on the HVAC system and giving the system a larger design margin.

The space freed-up by relocating the primary coolers has provided a much safer access to the secondary coolers and inline filters still located inside the original sample enclosure, lessening the potential for hands to get trapped and minimizing pinch points. Access to the double-block-and-bleed isolation valves in the external panel (Fig 2) has made isolating the system for repairs much safer and less time-consuming, resulting in less down time for the plant and minimizing the number of man hours involved in the LOTO process, without sacrificing the safety of technicians.

Project participants:

Phil Christopher, I&E technician (NAES)
Scott Misiura, O&M technician (NAES)
Jim Amos, O&M technician (NAES)
Curtis Speer, lead CRO (NAES)
Engineering team: Jeff Lellock (NAES) and CPV's Joe Michienzi and Preston Patterson

Signage to assist plant visitors, emergency personnel

Challenge. At Fairview Energy Center's main entrance, visitors are greeted by the control room operator (CRO) via an intercom system. Visitor verification and purpose confirmed, guests are directed to the location required. It can be challenging for the CRO to describe routes and landmarks around the plant, especially to first-time or infrequent visitors. This burden on the operator is compounded during outages and times of high-volume traffic, and magnified during an emergency situation.

Following a recent sitewide emergency drill with local emergency response teams, the suggestion was made to add signage to the plant to help in the coordination of emergency responders. The recently commissioned site had no efficient means for directing responders to the proper location or effectively identifying hazardous situations or hazardous areas within the plant.

Solution. Several factors were considered when developing routes around the plant, such as which visitors most often needed guidance, and what locations were most frequented or most difficult to direct someone to. After deliberation, three of the most common routes were mapped out in color-coded fashion: Green arrows direct traffic to the main administration building's visitor parking lot, blue arrows direct contractors to a designated contractor parking area, and orange arrows direct chemical deliveries to the chemical unloading area (Fig 3).

Additionally, areas presenting a flammable hazard are identified to warn drivers against prolonged engine idling and prohibit contractors from performing any type of hot work without a permit (Fig 4).

Results. Directional arrows and signs for each route's destination were procured and installed along the plant's roads (Fig 5). The signs chosen are of high-quality aluminum with a reflective surface suitable for roadway use, and visible at night. Existing lighting poles and structural columns were used as the mounting point for most signs to avoid additional posts and to maintain a cleaner look. All signs were positioned at a height which would easily be visible to drivers in personal and commercial vehicles.

This project has been an excellent aid to the CRO when giving directions to visitors at the main entrance. By instructing each visitor to simply follow the green, orange, or blue arrows to their respective destinations, the time devoted to gate communication has been greatly reduced. The well-marked and simplified routes make it easier for drivers to locate different areas of the plant, prevent miscommunication over the intercom, and negate the need to remember any potentially confusing directions after entering the plant.

Project participants:

Joe Naugle, CRO (NAES)
Greg Kilgore, CRO (NAES)
Joel Wantiez, CRO (NAES)
Shawn Simmers, EHS coordinator (NAES)

5. Orange route leads trucks delivering bulk chemicals to their unloading zone

Energía del Valle de México II (EVM II)

Owned by EVM Energía del Valle de México Generador SAPI de CV

Operated by NAES Corp

850-MW, 2 × 1 combined cycle powered by 7HA.02 gas turbines, located in Axapusco, state of México, México. Site conditions limit GT rated ISO output of 384 MW to 275 MW in baseload service

Plant manager: Javier Badillo

Mix demin, service water to improve evap-cooler performance

Challenge. EVM II's filter houses are equipped with evaporative coolers designed for service water consistent with vendor specifications. During the first year of operation, the evap-cooler media was encrusted with foulant because of water-quality issues. Result: The gas turbines lost power and efficiency. Media that had a lifetime expectation of around three years required replacement in year one. Cost estimate for new media for both evap coolers was about $250,000, plus outage time and the cost of replacement.

Solution. Determine the best option for improving water quality, keeping project cost and safety in mind. The approved plan was to mix 80% demineralized water produced by the plant's existing water-treatment system, and 20% service water, thereby increasing the cycles of concentration and reducing water consumption.

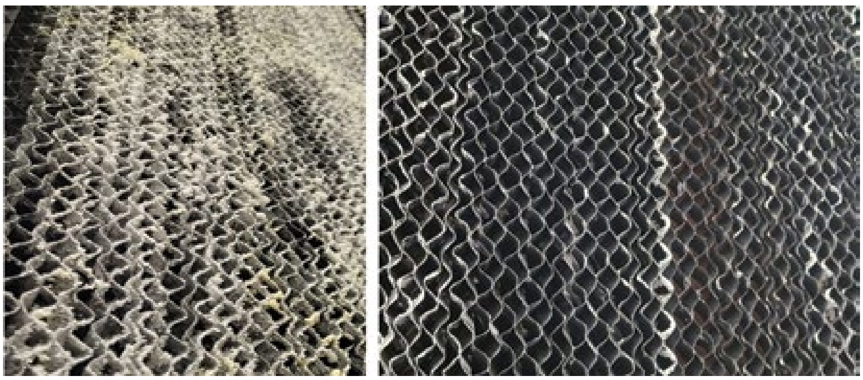
The new evaporative-cooling system consists of the following: HMI, PLC, control valves, and instruments with interlock of temperature and level. It is controlled by the DCS for each gas turbine.

During commissioning, the O&M staff was trained to understand how the new system works and how to troubleshoot problems to maintain high evap-cooler availability. Development of maintenance and chemical-analysis procedures were part of the program to maintain good control of water condition using the HMIs.

Results. The lifetime expectation for the new media is three to four years based on performing the maintenance procedures and conducting the required chemical analyses online twice monthly. The new system and operational plan boost power output by 15 MW per engine (Fig 1).

Equipment cost for both evaporative-cooler systems was $314,000. To his must be added the cost of demineralized water and the loss of generation for the week to install the new equipment. Evap-cooler water rejected after achieving the desired cycles of concentration, is sent to the plant's zero-liquid-discharge (ZLD) system.

Project participant:
Carlos Moreno, plant engineer



1. Media fouling was significant after operation for one year with poor-quality water (left). Mixing service water with demin achieved the desired result (right)

Integrating hydrogen leak detection on generators

Challenge. Each of EVM II's gas and steam turbines is coupled to a GE hydrogen-cooled Model H53 generator. The high-purity H_2 required by this equipment means the machines are constantly venting and adding hydrogen to assure purity. Nothing was provided by the EPC to detect H_2 at connections, cylinders, and the generator hydrogen-supply pipeline. Safety and H_2 consumption were ongoing concerns. Plus, the O&M staff had no procedure for safety training, nor a PM for detection of hydrogen leaks in the supply pipeline.

Solution. Conduct an industry review to identify the best methods for reducing hydrogen loss and promoting a higher degree of safety.

Example 1: Install H_2 detectors/transmitters in the generator enclosure and behind the generator, complementing those with visual means and audible alarm, to facilitate detection of a hydrogen leak by the O&M staff.

Example 2: Develop a safety procedure, "EVM2-SEG-023, Inspeccion de Fugas de Hidrogeno," and a checklist of inspections to do weekly in the various areas and zones, enabling O&M staff to track leaks and generate corrective work orders.

Example 3: Install hydrogen-detection tape at every pipeline, tubing, and hydrogen-analyzer connection to visually identify a leak, if present.

With PM safety procedures, hydrogen HazGas detectors/transmitters (Fig 2), and H_2 detection tape (Fig 3), staff and facilities have triple redundancy to easy leak detection.

Results. A diagram was developed,

2, 3. Leading options for safety improvement include HazGas detectors for hydrogen (left) and H_2 detection tape (right)

enabling staff to understand easily the way H_2 leaks are identified and reported, thereby making the plant a safer facility. Today, O&M personnel are more comfortable about safety because they have many ways to detect hydrogen leaks.

Cost of the equipment—including HazGas detectors/transmitters, detection tape, etc—was only around $5000. Plant's safety program now includes H_2 leak detection and emergency-situations training for staff. All of the equipment required was installed, commissioned, and implemented by plant personnel, as directed by the plant engineer.

Plant participant:
Carlos Moreno, plant engineer

Hydrogen generator mitigates gas-supply challenges

Challenge. As noted in the previous best practice, the H53 GE generators serving EVM II's gas and steam turbines are cooled by hydrogen with a high purity requirement. The cost of constantly venting and replacing gas to maintain its purity is significant. Important to note is that the as-built plant was not equipped to produce hydrogen onsite, making it necessary to buy gas on the open market and rent the cylinders to maintain coolant pressure and purity for each generator.

Recall from the previous best practice that EVM II did not have a system for detecting hydrogen leaks at piping/tubing connections, cylinders, and the H_2 supply pipeline—a concern regarding the safety of personnel and facilities.

In the event of a generator emergency—such as a trip or maintenance call-out—requiring the venting of hydrogen there were two major concerns: safety and the immediate need for a large quantity of the generator coolant.

4. A five-year payback for the hydrogen generators at EVM II is expected

Solution. Select equipment for producing hydrogen onsite by electrolysis of demin water and then drying and purifying the product gases. To integrate this system, EVM II required only a source of demin water and instrument air—both already available in sufficient quantity to support the production hydrogen required. The H_2 detector/transmitter in Fig 2 allows operators to detect any leaks that might occur.

Installation of two hydrogen generators (Fig 4) to serve the plant increase the reliability of electric supply—important given EVM II's close proximity to a major city.

Results. Cost of the hydrogen generators was about $260,000; upgrade of support facilities—such as for demin-water production, compressed air, and electric power—was not required. O&M personnel were trained on the new equipment and did the installation and commissioning under the watchful eye of the plant engineer.

System payback is estimated at five years. A cumulative cost saving of more than $400,000 is expected by the time the project reaches its 10th anniversary. Expected lifetime of the hydrogen generators is 20 years.

Plant participant:
Carlos Moreno, plant engineer

Realities of hydrogen come under close scrutiny

The 2023 symposium of the Gas Turbine Energy Network (GTEN), held in October 2023 in Banff, Canada, and reviewed in CCJ No. 77, p 96, included many presentations on hydrogen, proposed as a key fuel for a "net-zero world," when no additional carbon is being discharged to the atmosphere. GTEN focused on gas turbines for pipelines, petrochemical facilities, and in other industrial settings, in addition to their widespread use in electric power generation.

As illustrated in the summaries below, several of the experts were attuned to the realities of hydrogen as a fuel, especially for non-electric applications, rather than assuming that H_2, as a net-zero strategy, is a fait accompli.

H_2 for Gas Turbines—a Technical Overview, *Griffin Beck and Brian Connolly, Southwest Research Institute.* Presenters dove into the intricacies of hydrogen combustion versus natural gas and other fuels. The fuel blend percentage and combustion temperature are more important than pressure, they stressed. Additional "prompt NO_x" (Fig 1) can form from the oxidation of nitrogen in the air (as opposed to the fuel) at the higher combustion temperatures. H_2 can improve flame stability and extend the lean blowout limit compared to NG. But flashback hazards are amplified.

New gas-turbine designs employ micro-mixing nozzles in the combustor to achieve high H_2 blends. However, there are design challenges (Fig 2) in the areas of (1) flashback (flames can back-flow into the fuel lines and injectors), (2) hot spots (poor mixing, high NO_x, non-uniform heating), (3) large volumes of gas (H_2 requires more oxygen), (4) auto-ignition (H_2 auto-ignites at a wide range of concentrations), and (5) the Joule-Thompson effect (at process temperatures, H_2 heats when expanding).

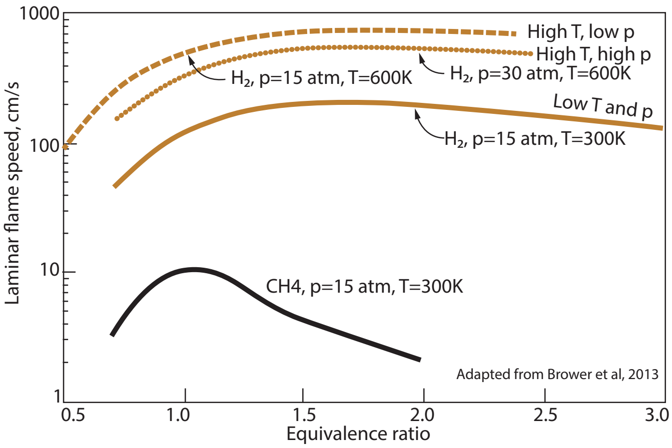
There are also impacts on the balance of the GT package. For example, combustion products contain more water vapor and heat transfer is higher. Both could introduce new corrosion risks in the hot gas path.

Prerequisites for the Use of Low-Carbon Alternative Fuels in Gas Turbine Power Generation, *Antonio Escamilla, ETN Global/University of Seville.* Alternative fuel-composition standards—such as for ammonia, biofuels, e-methanol, and others—lag other areas of technology development. These fuels are not primarily produced for use as a fuel in GTs, presenter observed.

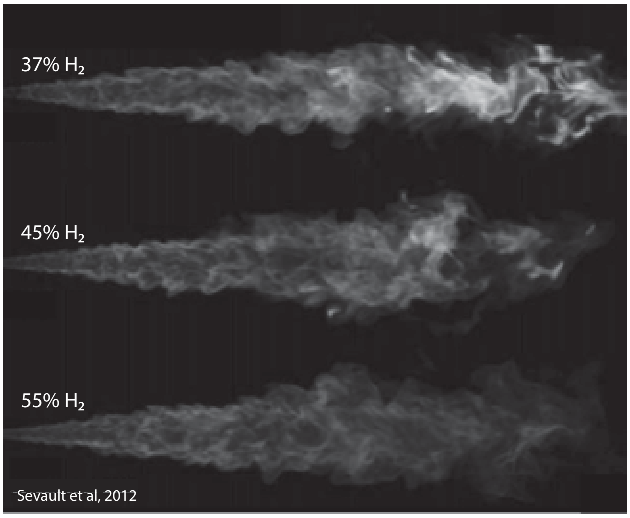
Example: Ammonia's exact composition is not known, so there's no good design basis for exhaust gases from combustion or interactions with the extremely sensitive alloys used in GTs. Industry needs to address this by developing new testing methodologies and measurement techniques.

Impacts of H_2 Blending on Mainline Natural-Gas Compression, *David Campbell, Enbridge.* Up to 20% hydrogen blends raise the parasitic power consumption of the compressor by up to 25%. Thus, the GT consumes more fuel to maintain an equivalent amount of natural gas moving through the pipeline, raising the specter of more carbon discharged rather than less. On top of that, a 20% blend in the pipeline drops its energy content by 14.5%.

This is in addition to the equipment impacts (Fig 5) noted elsewhere—such as flashback, auto-ignition, and combustion instability. Presenter suggests that 20% blends in pipelines are



1. Prompt NO_x, resulting from oxidation of nitrogen in the air at combustion temperatures appropriate for hydrogen blends, can form and overwhelm the emissions limit. H_2 fuel blend and temperature are more important than operating pressure



2. H_2 blends affect combustor design as well as the balance of the GT package. Recognize that hydrogen is considerably different from natural gas: (1) It has a much lower density, (2) Fuel momentum ratios, mixing efficiencies are considerably different, (3) It burns much faster and flammability envelopes are wider, and (4) Premixing designs that work well for natural gas may simply burn up with hydrogen probably achievable after review and equipment modifications, but 2.5%, ramping up to 5%, is a good initial goal.

Decarbonizing the Gas Turbine Fleet: Combustion Solutions to Meet Today's and Future Energy Demands, *Hany Rizkalla and Katie Koch, PSM.* Company's FlameSheet and LEC combustor technologies offer tri-fuel applications for plant-wide decarbonizing: refinery off gas (to avoid flaring), natural gas, and hydrogen. FlameSheet has now been demonstrated for up to 60% H_2/NG blends and requires "minimal changes" to use the same combustor in multiple GT frames.

How Energy Systems Change: The Energy Transition in North America, *David Burns and Brooke Cuming, Enbridge.* Company plans to produce and export up to 1.4-million tons annually of so-called blue/green ammonia and other e-fuels by 2028. Hydrogen can be produced via electrolysis using inexpensive (and carbon-free) renewable electricity and stored in pipelines and salt caverns. Presenters note that ammonia has 70% more energy than H_2, an important parameter when considering long-distance transport.

0-15% hydrogen by volume
- In general, no changes are required to the package.
- Changes to combustion-system programming may be required to accommodate fluctuations in Wobbe number.

15%-25% hydrogen by volume
- Exhaust and WHR plenum ventilation needed to prevent hydrogen buildup during flame-out.
- Fire-suppression system review.
- Fire and gas-detector calibration.
- Fuel system updates.
- Control settings updates to match blended-fuel characteristics.
- Package ventilation review, if enclosed.
- Nitrogen purge for dual-fuel engines.

25%-100% hydrogen by volume
- Same as 15%-25% hydrogen blend.
- Hydrogen gas and flame detectors.
- Electrical device updates (area classification)

3. GT package safety considerations rise with the percentage of hydrogen in the fuel blend. Here are the possible equipment impacts and package safety considerations

Industrial Gas Turbines in a Decarbonizing Environment, *Rainier Kurz and others, Solar Turbines Inc.* Presenters introduce concept of a dual-drive package with a gas turbine/electric motor, separated by clutches, to power centrifugal compressors on pipelines. Generator/motor can be used to augment gas-turbine power and produce electricity when compressor is operating at low loads, as well as add a level of security to keep the pipeline operating during electricity outages. In other words, dual drive offers arbitrage (gas and electricity market costs and contract prices) and optimization of emissions, energy sources, and equipment availability.

Practical Oilfield Applications of H_2 Electrolysis, *Richard Ens, Alberta H_2, and Mark Kuppe, Acero Engineering Inc.* Focus is on the Dynamic Brine Electrolysis (DBE) process to generate and use H_2, and potential advantages over traditional ion-exchange membrane, alkaline electrolysis, or solid oxide electrolysis. Key components are bipolar electrolytic cells relying on induction capacitance, which is said to allow easier plate cleaning and replacement. CCJ

Gas-turbine upgrades and their impacts on HRSGs

By Vignesh Bala, Vogt Power

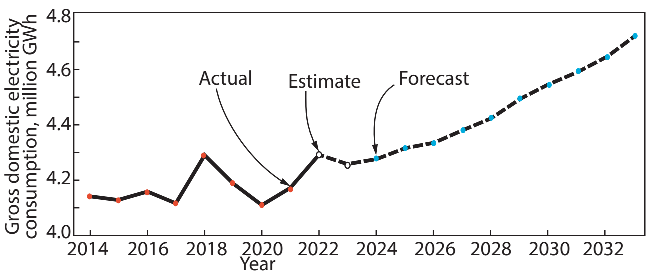
Editor's note: This is the first of three articles exploring the impacts of gas-turbine upgrades on heat-recovery steam generators (HRSGs). It examines the driving factors behind GT upgrades. Part 2 will focus on the concept of "re-rating" the HRSG after its upgrade. Part 3 will address implementing the HRSG mods onsite and the associated planning considerations.

Gas-turbine upgrades are becoming more prevalent due to a confluence of factors. There are three primary drivers behind upgrades. They are: growing demand for power generation, optimization of efficiency and heat rate, and flexibility or low-load operations.

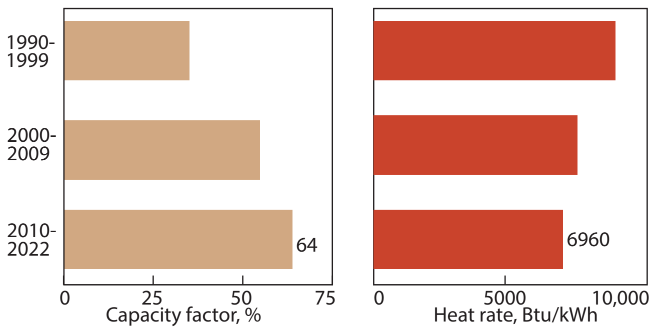
Growing demand. The US experienced little growth in net demand for electricity between 2007 and 2017. Although there was a need for more power, efficiencies resulting from technological improvements accommodated most of the net growth in demand and consumption.

This has changed in the last five years, with the demand for electricity forecasted to expand by more than 4.3% annually over the next eight years (Fig 1). This growth is driven by data centers, cryptocurrency, the expansion of domestic industrialization, and proliferation of electric vehicles. More concisely, the demand for electricity in the form of "final energy" is increasing. By boosting the capacity of existing combined-cycle assets through GT upgrades, companies can increase generation with minimal economical and operational impact.

Increasing efficiency. In deregulated merchant states, power producers are burdened with fuel cost and motivated to find ways to maximize efficiency. Turbine upgrades are a good tool for increasing efficiency while boosting output at affordable cost and with minimal impact to operations. As GT efficiencies and heat rates improve, combined-cycle gas-turbine (CCGT) plants can produce more power at less cost. Fig 2 shows capacity factors have risen significantly since 1990, in part through GT upgrades.



1. Electricity demand is forecasted to expand by up to 4.7% annually through 2032 by the Economist Intelligence Unit



2. Technology gains are cited by EIA as the main reason for capacity-factor and heat-rate improvements at combined-cycle plants for the 1990-2022 period

Flexible or low-load operation. Renewable generating resources may cause CCGT plants to cycle (shutdown/restart) multiple times daily. Cycling is an inherently slow process and can increase the fatigue experienced by the unit and its components. Vogt Power's field experience and customer feedback point to premature cracking and failure of pressure-part components, such as HP drums and superheaters.

To mitigate fatigue, GT upgrade packages are used to allow plants to operate at a very low load. This is a popular choice as operators decide how to best use their equipment to match demand and reduce the time need to ramp the GTs.

Many plants are performing GT upgrades because of the factors discussed above. However, the impacts of GT upgrades on the HRSG and the rest of the combined-cycle plant cannot be ignored because upgrades can result in significant changes in GT exhaust flows and temperatures. A detailed study is required to quantify the impacts of a GT upgrade on the HRSG and balance of plant. Regarding the HRSG, the impacts of GT upgrades can be classified into two categories: pressure parts and non-pressure parts.

Pressure parts impact the feasibility of the upgrade; therefore, this is a primary focus. The associated pressure parts most often affected are these:

- Superheaters and reheaters. The increase in HRSG exhaust temperature can mean higher operating temperatures for tubes and headers, and may exceed the design temperatures of these components. This can occur during low-load operation when exhaust-gas temperatures typically are high and exhaust-gas flows are low. Result: Low steam production at high temperature. This can be problematic because high temperatures increase tube operating temperatures and low steam flows mean less cooling flow to reduce the operating temperature.
- The economizer sections should be analyzed to ensure there is no steaming in them because of the GT upgrades. Steaming can disrupt flow through the economizer sections due to vapor lock. During low-load operation, low water flow through the economizer can cause buoyancy issues. These typically occur in downward passes of the economizer where velocities are very low (less than 2 ft/sec).

Furthermore, during low-load operation there also can be issues with the distribution of water within the header: Water sometimes flows

3. Cracked attemperator liners and moisture impingement on downstream bends can occur when attemperation flows are excessive after GT upgrades

to tubes directly below piping connections instead of being distributed through the header. This can result in some tubes operating with very little or no cooling flow and hence expanding differently than tubes with flow, thereby causing undue stress on tube-to-header welds.

- Drums. If exhaust flows increase because of a GT upgrade, drum internals must be evaluated to ensure there are sufficient cyclone separators and/or chevrons for steam/moisture separation. Undersized drum internals can result in moisture carryover into the superheater, which can quench and damage the tubes. Note that carryover also can cause undesirable steam-turbine deposits.

  If exhaust flows increase significantly because of the GT upgrade, drum retention time also must be evaluated to ensure there is no risk of the evaporators running dry during an upset condition.
- Attemperators. The need for attemperation can change significantly if a GT upgrade results in higher exhaust-gas temperatures. Analysis is required to properly size the control valve for the new range of flows. If increased attemperation flow is needed, the type of attemperators in operation (probe versus ring type), as well as downstream straight-length requirements, also must be analyzed to ensure there is no moisture carryover into the downstream superheater tubes (Fig 3).
- Safety relief valves may require replacement if the design pressure of the system is increased and the entire system is "re-rated." New safety valves also may be necessary if there is a significant increase in steam flow because of the GT upgrade.

GT upgrades often are performed to increase plant capacity or efficiency and these result in increased GT exhaust flows and temperatures which, in turn, increase steam flows. In a sliding-pressure unit, the higher steam flows result in higher pressures. Units with supplementary firing may require limits on the maximum firing rate so the maximum design pressure of the system is not exceeded. While these measures allow implementation of the GT upgrades without needing system re-rates, such firing limits also curtail power production and must be considered when evaluating the total capacity increases of GT upgrades.

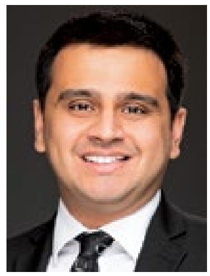
Regarding non-pressure parts, the following also could be affected by GT upgrades and should be inspected periodically:

- Liners in the diffuser duct and inlet duct are sometimes damaged after a GT upgrade—especially if there are significant changes in flows or exhaust-gas profiles.

4. Perforated plates help ensure GT exhaust gases are evenly distributed when they reach the HRSG's heating surface, burners, and catalyst

- Distribution grid (a/k/a perforated plate) helps ensure GT exhaust gases are distributed evenly when they reach the HRSG's heating surfaces and burners, and catalyst. However, a GT upgrade could change the exhaust-gas profile or flow rates, which can damage the grid (Fig 4).
- Catalysts. The temperature of the exhaust stream at the catalyst could change because of a GT upgrade. This could affect catalyst reactivity and should be analyzed. CCJ

About the author



Vignesh Bala is VP HRSG Services at Vogt Power, a Babcock Power Inc company. He leads a group providing cutting-edge analysis and retrofit solutions for combined-cycle powerplants to increase capacity and reliability in support of a changing power market. Bala and his team conduct studies, inspections, and turnkey retrofits, and provide parts for HRSGs manufactured by all OEMs.

Linden Cogen

Linden Generating Station

Owned by JERA Co (Japan), EGCO Group (Thailand), Development Bank of Japan, and GS EPS

Operated by NAES Corp

972 MW, 5 × 3 7EA-powered 800-MW combined cycle designed to burn natural gas and butane and equipped with three D11 steam turbines, plus a 1 × 0 7FA-powered 172-MW cogen unit (Linden 6) designed to burn natural gas and distillate and later modified to co-fire up to 40% hydrogen. Power station is located adjacent to the Bayway oil refinery in Linden, NJ

Plant manager: Stephen Reinhart

How Linden cleans its storm-water retention pond

1. Linden's storm-water detention pond is protected to the extent possible by the air-cooled condenser

Challenge. Linden Cogen is located on a very small footprint in Linden, NJ. Storm water is collected in one central location—a detention basin under the air-cooled condenser shown in the plant photo above. Given the pond is open to the environment, debris collects in the water, which is pumped into the Arthur Kill, a narrow saltwater channel that separates New Jersey from Staten Island.

To improve the quality of its discharge water, Linden Cogen began periodic cleaning of the detention basin to remove collected debris and organic growth (Fig 1). Manual collection of the detritus with shovels, brooms, and vacuum trucks was expensive and required removal of all the water. Plus, the exposed arrangement of the detention basin limited the site's ability to perform cleaning activities without consideration for the weather. Precipitation added water to the pond and made cleaning challenging at best.

Solution. To increase cleaning frequency, an in-situ process was developed. It uses a remote-controlled vacuum system to clean the pond (Fig 2).

Results. Use of the in-situ process described for periodic cleaning of the storm-water detention pond improved the quality of water discharged to the Arthur Kill while reducing the cost of cleaning.

An added benefit of the process: Employees and contractors were not exposed to the waste material collected, helping to prevent slip, trip, and dust issues.

Project participants:
Stephen Reinhart, plant manager
Barry Durham, EHS manager

2. Drive mechanism for the remote cleaning device is at the left, the brush doing the work is at the center, and the controllers regulating the activity are at the right

Lee County Generating Station

Owned by Rockland Capital

Operated by NAES Corp

688 MW, 8 × 0 7EA-powered peaking plant operating on natural gas, located in Lee County, Ill

Plant manager: Keith Koziol

Protecting operators from falling ice

Challenge. Lee County, a peaking plant in northern Illinois, experiences long periods between operations. Calibration cylinders for the facility's continuous emission monitoring system are located outside the CEMS shelter, only 4 ft from the 90-ft exhaust stack.

Safety hazard: During winter operations, snow and ice can accumulate on the grated walkway the encircles the stack 80 ft above ground level and directly over the space between the CEMS and exhaust stack (Fig 1). Snow and ice can fall unexpectedly from this height to where technicians stand to take pressure readings and replace calibration cylinders, thereby creating the potential for severe injuries.

Solution. The original design had only a small, lightweight, metal awning that barely covered the calibration cylinders. Using a local weld shop, a new larger awning made of heavy-gauge steel was designed and built. Site technicians mounted the new awning to existing mounting points on the CEMS shelter and used Unistrut to support the far end (Fig 2). This awning created a protected area for technicians to stand while servicing the CEMS cylinders.

Results. No one has been hit by falling ice; however, it can be unnerving when a chunk hits the new cover.

Project participant:
David Ackert, O&M technician.

1. CEMS shelter is located at the base of the stack and directly under the walkway where ice and snow can accumulate in winter (above)

2. Awning protects personnel from falling ice and snow (right)

Mobile electronic device makes plant readings more accessible

Challenge. A powerplant should not be operated solely from the control room. Operator rounds are a necessity because certain readings and observations are not available via turbine-control or plant DCS systems. Eyes and ears are needed out in the plant.

Paper rounds sheets were used for years with some notable shortcomings, including the following: paper logs are handled several times, readings are not always legible, historical data is not easily accessed, data trending is a cumbersome task, observation/issue comments are not always captured well and tracking the status of them is another administrative process, records retention results in many boxes in the warehouse.

Solution. Plant management evaluated several commercial solutions for electronic data gathering and retention and selected AssetSense. The vendor worked with plant personnel to perform database and mobile device interface screen setup tasks, define data observation points, set normal reading parameters, and organize operator routes.

The readings are entered on touch-screen iPads and out-of-parameter readings are highlighted in red. The previous reading is displayed just to the left of the data entry box. A comment can be added for any data point, or it can be marked "out of service" if needed. With a touch, an operator can view a graphical trend of the last 15 readings. A checkbox is provided to indicate if visual check is "Not OK," or alarms are present.

Back in the control room the data are uploaded to a cloud-based database via Wi-Fi. If a reading was missed or not marked out-of-service, the mobile device interface screen prompts the operator by highlighting the empty data box in yellow; an entry is needed to continue the upload. These data become readily available for review and trending analysis via a utility on the iPad as well as online.

Certain regulatory (or insurance company) routes are incorporated: SPCC (spill prevention, control, and countermeasure) walk-down inspections, EHS walk-down inspections, draining of SPCC containments, main breaker readings, etc.

Results:

- The burden of retaining box loads of paper logs is gone.
- Historical data can be accessed easily and trended on the AssetSense website, or downloaded to Excel.
- Inspection records can be retrieved easily.
- Issue comments can be retrieved separately, and each can be tracked to completion.

Project participants:
Keith Koziol, plant manager
Ryan Hmielak, maintenance specialist
Mark Lane, O&M technician
David Ackert, O&M technician
Mike Packer, O&M technician

Quail Run Energy Center

Owned by Starwood Energy Group Global

Operated by NAES Corp

550 MW, two 2 × 1 7EA-powered combined cycles equipped with A10 steam turbines, in Odessa, Tex

Plant manager: Andy Duncan

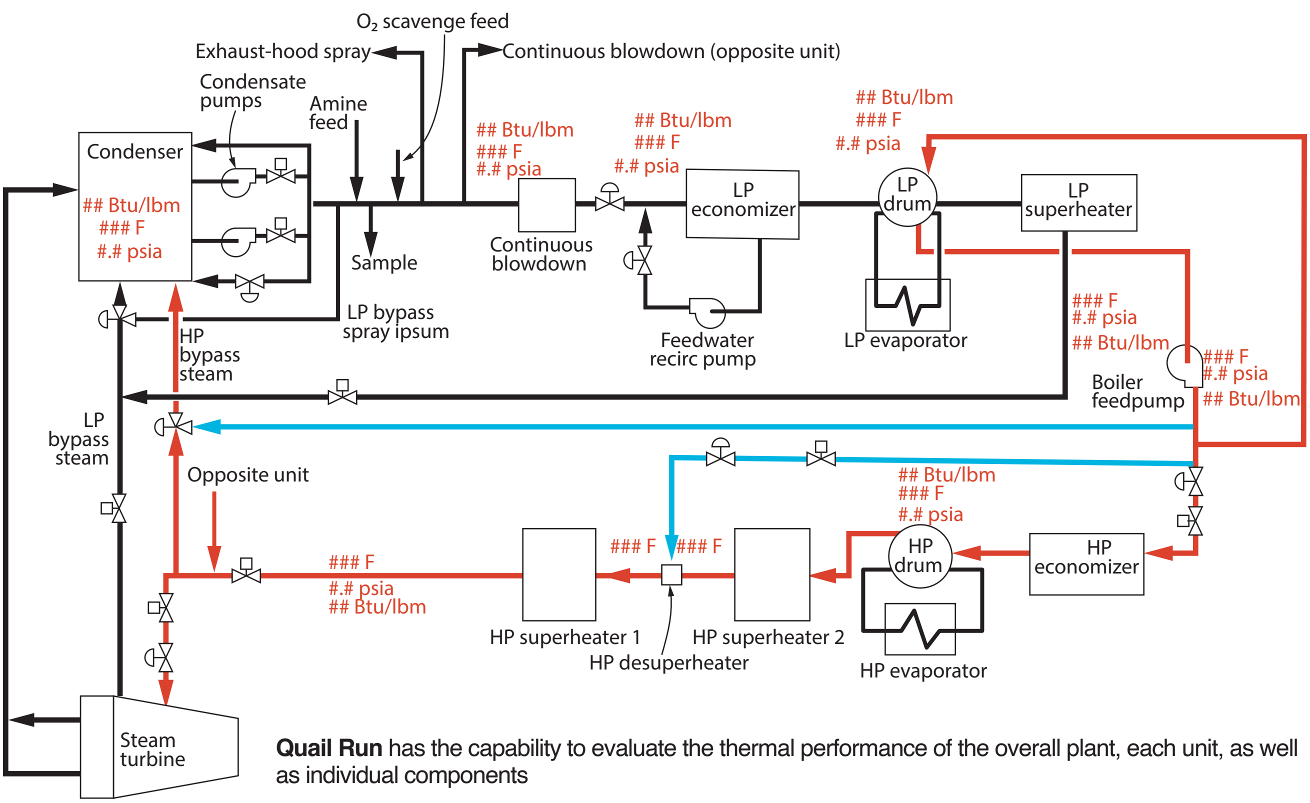
Plant thermal-performance monitoring

Background. When Plant Engineer Ed Nielsen arrived at Quail Run Energy Center about three years ago, the facility did not have any processes to monitor plant thermal performance beyond heat rate.

He took advantage of the performance equations in PI to create compressor-efficiency, live heat-rate, and steam-cycle/Rankine-Cycle enthalpy calculations. The well-traveled engineer told the editors he was surprised more facilities did not use available steam functions in their performance analyses because it is easier to trend pressure/temperature variations as enthalpy.

This also is beneficial to operators because a temperature or pressure change alone may not tell the whole story.

Challenge. Develop a robust monitoring program to evaluate the thermal



Quail Run has the capability to evaluate the thermal performance of the overall plant, each unit, as well as individual components performance of the overall plant, each of the two units, and individual components. Typically, an operator on shift would monitor temperatures, pressures, and flows, along with component operating status and system configuration. However, a proper thermal analysis is not always possible when using changes in temperatures and pressures alone.

Solution. By taking advantage of steam functions and performance equations in the plant's trending software, personnel were able to take this a step further and perform energy analyses of Quail Run's systems and components.

Steam functions and performance equations enable the calculation of live enthalpy values throughout the various plant systems, allowing staff to apply Bernoulli's principle to analyze system and component performance.

Recall that Bernoulli's equation is simply:

$$KE1 + PE1 + P1V1 + U1 + Q = KE2 + PE2 + P2V2 + U2 + W$$

where

KE = kinetic energy,
PE = potential energy,
PV = pressure energy,
U = internal energy,
Q = heat transfer,
W = work, and
PV + U = h (enthalpy).

For the purpose of analyzing heat exchangers and pumps, Quail Run staff assumes no significant change in potential energy or kinetic energy, thereby reducing the equation to:

$$H1 + Q = H2 + W$$

where

Q = H2 – H1 for heat exchangers and
W = H2 – H1 for pumps and turbines.

By evaluating the enthalpy change for each component in the steam cycle, you can quickly determine the energy added by pumps in the system, the heat transfer done by heat exchangers, and the work done by turbines—thereby eliminating the guesswork when multiple parameters change. Trending the historical change in enthalpy over a system or component allows you to quickly monitor for changes in performance.

Nielsen and colleagues are able to use live calculations in their trending software, but this also can be done manually using steam tables or the Mollier diagram.

Plus, there also are third-party Excel add-ons to perform steam-function calculations.

Quail Run personnel have incorporated these values into their trending software screens for live analysis in addition to extracting data into Excel to monitor historical performance.

Results. Use of the process described adds another tool to allow staff to monitor pump and heat-exchanger performance, desuperheater valves, approach temperatures, and overall performance, etc.

Project participant:
Edward Nielsen, plant engineer

Jackson

Jackson Generation

Owned by J-Power USA

Operated by NAES Corp

1200 MW, two 1 ×1 combined cycles powered by Mitsubishi 501JAC gas turbines and SRT40AX steam turbines with HRSGs from John Cockerill, located in Elwood, Ill

Plant manager: Rick Dejonghe

Establishing safety parameters for Jackson's retention pond

Challenge. When constructing a powerplant, the EPC takes the contract agreed on by the owners and begins to build the facility based on the engineering plans. The retention pond designed by the EPC for Jackson Generation met the specifications required by the contract. However, during the commissioning phase of the project different ideas were proposed to improve existing infrastructure and processes.

While the Jackson Generation team was creating plant rounds and water-chemistry procedures, participants noticed numerous safety/environmental challenges that would need to be addressed when monitoring and testing pond water. Examples included the following:

- How would staff safely retrieve water samples?
- How would staff rescue someone if they fell into the pond?
- How would plant personnel keep wildlife out of the pond?

Solution. To access and remove the pond-discharge manhole cover to verify discharge flow, staff would walk on the sloped foundation liner down to the engineered platform provided. This walkway proved to be a slip hazard, especially during winter operation.

A metal walkway was erected and

1. Walkway with handrails was installed over the pond liner

2. Ladders mounted around pond boundary facilitate escape from a potential hazard

3. Safety ropes with grab rings are highly visible on the pool fence

4. Fence impedes access to the pond by trespassers installed to mitigate slip hazards while performing this task (Fig 1). It provided personnel a solid foundation while verifying flow from the retention pond.

The Jackson team also purchased ladders, which were mounted around the pond boundary (Fig 2). They ensure staff can escape a potential hazard in a safe and immediate manner.

Lastly, the Jackson team equipped the retention-pond fence boundary with safety ropes with permanent grab rings attached (Fig 3). In the event the employee cannot use a ladder, a rescue rope is readily available.

A chain link fence was also installed around the border of the pond to keep wildlife and trespassers out of the area (Fig 4).

Results. The initial walkway to the retention-pond discharge had many hazards. First, the liner would become slick when snow, rain, or dust accumulated on its surface. This made grabbing water samples or checking discharge flow hazardous.

The liner also was black, so during night operation it became difficult to recognize where the engineered platform was without a flashlight. With the walkway installed, the operator now can walk from the gravel to the engineered platform without the need to be on the slick foundation liner.

The safety ropes and ladders make a rapid rescue feasible if a person were to fall in.

Plus, the 7-ft-tall chain-link fence provided a safeguard against encroachment by deer or other trespassers from the neighboring fields.

In sum, staff made it possible to enhance the safety factors around the pond and mitigate the hazards identified.

Project participants:
Corbine Shanklin, Lead control room operator
Entire plant O&M team

Develop your training program during commissioning

Challenge. Constructing and commissioning a powerplant is challenging. Each system goes through several stages—including construction, testing, commissioning, and turn-over to the startup team. All of these are handled by the EPC and its construction/startup crew.

Roadblocks in the process that the startup crew may experience may be aggravating, but they can serve as excellent training exercises for the operators who will take over after commissioning. Jackson Generation's management understood the importance of this experience and began building the plant's training program with every evolution witnessed.

Solution. First step: Each operator had to choose one or more systems that he or she would become a "system expert" on. Anytime a system walkdown, test, or vendor was onsite, or commissioning was to be done, the system expert was present, taking notes along the way.

This proactive approach proved more valuable than the traditional classroom training given before turning over the plant to its owners. From the notes taken, many different training tools were developed. SMEs (subject matter experts) used the information gathered to complete one-on-one training and table-top exercises with their peers to share the knowledge gained.

Results. Knowledge operators gained from their commissioning experiences was used to develop the plant's training program—including operating procedures and troubleshooting tips.

Vendors that were onsite participated by helping in the creation of operators' rounds checks/parameters and preventive-maintenance tasks.

Working hand in hand with the startup crew enabled staff to develop more-detailed procedures for starting, stopping, and troubleshooting equipment than could be produced by using equipment manuals only (Fig 5). Procedures developed incorporated Jackson's actual valve numbers, photos, and setpoints required for future use. Going a step further, the system experts labeled every pipe, valve, and important piece of equipment in their respective systems.

Next step was for the plant expert to gather every P&ID, system description, equipment manual, and procedure pertaining to a given system and build a so-called system folder—a collection of everything plant personnel would need to operate and maintain their systems. As you might imagine, such a library is invaluable for making decisions. Finally, the P&IDs were marked up by the operators to identify the critical valves and equipment for creating the LOTO points needed for tagging out certain processes.

The end goal of this exercise was to be prepared for any obstacles after the owners took care, custody, and control of the plant. By shadowing the startup crew, the system experts experienced many unusual events. Creating the system-expert folders laid the foundation for the training program future employees would benefit from.

Project participants:
Corbine Shanklin, Lead control room operator
Entire plant O&M team

5. Jackson employees join startup crew to commission the auxiliary boiler (left)

6. Plant operators use P&IDs to build LOTOs (right)

Cape Canaveral Next Generation Clean Energy Center

Owned and operated by Florida Power & Light (FPL)

1200 MW, 3 × 1 combined cycle powered by Siemens SGT6-8000H gas turbines, located in Brevard County, Fla

Plant manager: Chris Mabou

Gas assist when starting on fuel oil

Challenge. In Florida, the supply of natural gas through pipelines can be limited during severe weather events, such as hurricanes. Thus, it is imperative that powerplants in the state have the ability to start and operate on alternative fuels—such as oil. FPL owns and operates three 3 × 1 H-class combined-cycle plants in Florida and was experiencing lower starting reliability on fuel oil compared to natural gas.

Solution. Plant's approach was to initiate ignition on a small amount of natural gas and then switch to fuel oil early in the ramp-up sequence. At the time this entry was submitted, FPL's advanced-gas-turbine plants were being equipped with dedicated natural-gas storage tanks to assist in fuel-oil startup. Bear in mind that, in addition to the storage tanks, additional valves and piping, and logic modifications, also were needed to connect to the existing system.

Results. The solution described had been implemented on five gas turbines—including the three at Cape Canaveral—at the time this entry was submitted to CCJ and had demonstrated multiple successful starts. More specifically, reliability on fuel-oil starts improved to greater than 95% on some units since January 2023. Fleet average reliability was greater than 81% and expected to improve when all units are implemented.

Project participants:
Chris Mabou, plant manager
Tobias Augsten, principal engineer, FPL gas-turbine fleet team

PSM Asset Managers Conference

Segment 2 of CCJ's three-part report on PSM's 16th annual meeting, which showcased the company's technologies on its silver anniversary

This is the second segment of CCJ's three-part report on PSM's 2024 Asset Management Conference, conducted at the Westin Beach Resort in Fort Lauderdale, Fla, January 29-February 1. The first segment was published in CCJ No. 78, pp 58-63, the third installment will appear in CCJ No. 80.

The focus here is fourfold:

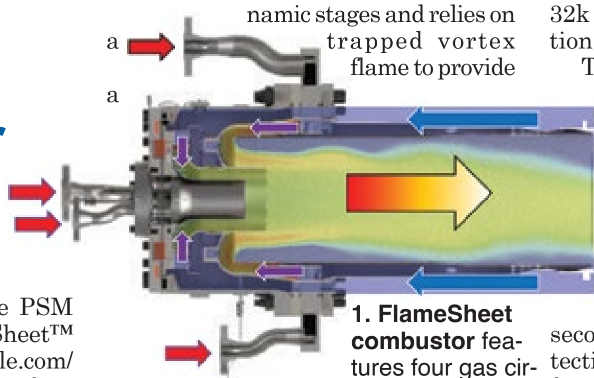
- FlameSheet™ keeps getting better.
- Benefits of additive manufacturing (AM) in the production of R1 vanes.
- Technical presentations by industry partners on (1) generator field rewinds, (2) impacts of GT upgrades on heat-recovery steam generators (HRSGs), (3) exhaust-frame mods and improvements.
- Shop tour.

Flamesheet platform broadens its reach for machines, fuels

It has been two decades since PSM specialists patented the FlameSheet™ combustor (https://patents.google.com/patent/US6935116B2/en). Soon after, in 2005, the first prototype was tested in a 501F machine. Commercial installations began in 2015 for a variety of F-class gas turbines.

By 2021, the technology was operating in seven 7Fs and one 501F, the latter as part of the first-of-its-kind FlameTop7 installation at Salt River Project's Desert Basin Generation Station (CCJ, No. 66, 2021). More recently, the technology has racked up an impressive list of milestones, including the first application to an E-class unit last year, and the first Frame 5 commissioning this year.

Recall that FlameSheet was originally developed for general operational and fuel flexibility. Simply, the concept includes four fuel circuits to enable a "combustor within a combustor" design for advanced flame staging. This arrangement has two unique aerodynamic stages and relies on trapped vortex flame to provide wide stability margin. The pilot and main stages are effectively two independent combustors, each with its own robust flame stabilization mechanisms, allowing either combustor to operate with the other one off, enhancing operational flexibility (Fig 2).



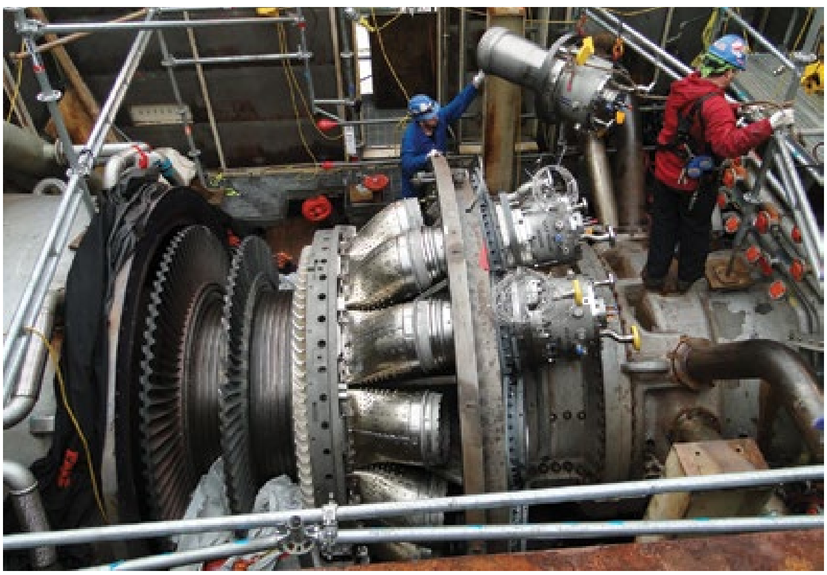
1. FlameSheet combustor features four gas circuits as shown

When FlameSheet™ was coupled with PSM's AutoTune and inlet bleed heat, turndown was improved from the 65% to 70% range of the OEM's standard combustion system to 25% to 30% for 7F and 35% to 40% for 501F from baseload. Adding the company's exhaust bleed system extends turndown an additional 5% to 10%.

Lately, FlameSheet™ demonstrated up to 80% hydrogen firing (depending on GT model) in high-pressure rig testing, turndown to under 30% with no sacrifice in emissions compliance, 60% H_2 firing for a 7EA unit, and a 32k operating-hour/1250 start inspection schedule.

The technology comes equipped with what is claimed to be an industry-leading combustor hardware protection system. An active flashback monitor/fast runback technique protects against slugs of poor-quality fuel on premix combustors. By cutting fuel to the affected circuit, emissions compliance can be restored within 40 seconds, according to PSM. The protection system has been demonstrated for the 7F and 501F. It also avoids hardware damage, outages, and trips from poor-quality fuel.

Today's FlameSheet™ Gen VI incorporates "micro-mixer" technol-



2. Combustor-within-a-combustor design enables advanced flame staging. Combustor's low pressure drop benefits heat rate, contributes to smaller footprint ogy to better handle highly reactive fuels like H_2. Generically, micro-mixing refers to the goal of decreasing the "scale" of the fuel/air mixture, reducing flame length and resonance time (for combustion reactions to take place), and making the mixture as uniform as possible. This is accomplished by replacing the pilot in each can with a pilot utilizing this technology. PSM's micro-mixing technology achieved sub-30% turndown in the 7F machine.

The four FlameSheet™ fuel circuits are called the pilot, pilot tune, main 1, and main 2. Subsystems include proprietary flashback monitoring and ignition designs. AutoTune is also part of every installation. Other salient features include these:

- Aerodynamic trapped vortex for wide stability margins.
- High pre-mixer exit velocities to tolerate highly reactive fuels.
- Robust mixing techniques for tolerance to Fuel Wobbe Index variations.
- Low-pressure-drop combustor for improved heat rate and smaller footprint.

FlameSheet™ with exhaust bleed also addresses steam-cycle attemperation issues. It allows a reduction in exhaust temperature while maintaining low turndown levels, improving attemperation margins.

Today's scorecard for FlameSheet™ includes the following highlights:

- 33 units operating and under contract through 2026.
- 320,000 operating hours since 2015.
- 60,000 operating hours for the fleet leader, with over 400 starts.
- Four units burning hydrogen.

As one example of FlameSheet™ plus GTOP benefits, the customer's goals were to raise unit output, improve heat rate, and burn shale gas with up to 10-12% C_2 compounds. The results from a low Δp FlameSheet™ install were 10% higher output, 2.2% better heat rate, 40% turndown with CO emissions in compliance (on reduced exhaust-temperature isotherm), NO_x emissions below 9 ppm under a +50F baseload firing temperature, and reduced start time of 30 minutes.

Additive manufacturing enables better R1 vane cooling

Most CCJ readers are familiar with additive manufacturing (AM), also called 3-D printing, at least in principle, but may not be aware of how AM has improved component designs. Greg Vogel, senior manager of PSM's technology program, and Mark Zangara, senior manufacturing engineer, explained during the Asset Managers Conference how AM has affected the R1 vane in the hot gas path.

PSM began investigating AM twelve years ago, experimenting with different powder formulations and machines. The R1 vane proved a convenient point of entry. The company had much experience reconditioning this Inconel 939 superalloy component. As importantly, the company's cooling system experts quickly realized that AM could be used to deploy a concept impossible to implement with traditional casting methods.

Called "near-wall cooling," the idea is to replace straight cylindrical holes, impingement, and baffle plates with a "shoelace" pattern of parallel channels which brings the cooling air flow closer to the hot surfaces on the other side. These channels are more easily inserted because the vane is built up from successive 40-micron layers of deposited alloy powder. AM is therefore more precise than traditional casting.

The technique brings more cooling air flow to where it is needed most— toward the center of the airfoil. Near-wall cooling also avoids a common problem with the typical "shower head" cooling holes on the vane's leading edge. Often in operation, the pressure of the cooling air inside the part is not as high as it should be, leading to ingestion of combustion gases into the cooling cavities and surfaces. Vogel says the channels correct this. Listen to him explain the advantages of the AM component by connecting to a short video via the QR code.

Better cooling not only improves the efficiency of the machine because less air needed for cooling, but also the durability of the part. The near-wall technique lowers the risk of thermally induced cracking by reducing the temperature differential between the airfoil and the platforms (not 3-D printed) it is attached to. Use of the AM-derived vanes and their platforms also cuts the total number of parts from 12 to four, which has positive implications for repair and reconditioning.

After successfully achieving a full interval of field operation, the R1 vanes returned to shop after the three-year period with no TBC spallation and no heavy oxidation. The set is completing repair now and will be available for another interval in GTOP7 operation. Stay tuned.

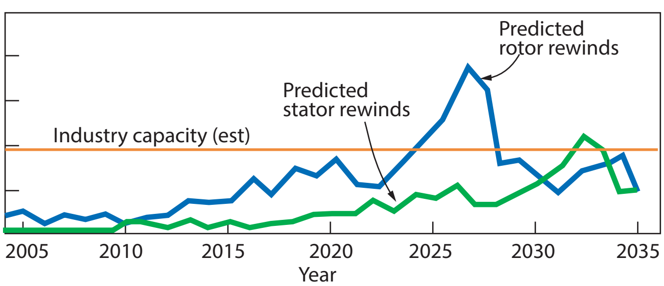
What PSM's industry partners had to say

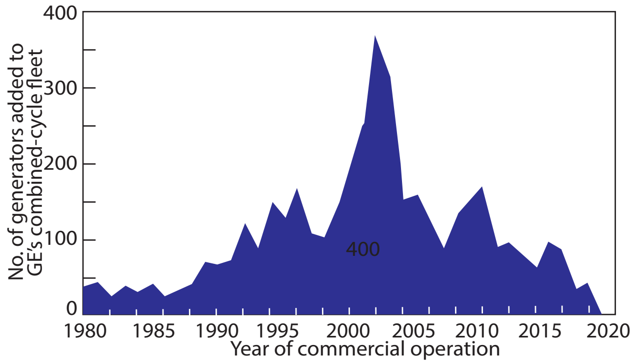
AGT Services: Surge in field rewinds ahead

Those who live along the Gulf Coast know that they are likely to suffer through one or more hurricanes (and the accompanying storm surge) annually. You just never know how many there will be or how severe.

The surge of combined-cycle generator rewinds hurtling towards the industry is at least predictable. Just map the commercial operating date (COD) of the units in service to the 25- to 30-year life of the field windings, as Jamie Clark, AGT Services, did to open his presentation (Fig 3). What isn't as predictable is the industry's capacity to handle the surge.

Given that the peak wave will hit in 2027, only three years from now, the estimated industry capacity is woefully





3. The surge in generator field rewinds is upon the industry, and service capacity is expected to be severely tested over a few years later this decade and into the next

- Why use a robot?
  - Avoids the perceived “risk” of field removal.
  - Avoids the cost and schedule of field removal.
  - Robotic inspections are not “cheap.”
  - If there’s need to unexpectedly pull the field, cost and schedule can increase substantially.
- When to use a robot?
  - When it fits. Bear in mind that not all generators are the same. There are different entrance gaps among generator models and OEMs.
  - When the unit has had a reasonably recent major inspection and all recommendations have been performed (such as re-wedging, endwinding work, rewinds, etc).
- Robot inspection challenges:
  - Oily stators (loose traction).
  - Deep slots.
  - Bumpy paint jobs.
  - Zone/baffle rings limit your mobility and what you can test/see.
  - Smaller air gaps and entrance gaps increase the risk of getting stuck.

4. Guidelines and considerations for use of robotic inspections. Make sure contractors offering robotics provide proof of successful fitment—including ElCid and wedge-map capability—on your specific model generator. Bullet points above will help you decide if a robotic inspection is an option for you

inadequate, and it can take years for a new service shop to tool up and train staff, ask yourself: Are my units properly positioned to weather this surge? If not, Clark’s slides, “Generator Outage Planning—Contingencies” offer a roadmap to get you started.

First, map out your plant/fleet, and organize generators by OEM, model, and vintage. Evaluate the fleet mix to determine “spares.” Identify long-lead-time components. Make sure you know what spares are typically available. For example, 7FH2 spare fields are common, but not 7A6, Aeropak, or WX/WY. Find out where and when you can get stator windings for your OEM/model. Consider carrying spare windings at the plant or fleet level. Map out diode/fuse supplies at each plant. Check to see if your service providers have high-voltage bushings, tubular leads, and other critical parts in stock.

Evaluate the baseline condition of your units. Consider minor inspections in lieu of field removal. If unit cycling has increased appreciably, shorten your outage intervals and factor in time on turning gear. Analyze your online monitoring data trends before any outage to get a snapshot of overall condition.

You’ll have to lock in contractors farther ahead of time than you may have been used to. Many units out there are well beyond their 25- to 30-year winding design life, and entering the period for a second, and even a third, field rewind.

Cycle times are increasing for critical parts and materials. Delivery of stator windings start at four to five weeks on an emergency basis. High-voltage bushings (HVB), brushless exciter fuses, and diodes are no longer routinely stocked by OEMs and fleet owner/operators.

Expect a minor generator outage (in-field, limited disassembly) to take one to three shifts, plus a shift for any brushless-exciter scope; a major outage (field rewind) to take three to five shifts plus a shift for the ElCid test and another shift for other special tests; and a “median” outage (robotic inspection) to take three to five shifts plus time for minor test/inspection scopes. These estimates do not include assembly/disassembly time.

Requests for quotes (RFQ) and purchase orders (PO) should be completed at least three months prior to outage start for a minor. For a major (field removed), RFQ and PO should be in place six months prior. Note that you can separate the mechanical scope from the generator contract. Plan on six months ahead for median-outage RFQs and POs to be in place. Plans for field rewinds and contractors should be in place six months before the outage begins, one year for stator rewinds.

Typical repair-project durations (again, not including assembly/disassembly) include:

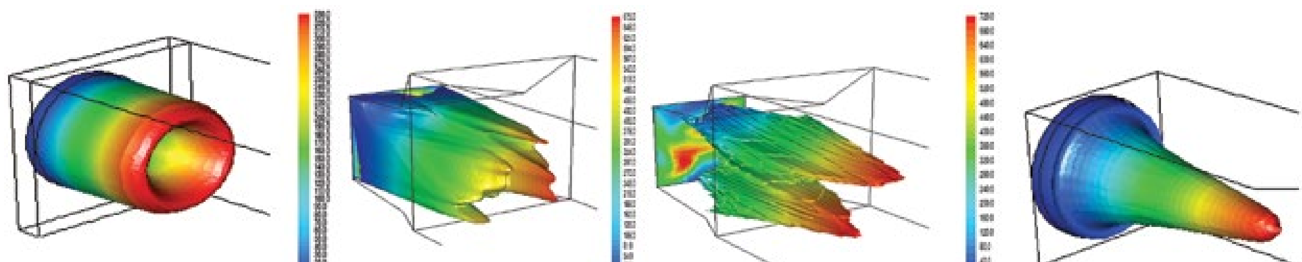
- Seven to 14 days for stator rewedging and end-winding repairs.
- Seven to 10 days for retainer-ring-off inspection and minor repairs plus two to three days for high-speed balancing.
- 14-30 days for field rewinds and two to three days for high-speed balancing.

Any outage should be preceded by online testing and monitoring to contribute to the snapshot of overall unit condition, including online partial discharge (offline techniques also available), endwinding vibration trends, electromagnetic impulse (EMI) testing, and flux probe survey.

Clark’s slides offer a granular look at typical inspection and testing scopes, not reviewed here. However, one highlight is the availability of better robotic inspections (Fig 4). Clark cautions users to make sure your contractor’s robotics methods and tools have demonstrated experience with your specific OEM and model. For example, the smallest robotic inspection vehicle that is said to fit in the smaller-air-gap machines may still be limited because of the add-on components for the ElCid test and wedge mapping.

Often a borescope-aided visual inspection, requiring only a simple end cover removal, can be just as useful and often less expensive and faster. This permits full visual inspection of endwindings, stator main-lead connections (may need insulation stripped and replaced though), visual and even in-situ retainer-ring NDE. Plus, examination under retainer rings of turn insulation, slot armor, and main leads, and inspection of field body and stator (limited by borescope length).

Clark also emphasizes that most every OEM has bulletins out for brazed-joint connection inspections—including phase, series, stator main leads, and HVB. Because some connection



5. GT exhaust profiles differ from unit to unit, and should be verified by CFD analysis for their potential impact on HRSG design and operation

	30% hydrogen	100% hydrogen
GT mass flow	3-5% decrease	5-7% decrease
GT outlet temp	1-2% decrease	2-3% decrease
GT water content	~+15%	~+60%
HP steam flow	<1% decrease	4-6% decrease
HP steam temp	Decreased	Decreased

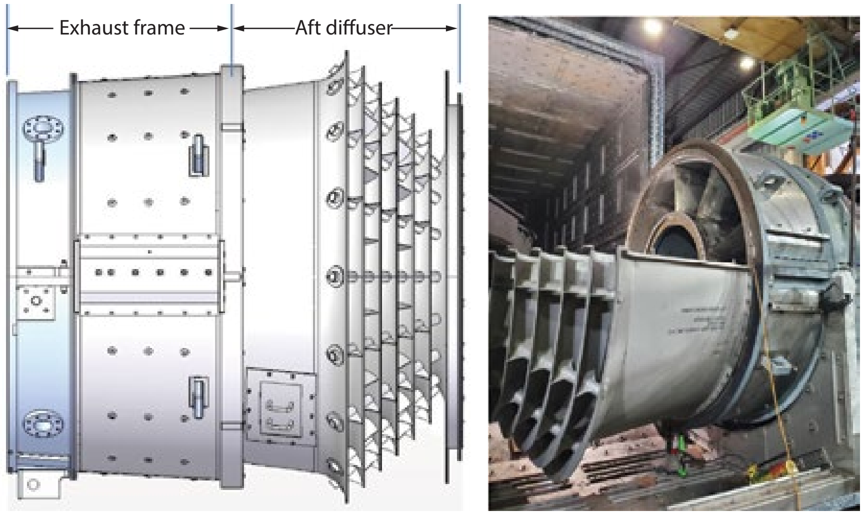
6. Variations in HRSG design parameters when burning hydrogen

7. Flex-seal retention assembly can extend the interval between seal replacements

endwinding designs severely limit access, radiography may be an option, especially since a pure visual exam or traditional NDE requires insulation removal and replacement.

However, challenges to radiography include access to joint locations, availability of resources, and outage coordination (may require cordoning off the entire turbine deck and best performed during the night shift). Also, if you discover one or more "indications," how do you interpret the findings and what do you do about them?

Clark's slide deck includes several photos of typical issues found during inspections, such as greasing at end wedges and connection ring ties, and various field winding conditions. Contact him at jclark@agtservices.com to request a copy.



8. Upgraded 7EA-style split aft diffuser (left) is installed in shop (right)

Vogt: Don't neglect the HRSG when evaluating GT upgrades

The gas turbine is part of a combined-cycle system and so the PSM Asset Manager's Conference, part of the company's global "Retrofit Revolution," also included a presentation by Vogt International, "GT Upgrade/Low-Load Considerations for HRSG—Hydrogen Firing." Most of the content mirrors the article elsewhere in this issue, "Gas-Turbine Upgrades and their Impacts on HRSGs."

The slides at the PSM AMC addressed non-thermal HRSG impacts (liners, baffles, flow distribution, catalyst, duct burner), as well as thermal impacts on pressure parts, tube/pipe velocities, drum/steam-water circulation system, attemperator, catalyst, safety relief valves, control valves, and I&C.

Of particular interest to CCJ readers may be that GT exhaust profiles can be quite different, depending on the design and configuration (Fig 5). And if you did already know this, at least the names are cute. There is the "donut" (peak velocities around 330 ft/sec), the "mountain" (peak velocity around 650 ft/sec), the "twin peaks" (peak velocity around 650 ft/sec), and the "bullet" (720 ft/sec). The exhaust profile should be verified by CFD analysis and accommodated, if necessary, through HRSG design modifications.

The last slide (Fig 6) is a handy guide to several important generic changes in HRSG design parameters resulting from 30% or 100% hydrogen firing. While the changes may seem modest on paper (the exception being GT-exhaust water content), an HRSG is a tightly designed subsystem and the impacts may be more than you think.

IPS: Exhaust frames need love too

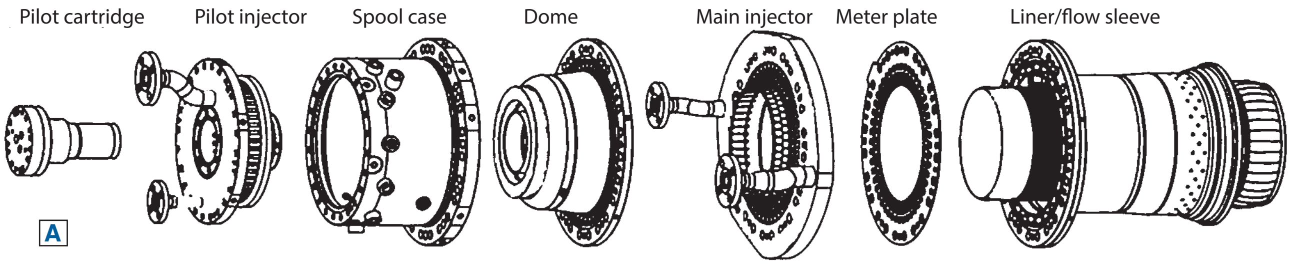
It's easy to forget that the non-flashy components of a modern combined-cycle plant can also affect performance. Case in point: the exhaust frame. Experts from IPS addressed fleet-level issues associated with exhaust frames in a preso entitled, "7F and EA Exhaust Frame R3 Modifications and Upgrades." Note that R3 is shorthand for repair, refurbish, replace.

Operationally, the issues include exhaust-frame cooling-air loss, overloading of cooling-air blowers, load- and bearing-tunnel temperature increases, running two cooling-air blowers and losing redundancy, high-temperature exhaust-spread risk, potentially high wheel-space temperatures, repair costs increasing over time and still not making outage intervals, material degradation, and casing structural cracks.

Specific mechanical issues were addressed in the presentation. The slide deck offers descriptions of solutions, along with photos, for most of these problems and four site case studies in which one or more of these solutions substantially improved performance for the customer. In two of the cases studied, the sites were able to return to operation with one blower running at normal amperage.

A good example of a solution is the patented flex-seal retention assembly (Fig 7) which has been installed in 60 units and is supported by 29,000 operating hours. IPS says it has reduced seal-failure risk, stopped cooling-air leakage, and is easier to install and maintain than alternatives.

One of the case studies features an upgraded, split aft diffuser (Fig 8), which addresses inner-barrel circumferential cracking, aft flex-seal ring separation, turning-vane cracking, and load-tunnel and back-wall insulation failures.



Shop tour

A focus of the shop tour conducted Feb 1, 2024 as part of PSM's Silver Anniversary celebration was the company's FlameSheet™ product. The assembly drawing **A** is helpful in understanding the nature of parts displayed at the various manned stations on the tour.

In **B,** Jose Gutierrez, manager of combustion manufacturing engineering, shows components critical to proper air and fuel flow in the FlameSheet assembly—specifically dome, metering plate, and pilot injector. The main injectors and flow sleeve are in **C.**

Recall from the text that FlameSheet is a "combustor within a combustor" with four fuel circuits—Main 1, Main 2, Pilot, and Pilot tune—to widen the operating envelope and allow for a larger fuel variance. It is characterized by an aerodynamic trapped vortex, creating recirculation zones to provide a wide margin of stability.

FlameSheet's modular design allows retrofit of components as the product grows. It also enables PSM engineers to properly dial in emissions and dynamics for the best performance in each engine.

Chris Varney, senior technician, flow system services, is in the final stages of FlameSheet assembly in **D.** Flow tests of individual components, then of the entire combustor, assure the best possible performance in the field. Last step: Inspection prior to packaging **E.** After crates are built around the combustors, they are shipped to the job site ready to mate to their respective transition pieces.

Other stops on the shop tour included the following:

- Mark Zangara, senior engineer, airfoil manufacturing (center) and Greg Vogel, senior engineering manager of technology (left), display new and engine-run 501F R1 vane segments **F**. The disassembled R1 vane, manufactured using 3D printing technology, is shown prior to coating removal. Its disassembly and inspection, conducted after the first full service interval, revealed no cracks in the vane, and vane segments were fully repairable.

  This stop also showcased the first full-interval GTOP7, including repair of PSM's first additive


E

F


G


H


I


J

manufactured set of hot-gas-path components (R1 vanes).

- Shear-wave testing **G** is used to check for cracks in OEM's 501F support housings. A cross section, shown on the left in the photo, was beneficial for supporting speaker commentary. The PSM team: Darius Marchal, technical lead, manufacturing engineering of combustion, cases, and rotors; Timothy Hleboski, technical lead, fuel system services; Ryan Griffen, cell lead, fuel system services.
- Joshua Eads, technical lead, metrology (x-ray, white light, blue-light scanning, CMM, and faro arm) calibrates portable scanning equipment **H** that allows PSM to ensure conformity with both repairs and new manufacturing activities. Fixed and portable equipment also is used to support field findings and activities.
- Derek Ji, engineering management, coating processes, shows PSM's new coating booth **I**, installed in 2023, to add capacity for both new manufacturing and repair processes. Robotic thermal spray booths accommodate bond-coat and top-coat applications. HVOF (high-velocity oxygen fuel) and APS (air plasma spray) are available.

Attendees were told that PSM offers several unique thermal barrier coating applications for both stationary and rotating equipment, developed in concert with the company's new manufacturing engineered solutions activities.

- Eric Rosenlieb, senior technical lead, workshop operations, introduces PSM's flow lab **J** to conference participants. Behind the speaker are fixtures for combustion components used to accommodate tight flow tolerances and wheeling of combustion systems.
- The M&D Center, last stop on the tour, operates 24/7 along with its sister facility in Houston. M&D Engineers Sanjana Singh and Vojtech Bednar, and M&D Operator Josh Massie, were on hand to discuss the company's experience in tracking the performance of 52 gas turbines, three steam turbines, and 55 generators.

Don't bet against GTs, but perhaps consider side wagers on OEMs

The popular keynote duo of Tony Brough, president, Dora Partners & Co, and Mark Axford, Axford Turbine Consultants LLC, kicked off the 33rd annual Western Turbine Users Inc (WTUI) conference with their analysis of the gas turbine (GT) market, players, and key drivers.

Brough began with the rhetorical questions: Are GTs going away? Is the GT market viable? Answers, No, and absolutely. And Brough had the receipts, based on hundreds of conversations with investors, OEMs, and users.

Annual global orders may have fallen 13% in 2023 in megawatts but the number of units was up slightly at 3%. Parsing out aeros from these numbers, Brough noted in his slides that North American aero orders were down 11% in units and 16% in megawatts in 2023. Worldwide, those figures are 5% and 16%, respectively.

Nevertheless, up to $137-billion is expected be spent on new packaged engines (just the engines) over the next 10 years, $22.3-billion for aero units. The forecasted aftermarket value for frames is around double that figure, and 50% higher for aeros. New machine design offerings add to owner/operator choices.

Brough explained that one reason for the inverse relationship between units and capacity is a pause in orders for the largest advanced GTs, like the latest F, G, H, and J designs, as users and OEMs work out technical issues.

The LM2500, which Brough described as a "market-killing machine," (Fig 1) took 61% of the market between 2018 and 2023, up from its previous five-year share of 53%. For power generation, the machine took a whopping 81% of the past five-year market in the 30-40-MW capacity range. In North America, GE Vernova/Baker Hughes garnered 100% of the aero market and 82% of the global in 2023.

As for other models, the FT8 gets a small share in North America only in the 20-30-MW category, while the Siemens SGT-800 dominates against the LM6000 outside of the US in the 40-100-MW segment. Brough said only five LM6000s were ordered in 2023 (Axford later said eight), although the 2024 outlook is more positive.

Nature abhors a vacuum, but so to do market players eyeing total market dominance by one competitor. Solar Turbines is aiming its new Titan 350 design squarely on GE Vernova's success with the LM2500. Brough gave a quick comparison of the two machines.

The Titan 350 has a slight advantage in dry-low-NO_x emissions (9 ppm capability), and the two machines are comparable in efficiency and output. Two big differences are in weight and footprint. The Titan 350 is 50 tons heavier and almost double the footprint of the LM2500. Both these parameters rarely are important except in the oil/gas offshore platform market. Another key difference Brough notes: A user has one repair option for the Titan 350, the OEM, while there are three or four options for the LM2500.

Brough concluded by forecasting that the peaking electricity market will be a huge driver for aeros over the next 10 to 15 years.

Geopolitical instability

Axford then took the stage and mused on geopolitical events impacting the GT market. Topping the list was the war between Israel and Hamas in Gaza which, adding to the military volatility in the West Bank and general tensions in the region, could blossom into a full-fledged Middle East war. This has already caused shippers to divert cargo vessels around the tip of Africa, adding 40% to shipping costs. What happens if military activities escalate in the Persian Gulf, Axford posed.

Axford invited his audience to contemplate the impact of blowing up the Nordstream pipeline in September 2022, which used to carry Russian natural gas to Europe. Curiously, all country-level investigations into that event have been closed, according to investigative journalists' reports.

Nordstream, claims Axford, has become a "dirty word," and something that, geopolitically, falls under "don't ask, don't tell." Yet since then, the US has displaced Russia as the chief exporter of natural gas (as LNG) to Europe. At the same time, US government regulators have "paused" permits for additional LNG export facilities, part of what Axford and plenty of others call the "war on fossil fuels."

1. Aero order numbers for 2023, for both the oil-and-gas and electric-power sectors, confirm the market success of the LM2500+. Note that the worldwide numbers include Russian OEM orders

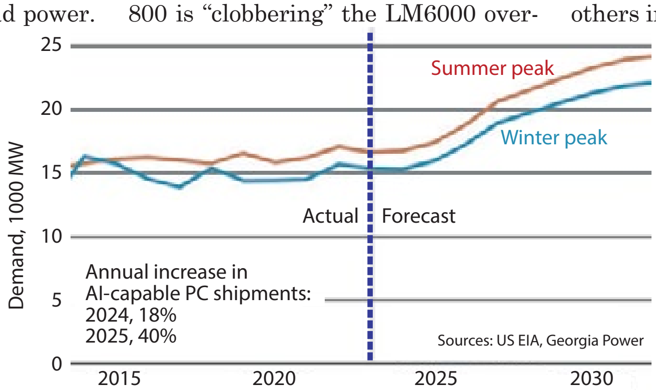
Axford labeled Nordstream the most important event in global energy markets since the Iraq War in the early 1990s. Even though LNG markets are currently volatile, the market for LNG is expected to rise 50% by 2026, he added.

Artificial stupidity

Joking that he's glad no one is pushing artificial stupidity as there is enough natural stupidity to last forever, Axford then explained how the need for electricity to power AI data centers is creating huge demand for baseload power. AI data centers run 24/7/365 and the "new breed" isn't just for storage of data but are "manufacturing sites converting data into intellectual property."

Utilities serving the AI clusters around Loudon County (Virginia), Chicago, Dallas, and Atlanta, have had to "correct" their load forecasts while economic developers are holding back new AI facilities until power supply catches up with demand. Coal-plant closures are even being delayed to accommodate the need.

"The AI demand spike on electricity is the single most important fact for you to take home," Axford said, unless you want to be considered naturally stupid. One utility serving the Atlanta area forecasts its summer peak to rise by 40% in 2030, partly because of AI data center growth (Fig 2).



2. Peak-load forecasts are spiking, prompted by growth in AI data centers, as data for Georgia Power show. Note the dramatic change in peak demand after nine years of little growth

OEM circle dance

The big story with OEMs is the spinoff of Vernova from GE, Axford noted, which was completed Apr 2, 2024. This didn't seem to affect LM2500 market activity, although the Siemens SGT-800 is "clobbering" the LM6000 overseas. MHI and Siemens are focused on their heavy frame machines; Siemens has had zero orders for aeros, MHI "hardly any sales." Echoing Brough from earlier, "it was a great year for the LM2500."

Axford also supported Brough's comments on the large gas-turbine market. Siemens and MHI were numbers one and two, respectively, for large turbine orders over the last two years. While GE has captured 95% of the aero market, the OEM has "lots of work to do to win back market share" in large units.

Next, Axford offered thumbnails of others in the aero market:

- ProEnergy is selling new LM6000 gensets on a turnkey plant basis (GE Vernova sells only the engine) and is repurposing overhauled CF6-80C2 aircraft engines as the PELM6000, while also manufacturing parts for this machine.
- Wattbridge, a ProEnergy affiliate, owns and operates 50 LM6000 gensets at various plants serving the Houston area. Axford coyly notes that ProEnergy's service shops overhaul LM2500 and LM6000 machines, "shops not authorized by GE, but by users."
- Dynamis Power Solutions will sell

you a trailer-mounted LM2500 package you can move from site to site, AMP (Accelerated Mobile Power) Solutions will lease same.

- Relevant Power Solutions also sells LM6000 and LM2500 trailer-mounted units (a/k/a TM2500).

A wild card in the market, according to Axford, is Wartsila, not a GT supplier, by selling a 24-MW reciprocating-engine genset to customers who traditionally buy aeros and have LM6000s. Several of the recent customers for this engine, notes Axford in a slide, are competing in two-minute-start balancing markets.

The envy of the world

The diversity of US power supply is "the envy of the world," says Axford. In order to keep it that way, Axford suggested that the industry needs to answer the question, "What is the optimal percentage of renewables?" By his account, that number is 30% to 40% if you want to balance the trifecta of reliability, sustainability, and affordability. Says a speaker who, in his opening remarks, likes to joke that "he identifies as a turbine" today, the renewables percentage is already at 26% (solar, wind, hydro).

Although the US is gunning for "net zero by 2050," he notes that 80% of the world's population is "not playing a role" countering global climate disruption. For example, in 2022, China approved the addition of 106,000 MW of new coal plants to its grid.

As for a fuel that many expect to play a large role in net zero, Axford asks "why do we even talk about hydrogen?" In his mind, it can't compete with natural gas. There may be some blending of 10% to 15% H_2 in pipeline gas, and some niche plant projects, but he doesn't think it will play a significant role in the US. Anyway, electric utilities strongly prefer battery storage paired with renewables to meet the net zero challenge. Perhaps think of hydrogen as the IGCC (integrated coal gasification combined cycle) of the power industry's future.

EVs: Kong vs Godzilla?

Tesla is the world's most valuable (by stock-market value) auto manufacturing company, Axford noted, as he delved into his last market-impacting trend, growth in the electric vehicle (EV) market. However, China's BYD, selling EVs at half the price of Tesla, is closing in and could be the market share leader by the end of the year.

This is important as Tesla is selling to the dwindling "wealthy buyer," early-adopter market, while BYD is ready to build low-cost manufacturing plants in Mexico to serve North America. Brakes on the market include the observation that "EVs are piling up on dealer lots," and that EVs have gotten some bad press for performance during winter storms.

While China dominates in processing lithium and has a tight grip on the market for EV batteries, large lithium deposits are being found and developed in the US. "2023 was a great year for grid-scale batteries, the fastest growing segment of the market," Axford concluded, with Texas and California leading in installations.

Form Energy's iron-air (reversible rusting technology) long-term battery storage solution, at 100-MWh an order of magnitude larger than current offerings, has attracted orders from at least four major utilities. It is reported to be 90% lower cost than lithium-based options.

A rosy 2024

Axford ended his presentation on an upbeat note, anticipating that US gas-turbine orders will be up by 7% to 10% over 2023 (though not matching 2022's banner year), largely driven by electricity demand in the AI sector. However, he cautioned that excessive lead times may inhibit follow-up orders. CCJ

AES Levant Power Plant

Owned by AES Corp, Mitsui, and Neberas Power

Operated by AES Levant Holdings BV Jordan

250 MW, tri-fuel peaking facility consisting of 16 diesel/generators located in Al Manakher, Jordan

Plant manager: Feras Hammad

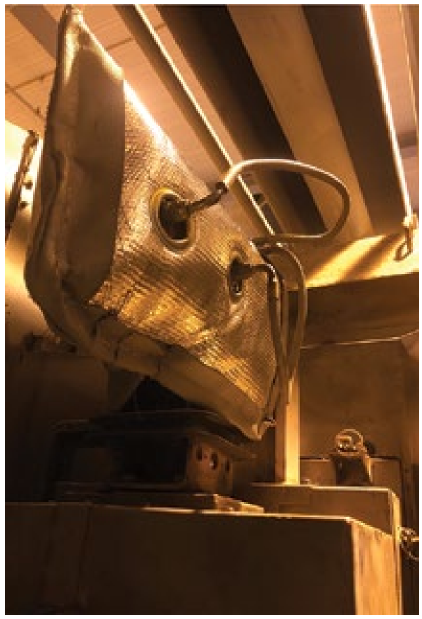
Protect waste-gate actuator from heat damage

Challenge. Function of the waste gate is to control the air/fuel ratio when burning natural gas in the peaking plant's diesel engines. Problem faced by plant staff: The waste-gate actuator (Fig 1) was prone to a controls failure caused by heat coming from a damaged bellows near where the waste gate is located.

Solution. Insulate the waste-gate actuator from the heat coming from the engine's exhaust-gas system. Do this by designing and fabricating an insulation jacket designed for use at up to 500F. Final step: Cover the waste-gate device with the fabricated jacket (Fig 2).

Results. Project goals of reducing maintenance man-hours and cost, and improving plant availability and reliability, were achieved. The saving during 2022 was about $28,000.

Project participants:
Amer Manaseer
Mohammad Abu Hayja



2. Thermal insulation to protect the waste-gate actuator

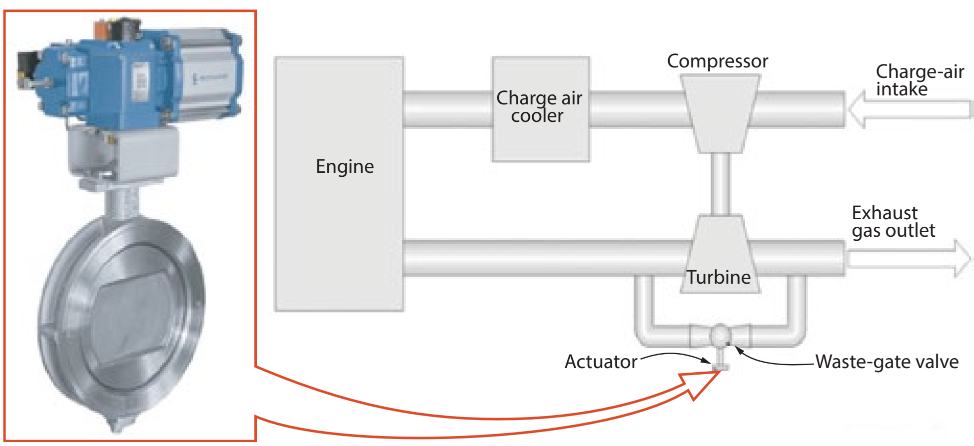
Isolate SCR control-air system to prevent a plant trip

Challenge. The 100-psig control air system for Levant's SCR is equipped with several leak-prone flexible rubber hoses. Should a leak occur, the plant could be at risk of tripping offline because of low control-air pressure.

Solution. Several possible solutions were evaluated for the effort involved in their implementation and effectiveness. The alternative selected: Install a shutoff valve with a pressure switch in the compressed-air pipe feeding the SCR system to cut off air at the SCR if leaks occur in the system. Keep a sufficient amount of control air flowing to keep the plant running smoothly until permanent repairs can be made.

Results. Saving in 2022 was estimated at $16,000, more than twice the $7700 cost of the improvement.

Project participants:
Mazen Alamro
Mohammad Jaradat
Ibrahim Arori
Ahmad Bani Hani



1. Controls for waste-gate actuator were compromised by leakage of hot exhaust gas

No instructions for servicing fuel-oil injectors, no problem

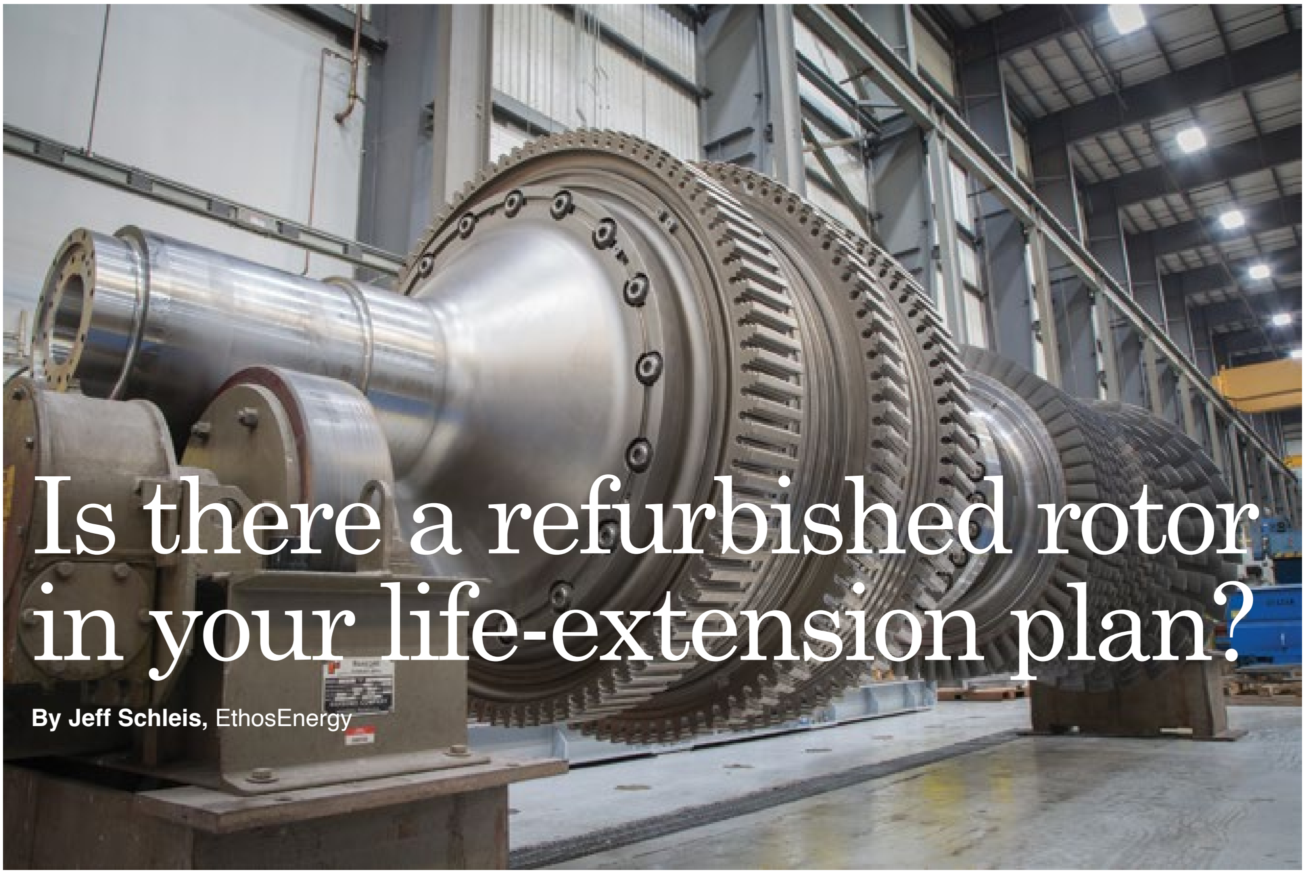
Challenge. Fuel-oil injectors on Levant's recip engines were failure-prone. There were several reasons for the poor performance, but the problem facing plant personnel was the absence of service instructions from the manufacturer. Undaunted, staff set about developing a project to reduce maintenance and shipping costs.

Solution. Several steps were involved: Dismantle the injectors with special tools designed and fabricated in-house, cleaning and servicing the solenoid with a special cleaner (Figs 3 and 4), bench testing the injectors more than 20 times, and verifying injector performance in the engine.

3, 4. In-house maintenance of fuel-oil injectors at Levant was highly successful

Results. All objectives were met: (1) Performance of serviced injectors was as good as that achieved with new injectors. (2) Maintenance saving in 2022 attributed to servicing injectors using plant personnel was about $170,000.

Project participants:
Dhanapalan Thangadurai
Ahmad Bani Hani
Abdullah Dabaybeh



Is there a refurbished rotor in your life-extension plan?

By Jeff Schleis, EthosEnergy

Natural-gas-fired powerplants are an essential part of our energy infrastructure, providing a significant portion of the electricity we use every day. But stricter environmental regulations and increased social pressure for a healthier environment have brought new challenges to the operation of these critical facilities.

In recent years, the energy industry has experienced a major shift toward renewable energy sources while coal-fired plants are retiring and the demand for electricity continues to increase. The massive push for cleaner energy can be observed in several ways, including these:

- Net-zero pledges. Governments, industries, utility companies, data centers, and petrochemical companies worldwide are pledging to achieve net-zero carbon emissions, aiming to reach this goal by as early as 2035, but no later than 2050.
- Restrictions on natural-gas use. As an example, some state and city mandates now ban the use of natural gas for residential consumption in new construction—a clear indication of the growing aversion to fossil fuels.
- Increased electrification. One of the major driving forces behind a predicted increase in power consumption is increasing electrification. This is visible in the growing popularity of electric vehicles (EVs) over internal combustion engines (ICEs), and the adoption of electric heat pumps for heating instead of natural gas, etc.
- Renewable incentives. Renewable sources such as energy storage, solar, and wind have become significant investment areas with incentives coming from city, state, and federal government programs.

Bridging the gap. While the majority of investment and focus in electricity production has been in renewable sources, natural-gas-fired generation still accounts for over 22% of generation globally and nearly 40% in the US (2022), with that domestic figure up from 32% five years earlier. Thus, despite the large growth in renewable energy, there is still an increasing dependency on natural-gas-fired generation.

Gas turbines are increasingly being relied upon to bridge the gap to the energy transition, as baseload generation from coal and nuclear decline. This brings serious challenges to the industry given the limited investment in natural gas amidst the push to net-zero. In broad terms, these units are being pushed to operate much differently than they have been in the past, and in the case of legacy units, being asked to run longer than their original design lives.

Among the operational challenges faced by gas-turbine owners are increased cycling, grid instability, faster startup requirements, and power price instability. The details:

- Increased cycling. The increase in variable generation from renewables and retirement of large coal-fired baseload plants requires gas-fired plants to ramp up and down, or start and stop their gas turbines, more frequently than originally designed, placing additional stress on the equipment.
- Grid instability. Utilities must still meet grid demands when renewable sources like wind or solar cannot, calling on natural-gas-fired generation to meet the demand. Additionally, renewables are vulnerable during extreme weather events, further increasing the criticality of natural-gas power generation.
- Startup requirements. Reliably starting units (including minimizing the time it takes to start up) is essential for adapting to the changing energy landscape, ensuring natural-gas standby (peaking) generation comes online in a timely manner when wind and solar generation are lacking.
- Power price instability. The volatility in power prices is closely related to the instability caused by the variable nature of renewable energy sources and their inability to provide power during extreme

weather events. Ironically, without this effect it would be difficult for many peaking powerplants to maintain profitability.

The life extension challenge. In addition to juggling the operational challenges in today's energy markets, gas-turbine owner/operators also may face critical decisions on life extension of their legacy units. Reason: GE heavy-duty gas turbines (Frames 5, 6B, 6E, 7E/EA, 7F, and 9E/F) have strict runtime limits—including total number of starts and total running hours, as outlined by the OEM in its Technical Information Letter (TIL) 1576.

Many of these units are coming to their hours or starts limit and owners face a major decision on a path forward. Should they:

- Sell or decommission the plant?
- Reconfigure the plant to adopt a new gas-turbine frame type/technology?
- Attempt life extension via rotor replacement (like-for-like swap) with a new or refurbished, grey-market turbine?

Selling or decommissioning is certainly an option, and some owners may prefer this and look to invest in renewables. However, the demand for reliable gas-fired generation is hard to ignore and is still an attractive investment. Taking additional gas plants offline only increases the burden on and challenge to those that remain.

Reconfiguration to a more efficient gas-turbine technology is attractive to some. However, the large investment also requires extensive downtime to install and make the modifications necessary (not to mention the lead time required to procure/manufacture a new unit), meaning the plant will not generate revenue for a considerable period of time.

Life extension via rotor replacement is routinely the most attractive option at the end of rotor life despite it being a significant capital investment—in large part this is because it requires the least amount of downtime if planned carefully.

The options for gas-turbine rotor replacement come down to new versus used, but not all used rotors are the same, even if they might be the same frame type and model. There are technical details to consider before a rotor swap, and in some cases, customizations will be necessary. These are among the things that a qualified engineering team should assess. Other considerations include growing lead times and increasing demand for rotors and their parts.

To address the market for rotor replacement, both OEMs and independent service providers of gas turbines have focused on providing alternative solutions to purchasing new rotors. Example: EthosEnergy, the OEM for mature Westinghouse and Fiat gas turbines, has developed life-extension solutions for GE's fleet that are flexible, depending on the desired runtime and goals of the plant.

One of these solutions, the Phoenix Rotor™, uses a "seed" rotor and replaces only the life-limiting parts defined from an extensive re-engineering effort. The remaining parts are inspected and refurbished or replaced as needed, providing a more environmentally friendly solution with up to the equivalent life of a new rotor that also meets the operational needs of the plant.

In conjunction with this, EthosEnergy has also developed the industry's first lifecycle assessment (LCA) solution for gas-turbine rotors. Created in partnership with leading scientists, the new CO_2 assessment tool provides comprehensive environmental insights across each phase of the lifecycle, quantifying the carbon and financial reductions you can make from rotor life extension compared with purchasing new.

The research has been conducted in partnership with Politecnico di Torino in Italy, where studies show carbon emission savings and abiotic depletion of up to 40% from rotor life extension.

Wrap up. Whether net-zero can be achieved by 2035, 2065, or somewhere inbetween, gas-turbine rotor life extension is certain to be a vital part of the transition, particularly in the US. Renewables will continue to make headlines, but it is abundantly clear that the vision won't be achieved without reliable production from natural-gas-fired plants as their stakeholders navigate the complex set of challenges.

About the author

Jeff Schleis, EthosEnergy's chief engineer for products and applications, is an experienced product manager with a career founded in turbine controls. Following his professional start as an engineer in the nuclear power industry, Schleis has spent more than 25 years managing products for OEMs and independent suppliers—including Woodward, GE, Siemens-Westinghouse, and EthosEnergy. He has been with the last since 2002.

A tale of two tube leaks

Tube leaks in heat-recovery steam generators certainly are not rare. CCJ has published many articles on the subject over the years—including one in the first issue (Q4/2003) that touted the benefits of full-penetration welds in HRSG tube panels to improve fatigue life.

That said, why should you read yet another article on tube leaks, these occurring in a couple of high-pressure economizer tubes at the Bouchain combined-cycle plant (sidebar below)? Perhaps because this is the world's first 9HA-powered combined cycle (COD July 2016), built for flexibility and responsiveness by highly regarded engineers at EDF and GE.

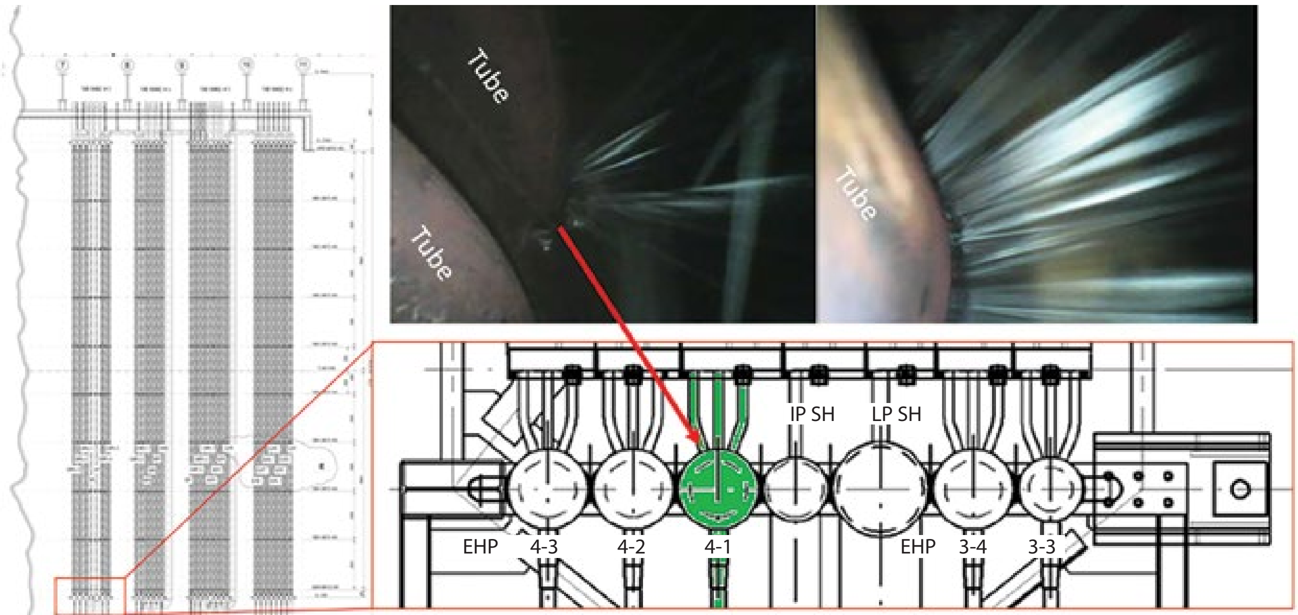
Understanding why these tubes failed unexpectedly and relatively early in the plant's life is important for making realistic decisions regarding the design of new units and the operation and maintenance of existing facilities.

Guillaume Grognet, Bouchain's maintenance mechanical manager,

Background

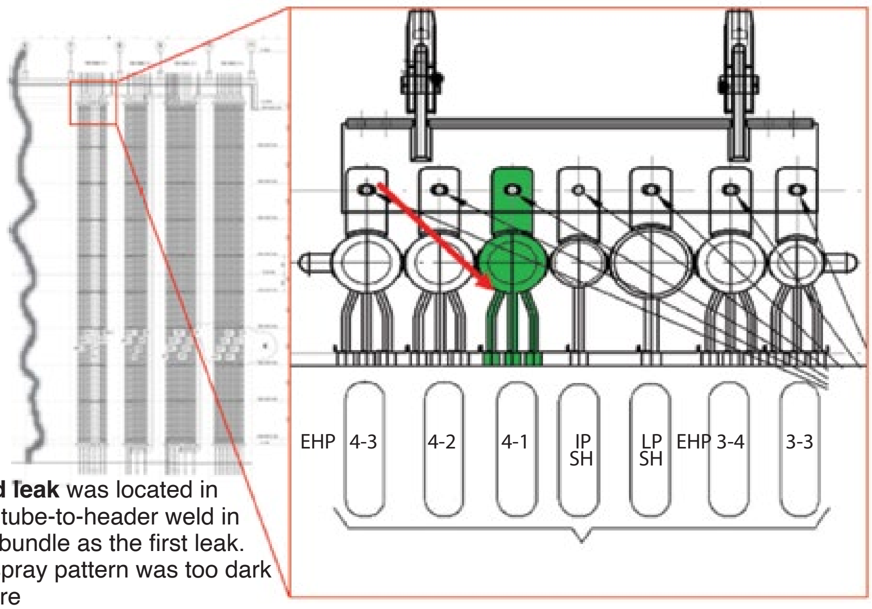
Bouchain, located in northern France, is a 604-MW, natural-gas-fired, single-shaft combined cycle operated by EDF. When commissioned in July 2016 with the first commercial 9HA gas turbine, Bouchain was touted by GE as the world's most efficient combined cycle, 62.22% according to Guinness World Records. Plus, the gas turbine was claimed capable of reaching full power in less than 30 minutes.

The power train includes a D650 steam turbine, W86 generator, and a horizontal triple-pressure HRSG from CMI. The generating unit reached 45,000 operating hours and 650 factored starts in 4Q/2023. Note that European combined cycles now are required to operate in a load-following mode and be able to accommodate major load swings.



1. First leak check performed with boiler feedwater pumps on and HP economizer full of water to easily locate the number and position of cracks as indicated by the spray patterns in the photos

2. Crack associated with the first leak is located on the root of the tube-to-header weld on the tube side. Crack length is about half the tube circumference



3. Second leak was located in the upper tube-to-header weld in the same bundle as the first leak. Photo of spray pattern was too dark for use here

shared his deep knowledge of the plant's HRSG tube-leak issue—including how the cracked tubes were found, inspected, repaired, results achieved, etc—in a technical paper you can access via the QR code provided. Grognet, an active participant in user discussions worldwide, has made himself available to answer questions from CCJ's Editorial Advisory Board (EAB, p 3).

The first leak was identified by water droplets found under an HP evaporator tube bundle during operator rounds in January 2023. Makeup flow increased dramatically over the next month or so to more than 15 gpm. The unit was shut down and a gas-side inspection conducted with feedwater pumps operating and the HP economizer full of water (Fig 1). Access to the crack (Fig 2) in a lower tube-to-header weld, and its repair, were challenging, as Grognet describes in his paper. The unit was restarted without incident.

The second leak was found 3000 factored fired hours later in the same tube bundle, but this time in an upper tube-to-header weld (Fig 3).

Access for repair was much more difficult here than in the first case. Typical solutions—(1) cut your way in, make the repair, and weld your way out, or (2) cut an access port in the header, plug the leaking tube, and restore the integrity of the header—were rejected in favor of cutting free EHP 4-3 and 4-2 and lowering those bundles to provide the necessary access. You'll want to read about how this was done.

A root cause analysis determined thermal fatigue was the primary cause of the failures, as explained in the paper.

Suggestion: As you read through Grognet's presentation, jot down your questions. The Bouchain case history is sure to generate discussion at upcoming user group meetings and you'll want to be prepared to get the information you need. The 2025 conferences of the European HRSG Users Group and the HRSG Forum (details at https://HRSGforum.com) are not far off.

Alternatively, you can email your questions to Scott Schwieger (scott@ccj-online.com) and he'll route them to Grognet or someone on the EAB who can help you.

Cybersecurity events morph from clever hackers to geopolitical actors

By James Azar, AP4 Group

While cybersecurity has been inoculated into most everyone who works in critical infrastructure, like the power industry, some may not realize that the threat vectors are shifting from clever hackers to state-sponsored malicious actors.

In 2015 and 2016, Ukrainian power grids targeted by state-sponsored actors suffered widespread power outages. The attacks, attributed to a group linked to the Russian government, exposed broader vulnerabilities within the energy sector's operational technology (OT) environments.

In 2020, a cyberattack on an Israeli water treatment facility was reportedly carried out by Iranian state-sponsored hackers. The attackers attempted to alter water chlorine levels, posing a significant risk to public health and highlighting the susceptibility of water infrastructure to cyber threats. A similar attack took place at the water plant in Oldsmar, Fla, during a Superbowl weekend in nearby Tampa. Once again, the events exposed vulnerabilities in OT control systems for infrastructure.

As geopolitical tensions continue to rise, so does the sophistication of cyberattacks aimed at critical infrastructure. Because the Russian cyber attack on Ukraine stands as one of the most significant and well-documented examples of a geopolitical cyber-event, much has been learned from it.

How it went down

The coordinated attack targeted three of Ukraine's regional electricity distribution companies, ultimately affecting approximately 225,000 customers on Christmas Eve:

- Initial compromise. The attackers gained initial access through spear-phishing emails containing malicious Microsoft Office documents. Once the documents were opened, the software installed BlackEnergy malware, a sophisticated tool used for reconnaissance and credential theft.
- Network reconnaissance. After gaining access, the attackers spent several months performing detailed reconnaissance within the IT networks of the power companies. They mapped out the network, identified critical systems, and harvested credentials.
- Credential theft. The attackers stole VPN and remote-access credentials, allowing them to move laterally within the networks and access the OT environments.
- Attack execution. Scada systems were compromised on Dec 23, 2015. The attackers opened circuit breakers at multiple substations, effectively cutting power to the affected regions.
- Destruction of systems. To delay recovery efforts, the attackers deployed KillDisk malware, which wiped the hard drives of key systems, and disabled uninterruptible power supplies, wreaking havoc on the system.
- Denial-of-Service attack. Concurrently, the attackers launched a DoS attack on the call centers of the electricity companies, preventing customers from reporting outages, impairing management's ability to respond.

General lessons

First, the attack underscored the importance of properly segmenting IT and OT networks to prevent lateral movement by attackers. Although the power industry has been focused on this for many years, there is still much to be done.

Second, the need became evident for robust incident response and disaster recovery plans that include cyber-attack scenarios—including regular drills and coordination with national cybersecurity agencies.

Third, the event drove home the need for continuous monitoring of network traffic to detect and respond to unusual activity and threats before significant damage occurs.

Finally, organizations must invest in regular training and awareness programs so that employees recognize phishing attempts, often the initial attack vector, as in the Ukraine event.

In the US, the mandate given by Congress to CISA (Cybersecurity Infrastructure Security Agency) and DOE, is serving as the playbook to help build resiliency in the energy sector. These and other agencies offer threat intelligence sharing forums to help keep powerplants informed and updated about actual threats and existing attack vectors.

What's behind it all

The emergence of Cyber Crime as a Service (CaaS) has lowered the entry barrier for committing cyberattacks. CaaS platforms offer various illicit services, from distributed denial-of-service (DDoS) attacks to ransomware deployments. These services can be purchased or rented by individuals with minimal technical knowledge. In effect, cyber-attacks can now be carried out by almost anyone, not just highly skilled hackers.

Regulatory frameworks for cybercrime are outdated and do not address the latest risks and challenges. A new legal framework should specifically address nations that harbor cybercriminals and allow them to operate with impunity. Economic and diplomatic consequences should be built into the framework, hopefully as deterrence.

Collaboration among various sectors and sharing of threat intelligence is crucial. The Electricity Information Security and Analysis Center (E-ISAC), operated by NERC, and

InfraGard, a partnership between the FBI and the private sector, both offer robust support for regional infrastructure businesses.

Bad actors know that traditional security measures are often inadequate against such a dynamic threat landscape. They simply are not nimble enough. Advanced threat intelligence and monitoring systems, falling under broad names like network monitoring, IDS (Intrusion Detection Systems) and IPS (Intrusion Prevention Systems) offer continuous, real-time monitoring.

It is well-known that the proliferation of Internet of Things (IoT) devices in critical infrastructure has introduced significant risks. IoT devices often serve as entry points for cyber threats because of their frequent lack of robust security measures. Some IoT devices provide no way for the powerplant to make network changes or change default passwords. Others introduce backdoor risks from poor coding and patching mechanisms that require additional network access.

What you can do

When scoping and purchasing IoT devices, ensure that you have the ability to change the default password, patch the device with limited or no downtime, and network and manage the device without having to change network topology. Insist on a full software bill of materials.

Conducting regular audits and penetration testing, and following industry standards and regulations, will help you identify vulnerabilities. Make sure your intrusion detection, anomaly detection, and firewall systems are specifically designed for OT environments.

Cultivate a culture of security awareness among all employees. When the water treatment plant in Oldsmar became a target during Super Bowl weekend, it was one engineer's awareness that prevented a disaster. Conduct training and drills regularly to ensure that staff are aware of the latest threat vectors and understand and adhere to best practices. Make sure you have a well-documented incident response plan in place and stress-test it regularly.

No one knows your powerplant or business quite like you. Assess your facility's weaknesses and areas of concerns. Cultivate program champions, reward great behavior, acknowledge the good, and deal with the bad as a team. Everything should be documented and organized in a binder available at multiple locations. Finally, join E-ISAC and InfraGard to gain more insights on how to defend and recognize threats to your business. CCJ

James Azar, chief information security officer (CISO) at AP4 Group, has two decades of experience leading information security and engineering teams to solve complex challenges head-on and align technology, security, and privacy to business goals. He is the host of CyberHub podcast, CISCO Talk, as well as Goodbye Privacy, a new podcast focusing on privacy concerns. The widely published Azar is a frequent speaker at industry events.

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