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COMBINED CYCLE Journal

7F USERS GROUP
2024 Conference and Vendor Fair
Marriott St. Louis Grand • May 20 - 24

PSM Asset Managers Conference
16th Annual Meeting • Jan 29 – Feb 1, 2024
Westin Ft. Lauderdale Beach Resort

HRSG FORUM
2024 Conference and Vendor Fair
Marriott St. Louis Grand • June 10 – 13

Legacy Turbine Users Group
7EA Users Group · Frame 6B Users Group™ · FRAME 5 Users Group

2024 Conference and Vendor Fair
The Woodlands Waterway Marriott • July 15 – 18

Also in this issue:

INDEPENDENT VOICE OF THE GAS-TURBINE-BASED GENERATION SECTOR

NAES names Dobler president/CEO, makes other executive appointments

NAES Corp, Issaquah, Wash, considered by many the power-generation industry's largest independent services provider, named Mark S Dobler president and CEO in early March. The company announced executive appointments at that time as well.

Many readers will remember Dobler as having served in a wide range of management positions in both the powerplant ownership and aftermarket-services sectors over the last three-plus decades. Career highlights include president of Operational Energy Corp, chief executive of Wood Group Gas Turbine Services, and CEO of EthosEnergy Group. Most recently, Dobler served as a non-executive member of the NAES Board of Directors.

Those unfamiliar with NAES (www.naes.com) might note that the company, a wholly owned subsidiary of Japan's ITOCHU Corp, is dedicated to optimizing the performance of complex industrial facilities across the traditional and renewable power-generation landscape, and other industries as well.

NAES's more than 4000 employees share deep experience in operations, maintenance, construction, engineering, and technical support to build, operate, and maintain plants to run safely, reliably, and cost-effectively, and in compliance with federal, state, and local regulations.

The appointment of Dobler as CEO was just one of several recent executive changes at NAES, Charlie Hoock, SVP of energy services told the editors: "This is part of a larger strategy by NAES to further strengthen our position as the dominant force in independent turnkey services for the energy and infrastructure sectors." Continuing, Hoock said that 2023 brought "unprecedented growth" in new O&M contracts to NAES and that the company is fortunate to have the depth and talent to transition that volume of business smoothly.

As part of the company's mission of delivering best-in-class service, Hoock pointed to NAES's commitment to developing its people to assume leadership roles, as well as ensuring the company's recruiting team is on a continuous search for talent at all levels. Examples include the appointments of Bob Renaud and Anthony Ligato to VPs of O&M services. The former was promoted from within NAES, while Ligato was a client prior to joining, having served as plant director at RiverBay Energy, asset manager for Direct Energy, and as plant director for Calpine's Baytown Energy Center.

Dobler

Hoock

Renaud

Ligato

COMBINED CYCLE Journal

Editorial Staff

Scott G Schwieger
General Manager
Print and Electronic Products
702-612-9406, scott@ccj-online.com

Kiyo Komoda
Creative Director

Steven C Stultz
Consulting Editor

Clark G Schwieger
Special Projects Manager

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

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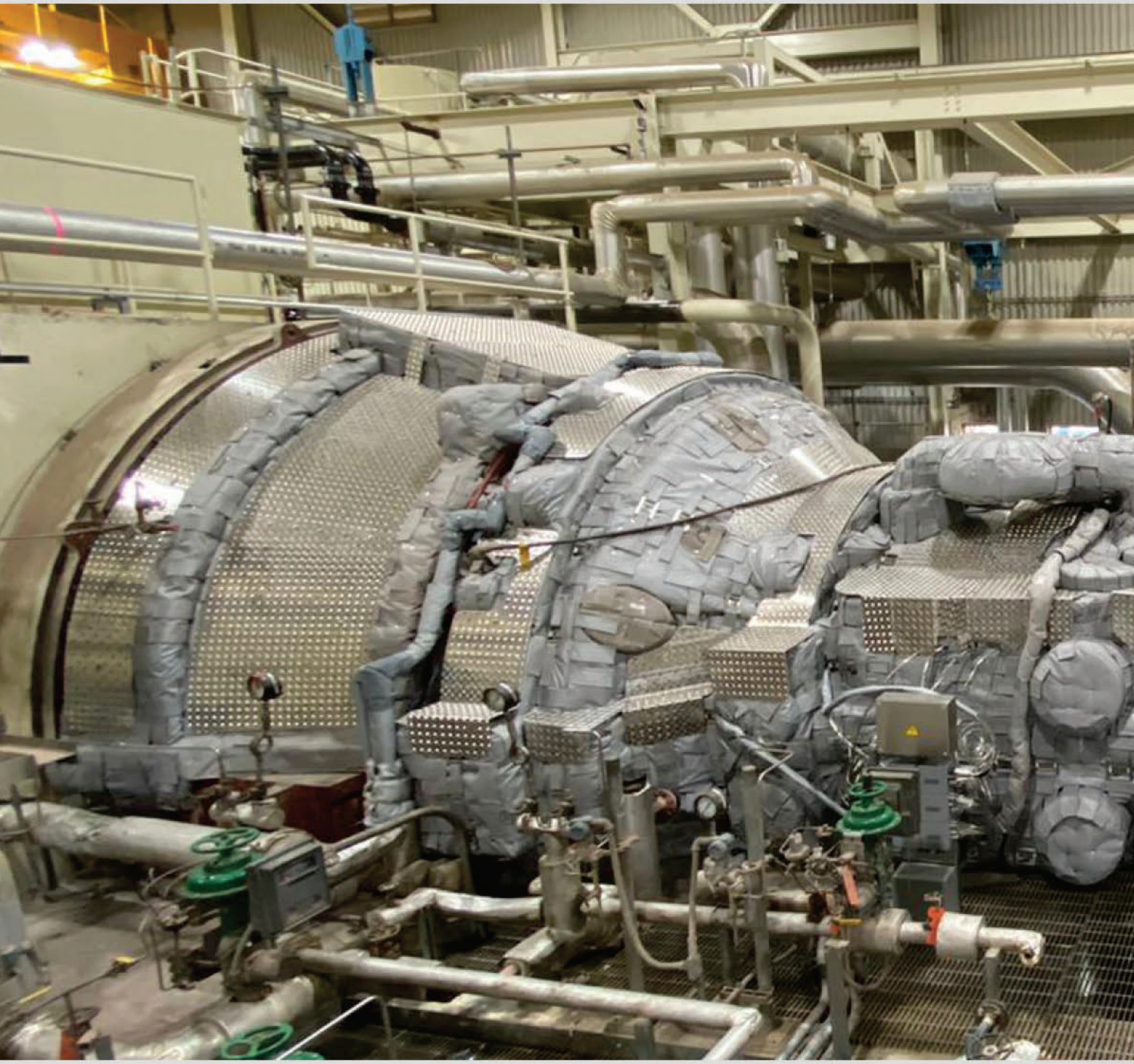
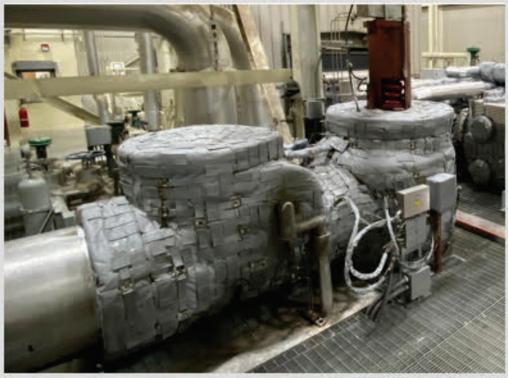
Advanced Single Layer Steam

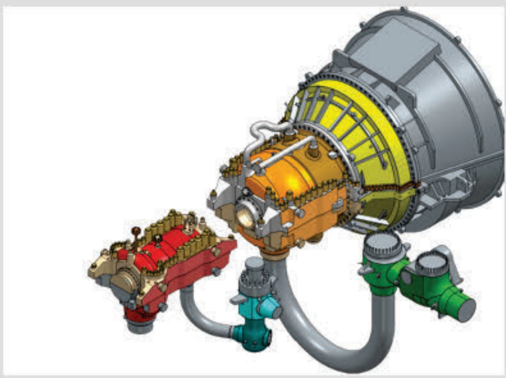


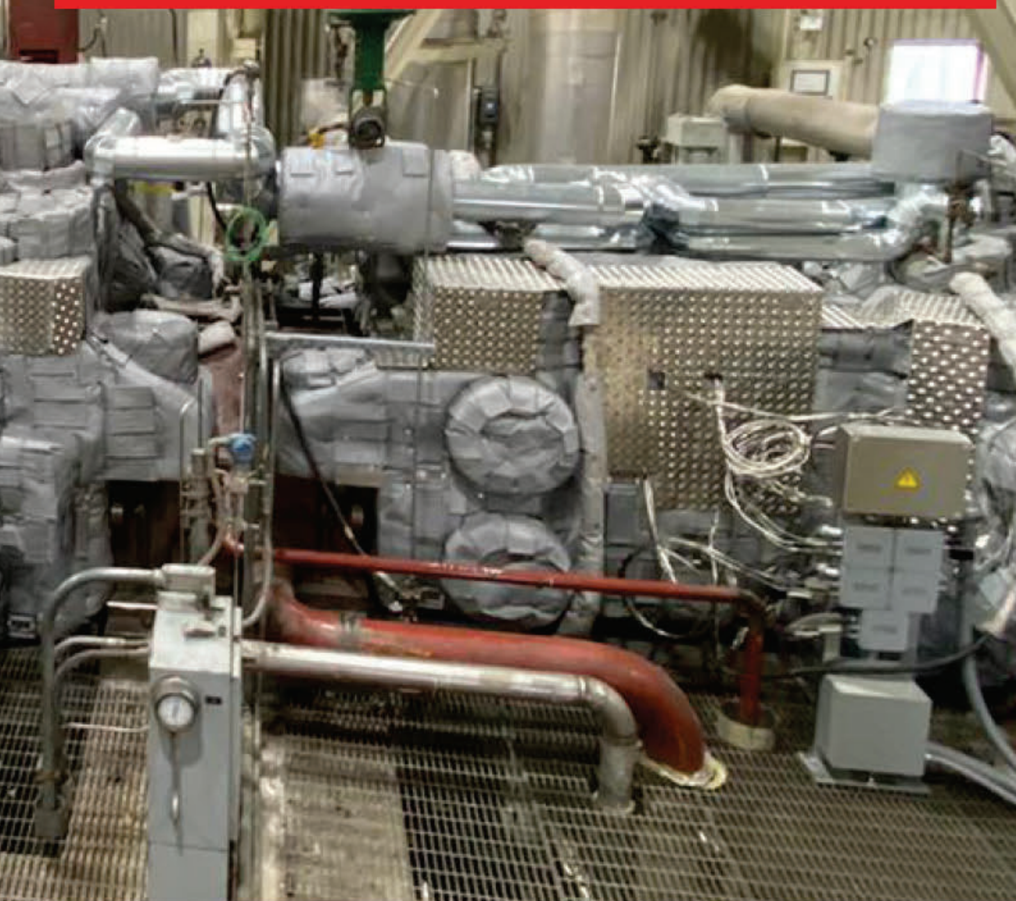
Turbine Shell Warming Systems

Advantages of the ARNOLD Steam Turbine Warming System

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







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The world's largest user organization supporting owner/operators of 7F gas turbines promises a robust in-person event when the group gathers at the Marriott St. Louis Grand, May 20-24, for its 2024 conference and vendor fair.

This year's program begins with a seven-stop tour of MD&A's turbine/generator repair facility (users only) on Monday morning (May 20), followed by lunch and an afternoon-long session of practical technical presentations by MD&A's leading engineers.

Tuesday (May 21) is dedicated to vendor presentations selected by the steering committee. The program is arranged in five 30-min sessions with four services providers presenting simultaneously in each session. Highlights of the topics covered by the vendors can be found on p 10.

The classroom programs on Monday and Tuesday conclude by 4 p.m. so attendees can participate in the vendor fair, which runs until 7. Seventy-five companies will be on hand each day to help you navigate their products and services offerings, but only a few will be available both days. Review the exhibitor lists on pages 8 and 9 to be sure you don't miss someone of interest. No need to rush through the aisles: Heavy hors d'oeuvres and open bar won't allow you to go hungry.

Wednesday is dedicated to user-only sessions with presentations and discussion focusing primarily on safety, combustion, auxiliaries, rotors, exhaust systems and components, and controls.

Thursday is GE Day.

The Friday morning session, which was greatly improved by the steering committee last year, includes both the OEM's traditional deep-dive knowledge-sharing program and two special user-only sessions—one on how to prepare for borescope inspections, the other on coupling alignment. A feature of GE's Friday program is a one-hour session on effective technical communications and how to maximize the value of the OEM's customer portal.

7F Users Group 2024 Steering Committee

Chairman: Dave Such, *Xcel Energy* (2006-2019; 2022)
Vice Chairman: Zach Wood, *Duke Energy* (2020)
Luis Barrera, *Calpine* (2014)
Sam Graham, *Tenaska* (2007-2018; 2022)
Edwin Rivera Hernandez, *Dominion Energy* (2023)
Clinton Lafferty, *TVA* (2020)
Doug Leonard, *ExxonMobil* (2020)
Justin McDonald, *Southern Company Generation* (2013)
Dan McQuade, *Vistra Corp* (2023)
Brian Richardson, *FPL* (2022)
John Rogers, *SRP* (2019)

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- Pressure waves penetrate deep into the module
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- No need for scaffolding, which makes it a safer, faster, and more cost-effective solution
- More than **300** PressureWave+ cleanings without any safety issues

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Helps ensure the reliability of your aging HRSG unit, saves on O&M costs and extends the lifetime of your plant. GE Vernova can offer replace-in-kind or tailor-made pressure parts for any HRSG.

- Restored reliability up to **98.5%**
- Reduced risk of forced outage up to **90%**
- Reduced O&M costs up to **$100k/year** (vs. repairs)
- Extend lifetime up to **25** years

THE WORLD'S ENERGY TRANSITION:

GAS TURBINES

7E Advanced Secondary Fuel Nozzle Upgrade

The 3D-printed fuel nozzle upgrade remixes air and fuel in 7E DLN1/1+ combustion systems to provide a rapid, cost effective MW boost with lower emissions and better reliability.

- Up to **37%** lower NOx emissions
- Up to **+55F** emissions-compliant peak fire
- **6-8%** greater emissions-compliant turndown

7F.04-200 Upgrade

A total-solution upgrade package consisting of an advanced compressor, gen 5 turbine rotor, AGP Tech hot gas path, DLN2.6+ combustion, and all associated accessories and controls.

- Higher output at all ambients, up to **16%** on hot days
- Up to **-3%** heat rate
- **32K** FH/**1250** starts interval
- Field replaceable blades
- Wet compression compatible

To learn more about these offerings, contact your sales representative or visit
gevernova.com/gas-power

Vendor Fair

Majestic Ballroom

Monday, May 20, 4 – 7 p.m.

Tuesday, May 21, 4 – 7 p.m.

Monday

Companies	Booth
Advanced Turbine Support	13
AGTServices	1
Allied Power Group	31
AP4 Energy Services LLC	49
ARNOLD Group	5
BBM-CPG Technology Inc	28
Bearings Plus	40
Camfil Power Systems	53
Chevron	69
Conax Technologies	74
CTTS	33
CUST-O-FAB	8
Cutsforth	42
Dekomte de Temple LLC	27
Direct Turbine Controls	66
Doosan Turbomachinery Services	50
Emerson	70
Environex Inc	64
Environment One Corporation	4
EthosEnergy	54
ExxonMobil	25
Falcon Crest Aviation Supply Inc	21
Filter-Doc Corporation	6
Frenzelit Inc	67
Gas Path Solutions	16
Gas Turbine Parts & Service Inc	65
Hy-Pro Filtrtation	60
IC Spares	56
Industrial Air Flow Dynamics Inc	20
Integrity Assessment Group (IAG)	35
Integrity Power Solutions	37
ISOPur Fluid Technologies Inc	52
ITH Engineering	9
JASC	63
K Machine	38
Koenig Engineering Inc	39
Lectrodryer LLC	57
MD&A	17
Mee Industries Inc	44
Munters Corporation	58
National Electric Coil	3
Nederman Pneumafil	29
Nord-Lock Group	61
NRG Faist Corporation Inc	18
Oilquip Inc	73
ORR Protection Systems Inc	46
Parker Hannifin Corporation	51
Pinnacle Parts and Service Corp	11
Pioneer Motor Bearing Co	19
Power Services Group	30
Power Valves LLC	10
PowerFlow Engineering Inc	43
Powmat Ltd	55
Premium Plant Services	26
Prince & Izant Company	47
PSM	12
Rapid Belts LLC	23
Republic Turbines	15
Riverhawk	59
Rochem Technical Services	71
Roper Pump Company	34
Schock Manufacturing	48
Shell Oil Products	45
Stork H&E Turbo Blading Inc	68
Structural Integrity Associates	2
Sulzer Turbo Services Houston Inc	75
SVI BREMCO	24
Taylor's Industrial Coatings Inc	7
Tetra Engineering Group Inc	32
Trinity Turbine Technology	22
TTS Energy Services	36
Turbine Services Ltd	62
Veracity Technology Solutions LLC	41
Viking Turbine Services Inc	14
Young & Franklin	72

Booth	Companies
1	AGTServices
2	Structural Integrity Associates
3	National Electric Coil
4	Environment One Corporation
5	ARNOLD Group
6	Filter-Doc Corporation
7	Taylor's Industrial Coatings Inc
8	CUST-O-FAB
9	ITH Engineering
10	Power Valves LLC
11	Pinnacle Parts and Service Corp
12	PSM
13	Advanced Turbine Support
14	Viking Turbine Services Inc
15	Republic Turbines
16	Gas Path Solutions
17	MD&A
18	Universal Plant Services
19	Outage Support Resource LLC
20	Industrial Air Flow Dynamics Inc
21	Vector Systems Inc
22	Groome Industrial Service Group
23	Metroscope Inc
24	SVI BREMCO
25	ExxonMobil
26	Premium Plant Services
27	Dekomte de Temple LLC
28	BBM-CPG Technology Inc
29	Nederman Pneumafil
30	Power Services Group
31	Allied Power Group
32	Tetra Engineering Group Inc
33	CTTS
34	Roper Pump Company
35	Integrity Assessment Group (IAG)
36	TTS Energy Services
37	Integrity Power Solutions
38	K Machine
39	Koenig Engineering Inc
40	Bearings Plus
41	Veracity Technology Solutions LLC
42	Cutsforth
43	PowerFlow Engineering Inc
44	Mee Industries Inc
45	Shell Oil Products
46	ORR Protection Systems Inc
47	Prince & Izant Company
48	Schock Manufacturing
49	AP4 Energy Services LLC
50	Doosan Turbomachinery Services
51	Parker Hannifin Corporation
52	ISOPur Fluid Technologies Inc
53	Camfil Power Systems
54	EthosEnergy
55	Powmat Ltd
56	IC Spares
57	Lectrodryer LLC
58	Munters Corporation
59	Riverhawk
60	Hy-Pro Filtrtation
61	Nord-Lock Group
62	Turbine Services Ltd
63	JASC
64	Environex Inc
65	Gas Turbine Parts & Service Inc
66	Direct Turbine Controls
67	Frenzelit Inc
68	Stork H&E Turbo Blading Inc
69	Chevron
70	Emerson
71	Rochem Technical Services
72	Young & Franklin
73	Oilquip Inc
74	Conax Technologies
75	Sulzer Turbo Services Houston Inc

Tuesday

Companies	Booth
AAF International	65
Advanced Turbine Support	13
AGTServices	1
Allied Power Group	31
Alta Solutions Inc	71
AMETEK Power Instruments	2
AP4 Energy Services LLC	49
Applied Technical Services	48
ARNOLD Group	5
Avail Bus Systems - The Calvert Company	63
Badger Industries	68
Baker Hughes	38
Brayton Power	32
CC JENSEN Inc	29
Caldwell Energy Company LLC	10
CECO Environmental	37
Chentronics	47
Chevron	69
Conval	40
CRDX - Carbon Reduction Systems	3
Doble Engineering Company	44
Donaldson	52
Doosan Turbomachinery Services Inc	50
Durr Universal Inc	7
EagleBurgmann Industries LP	58
Environment One Corporation	4
EthosEnergy	54
ExxonMobil	25
Fluitec	51
Gas Path Solutions	16
Groome Industrial Service Group	22
Gulf Turbine Services	59
HILCO Filtration	64
HRST Inc	30

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3	CRDX - Carbon Reduction Systems
4	Environment One Corporation
5	ARNOLD Group
6	Webster Associates
7	Durr Universal Inc
8	TRS Services
9	TOPS
10	Caldwell Energy Company LLC
11	Marioff NA
12	PSM
13	Advanced Turbine Support
14	Macemore Inc
15	Paragon
16	Gas Path Solutions
17	MD&A
18	Universal Plant Services
19	Outage Support Resource LLC
20	Industrial Air Flow Dynamics Inc
21	Vector Systems Inc
22	Groome Industrial Service Group
23	Metroscope Inc
24	SVI BREMCO
25	ExxonMobil
26	VOOM LLC
28	Nooter/Eriksen Aftermarket Services
29	CC JENSEN Inc
30	HRST Inc
31	Allied Power Group
32	Brayton Power
33	SG Energy Solutions
34	Kobelco Compressors America Inc
35	Iris Power
36	TesTex
37	CECO Environmental
38	Baker Hughes
39	WL Gore & Associates
40	Conval
41	Woodward Inc
42	Mitten Field Services LLC
43	REXA Inc
44	Doble Engineering Company
45	Shell Oil Products
46	Moog
47	Chentronics
48	Applied Technical Services
49	AP4 Energy Services LLC
50	Doosan Turbomachinery Services
51	Fluitec
52	Donaldson
53	Turbine Generator Advisers
54	EthosEnergy
55	Liburdi Turbine Services
56	ST Cotter Turbine Services
57	Toshiba America Energy Systems
58	EagleBurgmann Industries LP
59	Gulf Turbine Services
60	Power House Resources
62	HYTORC
63	Avail Bus Systems - The Calvert Company
64	HILCO Filtration
65	AAF International
68	Badger Industries
69	Chevron
70	Precision Iceblast Corporation
71	Alta Solutions Inc
74	Vogt Power
75	Sulzer Turbo Services Houston Inc

Technical program at a glance

Editor's note: Presenter names, times, and meeting rooms are as of April 20 and subject to change. Please check at the registration desk for current information.

Monday, May 20

8 a.m. – noon, Tour of MD&A's turbine/generator repair facility

1:30 – 4 p.m., MD&A session

Presentations:

- 7F outage planning and solving issues—including best practices, inspection requirements, parts management, and risk mitigation. *Richard Rucigay*
- Rotor life assessment with 1-2 spacer cracking evaluation—including use of a finite-element model to identify likely crack-initiation sites. An improved spacer design is offered. *Mark Passino*
- Gas-turbine parts update with wheels availability for rotor life extension. *David Fernandes*
- 7F component life extension with 7F.04 repair development. Covers the typical limiting factors of 7F engine components and how they can be repaired. Case studies are included. *José Quiñones PE*
- Step-iron liberation from a 7FH2 generator (case history)—including details of the inspection process and repair method. *James Joyce*
- Controls strategies for life extension.

4 – 7 p.m., VENDOR FAIR

Tuesday, May 21

8:45 a.m., Vendor solutions 1

- TFH2 generator "minor" outages: What can you see? What can you do? *AGT Services, Jamie Clark*
- Fuel nozzle repair and innovation, *Allied Power Group, Jeremy Clifton*
- 7F flex seal expansion-joint solutions, *Dekomte de Temple, Jake Waterhouse*
- Engine-ready advanced TBC for IGTs, *Liburdi Turbine Services, Josh Smeltzer*

9:30 a.m., Vendor solutions 2

- How to run inlets during extreme events, *Donaldson, Bob Reinhardt*
- Achieve overhaul-to-overhaul reliability with the right advanced oil analysis, *ExxonMobil, Jim Hannon*
- Enhancing outage efficiency and reliability through owner engineering expertise, *Gulf Turbine Services, Joe Mitchell*
- GT rotor-lifting risk associated with cyclic and load-swinging operation, *Structural Integrity Associates, Matthew Ferslew*

10:15 a.m., Vendor solutions 3

- Rotor life extension: Understanding new benefits and design, *EthosEnergy Group, Jeff Schleis*
- Understanding the impact of BOP equipment on liquid-fuel-system reliability, *JASC, Schuyler McElrath*
- Generator stator endwinding vibration operating deflection shape confirms global resonance, *Qualitrol—Iris Power, Aaron Doyle*
- Interpreting borescope reports: 7F gas turbines, *Turbine Generator Advisers, Jason Neville*

11:00 a.m., Vendor solutions 4

- Generator monitoring, *Environment One Corp, Christopher Breslin*
- GTOP4 and FlameSheet™: An alternative to advanced OEM solutions, *PSM, Kevin Powell and Katie Koch*
- Developing a tactical plan for turbine lubrication lifecycle management to mitigate varnish formation, *Shell Oil Products, Chris Knapp*
- Navigating F-class rotor end-of-life, *Turbine Generator Advisers, David Bitz*

11:45 a.m., Vendor solutions 5

- Performance evaluation and instrument calibration, *ap4, John Downing*
- Effects of GT operational changes on HRSG pressure components (case studies), *HRST Inc, Souren Chakirov PE*
- R3 modification and upgrade options for the exhaust frame and aft diffuser, *Integrity Power Solutions LLC, David Clarida and David Yager*
- Everything 7F rotor: Upgrades, life extensions, and supply chain, *PSM, Brian Loucks*

1:15 – 4 p.m., General sessions (users only)

4 – 7 p.m., VENDOR FAIR

Wednesday, May 22

8 a.m. – 4 p.m., General sessions (users only)

Timelines for the Tuesday afternoon and Wednesday user presentations and discussion sessions had not been finalized before CCJ went to press. However, the topics to be addressed include the following:

- Trip-reduction efforts in a 7FA fleet—including determination of focus areas, single-point vulnerability, and a case study on how some findings were addressed to improve reliability.
- 7F DLN 2.6+ combustor washer distress will provide a brief overview of the RCA for the existing washer and discuss the importance of replacing it with an upgrade.
- Combustion fallout because of inner-support-ring failures.
- Finding turbine-compartment leaks.
- Chemical foam cleaning of 7FA.03 compressors fouled with minerals.
- Compressor IGV adjustments to compensate for gas-turbine operational issues.
- Issues with a non-optical flame detection system.
- Design evolution and inspection quality control of first-stage buckets.
- HMI and controls enhancement.

When you receive your conference registration packet, be sure to look through the programs for Tuesday afternoon and Wednesday. There are sure to be more topics than those listed above; plus, you'll have access to the final lineup of presentation times.

Thursday, May 23 (GE Day)

8 – 10:45 a.m., GE session (users and GE only)

Following the opening session there are four one-hour GE breakout sessions, each with three concurrent presentations. Here's the lineup:

11 a.m., Breakout 1: Combustion turbine 101, Compressor and turbine, Digital solutions.

1 p.m., Breakout 2: CT auxiliaries, Power management, Supply-chain overview.

2:15 p.m., Breakout 3: Combustion, Running my plant to 2055 (part 1), Technical dialog (NCR, ER, TIL, RCA).

3:30 p.m., Breakout 4: 7F.04-200 upgrade, Running my plant to 2055 (part 2), Controls.

Here's what each of the GE breakouts promises in terms of content:

- Digital solutions. How predictive and prescriptive analytics are leveraged to optimize efficiency, reliability, and profitability.
- Combustion turbine 101. An introductory session covering powergeneration and CT fundamentals, combustion theory, 7F evolution, Brayton cycle.
- Compressor and turbine. Latest field experience and best practices,

emerging fleet issues, TIL revisions, new PSIB/PSSB releases.

- Power management. Getting comfortable with what's happening outside the plant fence and thinking about ways to mitigate likely risks.
- Supply-chain overview. On-time delivery of parts, quality assurance, inventory, planning, etc. Rotors are a key topic in this session.
- CT auxiliary systems. Reliability improvements for auxiliaries, liquid-fuel and auxiliary upgrades, TIL revisions, emerging fleet issues.
- Technical dialog. Overview of GE's engineering-request process, field statistics, top five TILs.
- Combustion. AutoTune troubleshooting, upgrade on Axial Fuel Staging for the DLN 2.6+ combustor, emerging fleet issues.
- Running my plant to 2055 plus. What SMEs think your plant should be considering for the coming decades and the emerging stressors you may not know about.
- 7F.04-200 upgrade involves an advanced compressor to boost hot-day output and other improvements.
- Controls session includes a fundamental model-based control education with practical troubleshooting.

Friday, May 24

This half-day program encompasses five hour-long sessions, some of which run concurrently. Two segments are sponsored by Power Users, three by GE. Here are the details:

Power Users sessions:

- 8:30 a.m., Borescope preparation and information sharing reviews lessons learned and provides guidelines for a successful inspection.
- 11:00 a.m., Coupling alignment focuses on the methodology and lessons learned to ensure success. A panel of users with overhaul experience leads the discussion.

GE sessions:

- 8:30 a.m., Combustion turbine 401 is an advanced session for users focusing on real-world examples shared by highly experienced colleagues. Controls philosophy is part of the planned discussion.
- 9:45 a.m., Winterization and liquid fuel examines equipment failures caused by cold weather events and how to avoid problems in the future. A focus of the discussion is reliability improvements for liquid fuel systems.
- 11:00 a.m., Customer portal and technical communication reviews portal navigation and provides assistance to users having specific problems. Turnaround time for proposals also is on the program.

7F USERS GROUP

Seasoned owner/operator personnel tackle the biggest industry issues

The depth and breadth of experience represented by 11 owner/operator presentations at the 2023 7F Users Group Conference can be summed up like this:

- Chronologically, they represent machines dating back to the original F-class gas turbines (GT) off of the test stands in 1988.
- Numerically, these users are responsible for at least 150 7F units, maybe closer to 200.

The presenters themselves are some of the most seasoned experts in GT operations and maintenance in the nation; many are names familiar to the GT user group community. Topically, the presentations can be grouped as follows:

- Two deep dives into specific compressor issues.
- Two deep dives into specific combustor issues.
- One addressing myriad control system issues.
- One discussing the exhaust end.
- One on turbine-bucket creep failure.
- A primer on the latest 7F combustor system (the DLN 2.6+).
- One on a fuel-gas stop/speed ratio valve actuator.
- Two "system" presentations on lifecycle management and R&D aspects.

At the risk of sounding like a late-night Ronco commercial, don't delay. After reading the high-level summaries presented here, go to www.powerusers.org and look at the slides, available for viewing to members of Power Users (non-members will have to apply and be approved by the leadership). If you are responsible for 7Fs in your fleet, the editors believe you'll be glad you did.

User presentations

Beware shrouded S17 blades

An owner/operator representative with 15 7F units dating back more than 30 years described the company's strategy for replacing, upgrading, and enhancing the compressors in the fleet and subsequent operating experience. The program began in 2009 and the last of the simple-cycle units is expected to be completed in 2025.

Others with or eyeing shrouded contoured S17 blades as an enhancement, take note. The presenter's conclusion is succinct and blunt: The enhancements went smoothly and performed well except for the shrouded S17s. Two units experienced pressure-side root rubs in the S17s, which subsequently had to be "surgically removed and replaced."

Execution lessons learned include making sure to use the right gages (taper versus feeler) in the right places when collecting all the necessary data, walking down the rotor transport route as each site is different, and managing expectations on the condition of a "just in time" rotor in layup.

Addressing T-fairing distress

Described in TIL-2212, T-fairing is a circumferentially loaded platform on the compressor rotor that has an inner flow path between R1 and R2 and R2 and R3 under the tips of variable stator vanes (VSV) 1 and 2. An expert for an owner/operator with a fleet of over 50 7F machines noted the general concerns: VSV tip rubs and liberated material, circumferential gaps and T-fairing shingling leading to rotor imbalance, compressor blade platform damage, and rotor/wheel dovetail slot wear.

The presenter noted that the three TIL revisions to date, the most recent in August 2022, express a progressive level of urgency to address this issue. Recommendations to mitigate the original T-fairing operational risk include:

- Borescope inspection (BI) as specified in the TIL to inspect for VSV tip loss, excessive gaps, and wear/rubs.
- Monitor units even more closely if equivalent turning gear (ETG) hours are greater than 15,000.
- Monitor T1 and T2 seismic vibrations; alarm at 0.50 in./sec, runback at 0.82 in./sec, and trip at 1.00 in./sec.
- If T1/T2 alarm is triggered via step change, inspect at next opportunity and suspect T-fairing shingling or hard rub.

When replacing T-fairing, ensure lockers did not migrate or disengage per TIL-2391: Torque-check exposed lockers (four per stage) in R3-R6, and BI R7-R14.

Results with DLN2.6+ with AFS/OBB

An owner/operator with 32 7F machines in its fleet reported on turndown performance after retrofitting four FA.04 units at one site, between 2020 and 2022, with dry low NO_x (DLN) 2.6+ combustion hardware along with axial fuel staging (AFS) and overboard bleed (OBB).

While all of the machines met or exceeded their performance guarantees (numerous graphs provided), the user did underscore effusion-plate cracking found during a spring 2023 BI after 25,000 fired hours affecting 14 of 56 combustor cans. The OEM plans to modify the area with thermal barrier coating (TBC) per TIL-2292 at the next hot-gas-path inspection (HGPI).

Separately, the speaker noted that limited tuning capability on the part of the OEM's service team for this new technology led to 12 schedule modifications. Up to 12 days were required to tune each 2 × 1 block.

Other lessons learned: Ensure outside instrumentation is heat-traced (a compressor discharge pressure transmitter for the AFS froze up and kicked out AFS operation); ensure that the SSO (safety shutoff) valve blank is removed (caused a two-day delay getting back online); check for looseness in the AFS damper (one-day delay for inspection and tack welding); and have a backup emissions analyzer available.

Combustor end-cap failure RCA

You'll have to check out the slides to experience the "perfect storm" which led to a catastrophic failure in 2023 of combustor end caps following a flange-to-flange replacement in 2022 of an unflared 7FA.01 (with 181,000 fired hours) to a flared 7FA.04 with DLN2.6+ and AFS.

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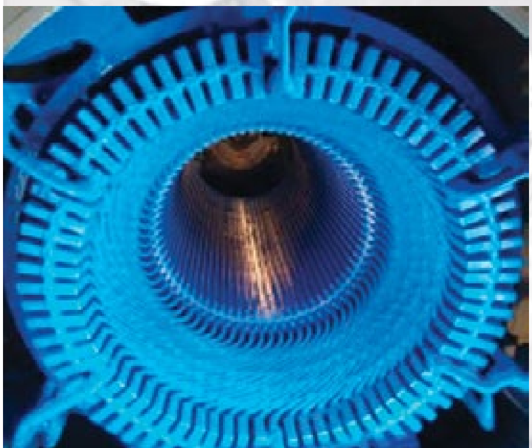

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Stator Rewinds

- Winding cycle times expanding
- Backlog of existing winding production grows
- Consider purchasing bars for stock

VPI'd Stator Owners

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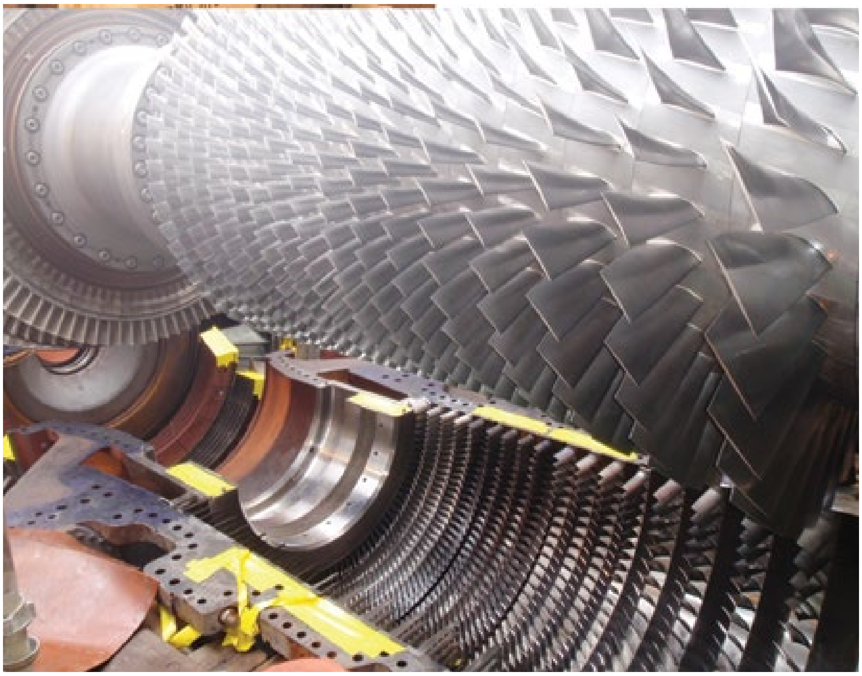
AGTServices is currently looking to purchase a new or used, operational or in need of TLC, GE Schenectady-built 7A6 air cooled generator field. Please contact Jamie Clark.

jclark@agtservices.com

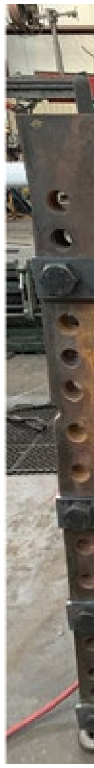
Open discussion topics at 7F

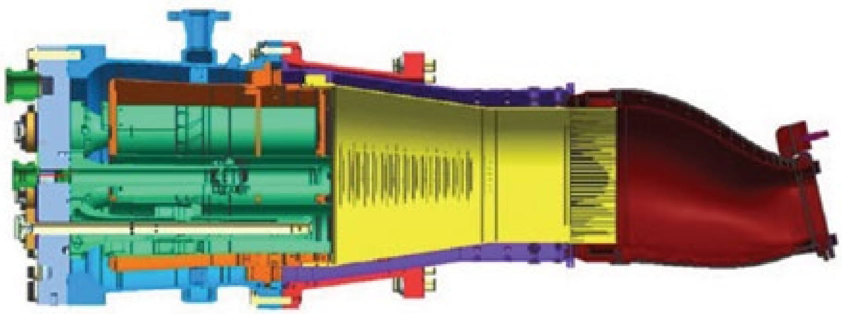


Compressor rotor enhancements

Borescope inspection for VSV tip loss

Failed combustor end caps





Upgrading combustion hardware to DLN2.6+

Coke prevents fuel flow after burning diesel oil

Some of the elements in the storm were the result of what the presenter called "downgrades" from the replacement (as opposed to "upgrades")—such as switching the control system from Ovation to Mark VIe and changing the tuning option from manual to the OEM's Autotune MX.

As recently as October 2022, a BI turned up no significant findings on the unit. The presenter's frustrations with the OEM are also clear in the slides, especially when poking fun at the OEM's euphemisms and obfuscating language. Reportedly, the OEM was essentially no help during the short-term recovery of the unit after this catastrophic failure; site personnel had to figure stuff out on their own. As for a long-term solution, a new TIL to fix the bugs in Autotune, which disregarded the high dynamics (a key part of the "storm"), wouldn't be available until fall 2023.

Cornucopia of controls issues

One of the industry's leading user experts on GT controls reviewed myriad issues, some associated with TILs, but also controls associated with emergency bearing-oil pumps and lube-oil seal-pump starter failures; liquid-fuel purge systems; non-optical flame detectors; high turbine-compartment temperatures; compressor-bleed-valve drain lines; modified exhaust-temperature-spread monitoring in EMS2100, Mark VIe TTUR card (associated with the primary trip terminal board) failure associated with generator synchronizing out of phase; and compressor discharge temperatures.

Robust exhaust replacement

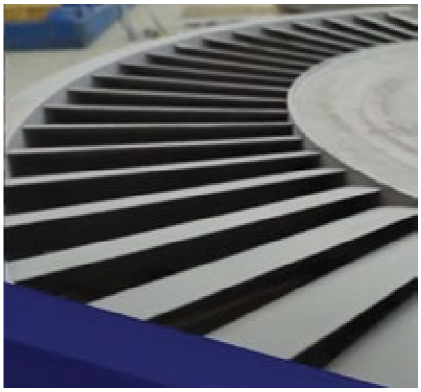
These slides offer a pictorial view and chronology of an exhaust-system replacement at a 2 × 1 combined-cycle facility. Drivers for the project included exhaust liner cracks, flex-seal failures, horizontal joint separation, high exhaust-frame-blower amperage readings, and frequent exhaust-frame-blower motor change-outs over the five years before the project. Solution was to replace the back end with the OEM's "Robust Exhaust Upgrade."

Post-installation photos are included of both units, one after 1500 hours and 15 starts, and the other after 19,000 hours and 70 starts. Graphs show that the blower motors are operating generally below the threshold of high amperage. One caution: Be sure to thoroughly check that no insulation is missing if you are planning one of these replacement/upgrades.

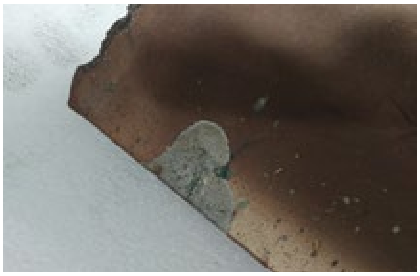
Fleet R&D activities

A representative from the Electric Power Research Institute (EPRI) identified and expounded upon areas where R&D is being conducted on behalf of all EPRI member fleet owner/operators.

Exhaust refurbishment in the field

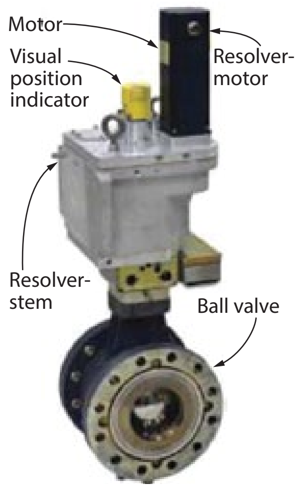


Additive manufacturing improves cooling of first-stage vanes



Impact damage/cracking to turbine S2B airfoils

Reduced component lifetimes concern owner/operators



SRV issues cause multiple engine trips

Damage caused by acoustic dynamics

Examples offered of R&D projects with "proven value" include the following:

- Using EPRI's digital-twin technology for managing regular maintenance activities and enhancing GT dispatch.
- Balancing operational risks from power augmentation with market opportunities to sell additional power during high-price periods.
- Providing guidance on overall quality control and assurance during major planned HGP outage activities.
- Applying additive manufacturing to enhance first-stage vane cooling and overall engine performance.
- Applying process component resonance (PCR) testing to validate repairability of second-stage turbine blades.
- Demonstrating 20% to 40% hydrogen blending in LM6000 and 501G units.

Second-stage-bucket creep failure

A metallurgist for one of the largest fleet owners in the US analyzed the March 2022 failure of 7FA.03 second-stage buckets in a combined-cycle unit with commercial online date (COD) of 2007. The failure occurred after a shutdown on abnormal vibration following 22,300 hours and 95 starts since the last HGPI in November 2018. A subsequent BI showed S3B material liberation but no evidence of foreign object damage.

Further inspection revealed SB2 degradation on 92 10-hole (cooling) blades supplied by a third party, including airfoil impact damage/cracking on 14 blades, shroud damage on 89 blades, missing leading-edge shrouds on four blades, and shroud cracking on 85 blades. Regarding the SB3 row, all blades lost shroud area, but there was no noticeable root damage or fractured, heavy impact damage.

Fourteen of the third-party S2B blades were compared to original OEM blades and it turned out that airfoil and tip shroud geometries were not placed in the same position and bucket tips were lifted significantly. Six S3B blades similarly compared were consistent except one blade showed localized differences because of bending from impact damage.

Overall, there was "strong evidence" of creep damage in the S2B shrouds and no noticeable evidence of creep damage in the S3B shrouds. Site-to-site comparisons of operating data revealed that the failed unit runs relatively hotter than the other 7F.03s in the user's fleet—similar to Dot 04s in fact, based on historical exhaust temperature data. Long-term solution was to replace the S2B rows of blades

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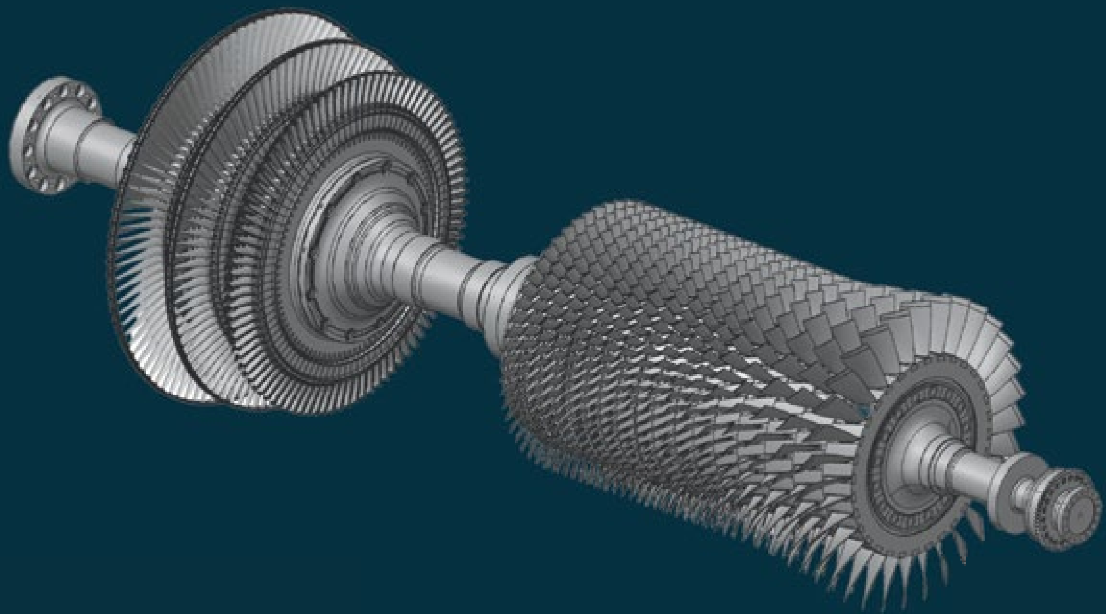

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with ones of OEM design.

Component lifecycle management

While these slides act mostly as prompts for a facilitated discussion with the audience, they do offer insights into what is keeping this owner/operator GT expert up at night. In particular, as components approach end of original expected life, there is competition for supply of new parts and shop refurbishment space.

Meanwhile, additional lifecycle issues continue to be discovered, putting additional pressure on fleet owner/operators. Another complicating factor: OEM TILs and bulletins go through many revisions. The presenter cited GER 3620, now on revision P (2021).

If you and your team are trying to set an overall fleet life and refurbishment strategy, this likely is a presentation worthwhile reviewing.

Fuel-gas SRV actuator issue

At this 7FA.05 site, the safety/speed ratio valve (SRV) (with digital valve positioner DVP) tripped on a fault, then the same SRV tripped in the companion unit. The first unit then tripped twice, after the SRV was repaired, because of relay issues. There was actuator gear damage, for which the OEM is performing an RCA. The P2 cavity pressure transmitter reading was fluctuating rapidly, but once the input filtering was changed, the fluctuations were greatly reduced.

Although the site-specific details (including many control system diagrams, jargon, and acronyms) are available in the slides, the action items are probably of most use to readers:

- Have full SRV spares available, including the DVP, onsite and backup the DVP software.
- Make sure spare relays and contacts are available and *test new relays in the shop before stocking them in the warehouse.*
- Be familiar with Woodward diagnostic tools and software.
- Lubricate actuator and stroke valves periodically.
- Monitor deviation between valve command and feedback.
- Review alarming strategy and configure additional signals if necessary.
- Review P2-cavity pressure-transmitter signal input filters and adjust as necessary.

DLN2.6 system tuning

This user presentation with over 50 slides is essentially a primer on the DLN2.6 combustion system. Broad topics covered include an introduction to fire and flames, fuel gas system and combustion components, control variables and terminology, DLN modes and startup sequence, acoustic dynamics, emissions, DLN2.6 tuning, and overview of DLN2.6+ and AFS.

Vendor presentations

Gas turbines

Gen 2 combustor-cap effusion plate design is said to have a service life of 48,000 hours and 1800 starts (Fig 1). It takes advantage of the vendor's stated unparalleled repair experience with liners, transition pieces, and caps over 18 years. Expansive design details include new materials, new cooling-hole dimensions, more closely spaced outer-diameter holes, changes to lip height, and others. Slides offer a thorough review of OEM and Gen 1 designs and operating history. Presenter challenges the notion that the OEM's Technical Information Letter (TIL) recommendation to include a thermal barrier coating (TBC) to the part will always solve problems.

Design and Development of a DLN 2.6 Combustor Cap Effusion Plate, Aaron Frost, APG

Flow testing of transition pieces, an "uncommon practice" in the industry, has been implemented at vendor's shop for combustion-system optimization. It can help address exhaust-temperature-spread issues, ease combustor tuning, and assist in troubleshooting. Photos of sonic and vacuum flow testing equipment are included, along with diagrams and descriptions of combustion system components.

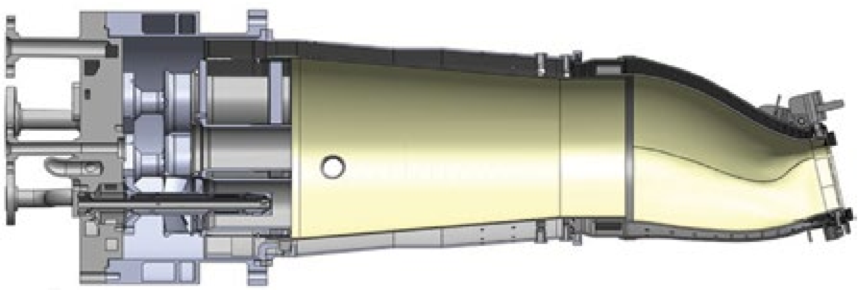
Combustion System Optimization, Jim Neurohr, Sulzer Turbo Services Inc

Single-crystal components are "fully repairable," with attendant performance improvements, and has been demonstrated through company's experience, beginning with an EPRI demonstration project. Case studies review first-stage-blade tip restoration and coating, and first-, second-, and third-stage nozzle repairs.

Gas Turbine Parts Repairs and Solutions, Jose Quinones, MD&A

Upgraded 1-2 spacers featuring 11% cyclic stress reduction are just

1. Reverse-flow DLN 2.6 combustor has many features conducive to long life based on the company's extensive field and repair experience



- A failure analysis reveals a chain of events.
- The investigation usually works backwards, chronologically, as described by the following example:
  - Cause of blade failure—fatigue
  - Cause of fatigue—resonance
  - Cause of resonance—incorrect blade dimensions
  - Cause of incorrect blade dimensions—blade bent during installation
- Multiple contributing factors may exist, that is, branches in the chain
- Multiple engineering disciplines typically are involved, such as:
  - Materials engineering (mechanism of failure, material factors)
  - Mechanical engineering (heat transfer, stress, aerodynamics analysis)
  - Human factors (training, tools, supervision)
- Root-cause failure analysis (RCA) determines the event(s) at the start of the chain(s) leading to a correctable action
- Not all failure analyses are RCAs (buyer beware)

2. What is a failure analysis?

one of several component replacement and repair options as a result of company's reverse engineering, production, and repair development programs. There are "replacement options for all problematic components," and repairs to correct disc issues, compressor dovetail cracking, first-stage-disc balance weight and groove cracking, first- and second-stage-disc cooling-slot cracking, 1-2 spacer rim cracking, and second-stage-disc lockwire-slot cracking, among others.

7FA Rotor Life Assessment with 1-2 Spacer Cracking Evaluation, Mark Passino, MD&A

Failure analysis can be a "strong learning opportunity," says the presenter of this tutorial, which is based on a chapter from a one-day course offered by the vendor. Collecting O&M data and history, conducting root-cause analysis, elements of expert witness activities, writing good reports, and metallurgical analysis and NDE techniques are all explored (Fig 2). Conclusion? An expert at failure analysis is a "bad-ass miracle worker."

GT Failure Analysis, Doug Nagy, Liburdi Turbine Services Inc

Exhaust noise at a simple-cycle GT site is addressed in a case study including problem definition, site engineering (noise study, vibration testing, and thermography), modeling, engineering solution, and evaluation of performance, which proved to be better than predicted. The 9 × 9 bar silencer array and modified turning-vane set subsequently installed also reduced total pressure loss by 0.5 in. H_2O.

Dynamic Case Studies on Turbine Exhaust Systems—Gas Path Upgrades, Scott Schreeg, SVI Industrial

Managing end-of-life (EOL) rotor issues requires at least a two-year planning cycle, maybe three, if you have one of the 400 7F units installed between 2000 and 2004. Reason: A hundred of those rotors will need major service or replacement over the next few years. Presenter covered many life evaluations, upgrade packages, and replacement options—including complete flared and unflared offerings—as the industry struggles to handle the volume of 7F EOL needs.

Managing the 7F Rotor Wave with Ingenuity, Brian Loucks and Katie Koch, PSM, a Hanwha company

3. Tube leaks can happen anywhere in an HRSG—superheaters, evaporators, economizers, preheaters, etc. There are many causes—including chemistry issues, overheating, poor fabrication practices, wear and tear, etc. Presentation focuses on tube-leak repairs by plugging

Hypothetical nighttime emergency trip at full speed/full load is imagined to illustrate how company can work with a customer after the borescope inspection reveals heavy compressor damage. Simulated failure situation steps through mobilization of field service crew, preservation of evidence, on- and offsite activities, in-shop rotor evaluation, client reports, repairs/coatings, replacement parts and manufacturing, rotor balancing, root cause analysis, materials evaluation of failed components, and rotors and components successfully returned to site and put in service.

A Bump in the Night, Jim Neurohr, Sulzer Turbo Services Inc

Options for extending unit turndown to remain relevant during the market transition from fossil fuels to non-carbon energy sources are explained. Options are anchored by the vendor's Ecomax® software, including the integration of inlet-guide-vane (IGV) angles with an inlet-bleed-heat (IBH) engineering upgrade. Interestingly, investment attitudes, based on a popular annual survey of executives, around solar, wind, and storage dropped significantly between 2021 and 2022, while natural gas grew three percentage points.

Turndown or Shutdown? Combatting the Effects of Increased CCGT Cycling, Jeff Schleis, EthosEnergy Group

Fleet issues with exhaust frames are described and enumerated, along with company's upgrades for the flex-seal retention assembly, L seal monoblock, parting joint, and airfoil and insulation packages. Replace, refurbish, and repair decision methodologies are illustrated with several case studies.

7F Exhaust Frame R3 Modifications and Upgrades: 2023 Update, David Clarida, Integrity Power Solutions

Upgraded or repaired liner plates in transition ductwork between the turbine exhaust and HRSG can be provided along with exterior (for example, thermography) online, and interior offline, inspections to identify problems and failure areas. Also discussed are services around compliance with the ASME Power Piping Code for high-energy and covered piping systems. Expansion joints, HRSG pipe penetration seals, and HRSG inspection and performance analysis complement vendor's portfolio of services.

I.A.F.D. Services Group

Water-repellent air intake filters made of synthetic materials are now available from company which has been exclusively supplying one major GT vendor since 2019 and now has special agreement for the US market beginning 2023. Data from case study of an F-class unit in a coastal wet/foggy northern European plant supports claims of better performance. Other company capabilities: acoustics, wet compression, evaporative coolers, chillers, and anti-icing systems.

Gianluca de Arcangelis, NRG-Faist

HRSGs

Fouling of HRSG tubes, contributing to higher turbine exhaust backpressure adds risk for machine trips and runback during cold-weather operation, which has been under the regulatory microscope in recent years. Actions for preventing gas-side fouling are presented, with a caution not to ignore baffles, relatively inexpensive and often overlooked. Expert examines six topics which, when addressed together, can restore up to six megawatts of output.

Improving HRSG Efficiency with Operational and Design Modifications, Cesar Moreno, HRST Inc

HRSG tube-plugging options are worthy of consideration because "tube leaks happen" and often it is necessary to get the unit back online quickly (Fig 3). Generally, though, you should strive to fix the leak and seek to identify and address the cause. Slides run through the typical causes of tube leaks with plenty of detail on four tube plugging options, attention to ASME Boiler & Pressure Vessel and National Board Inspection Codes; and pros and cons of plugging. Always insist

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on a documented repair plan before beginning a plugging project and be sure to stock tubes and plug materials at the plant.

HRSG Tube Plugging Strategies to Simplify Tube Leak Repairs in Aging F-Class Units, Lester Stanley and Rich Miller, HRST Inc

4. Steam-turbine warming dramatically reduces unit startup time. Here technicians install removable heating panels on the upper portion of the turbine casing

5. Complete stator replacement in two steps: Slide damaged stator off its foundation and onto a trailer (left) and slide new stator onto the foundation (right)

1. Plan to start and finish any flange in a given shift.
2. Studs and flange should be at the same temperature.
3. Measurements should be to within 1 mil and recorded on sheets supplied in manuals (www.riverhawk.com/knowledge-center/downloads/)
5. Measure stud in its relaxed state and again once the stud has been tensioned to its final 100% load. Measuring at 50% tension is unnecessary.
6. Coupling stud measurement verifies stud was tensioned.
7. Trust the pump gauge: Consistent pressures=consistent load in studs.
8. Do not alter pressure to obtain correct stretch measurements! Note that most variations in stretch are caused by inaccurate measurements. Inconsistent pump pressure results in uneven loading of the coupling.
9. If your measurement comes up short, re-tension a second time at 100% pressure and tighten the nut. Remeasure and verify. If the total stretch still is wrong, de-tension the stud and remeasure the initial length (cold stretch). Then repeat installation and remeasure.

6. Tips on measuring bolt stretch

Steam turbines

Warming your steam turbine and HRSG between shutdown and startup addresses fatigue issues, emissions and fuel consumption, and performance losses. A D11 case study reveals impressive results, such as combined-cycle start times improving from 266 to 149 min (Fig 4), and reduction of high-pressure-rotor life consumption by 25%. Photos and explanation of sophisticated insulation and electric warming systems for ST/Gs are provided. A beta site is being sought for a new HRSG warming system developed with EPRI. Vendor has added onsite machining services for steam valves.

Complete Cycle Solution, Pierre Ansmann, Arnold Group

Generators

Emergency purge of generator H_2 coolant can avoid catastrophic loss during fires, seal-oil issues, H_2 piping failures, and severe weather events. A photo montage of explosions reveals how serious such loss can be. Fast-purge package, including the fast degas CO_2 skid and gas monitoring and control piping, allows all purge operations to be managed from the control room via DCS or locally on HMI. System also can reduce purge times to less less than one hour.

Benefits of the Generator Fast-Purge Package on a GE7FH2 Generator, Rob Kallgren, Lectrodryer

Generator collector performance depends on consistent and adequate brush film, adequate contact pressure, proper ring surface conditions, and continuous brush-to-ring contact. Daily/weekly monitoring with minor maintenance is key. A plethora of photos document and illustrate common problems and solutions such as footprinting (also called ghosting, photographing), brush restrictions, brush-holder spacing and alignment, contamination, wear patterns and mechanisms, repair indications, collector-ring resurfacing, and vibration.

Generator Collector Performance and Maintenance, Jamie Clark, AGT Services

Complete stator replacement is reviewed as a veritable photographic journey for a unit which, in October 2020, experienced core looseness at the turbine end and broken off core laminations (Fig 5). Site involved has two 2 × 1 blocks with dual-fuel 7FA gas turbines, one block with a D11 steamer (commissioned in 2011) and the other with an Alstom turbine/generator

(commissioned in 2006).

7FH2 Stator Replacement, Shawn Downey, MD&A

General, BOP

Incorrect tightening of bolts can lead to catastrophic failure, and bolt stretch is a key factor in proper bolt tightening, because stretch is directly proportional to the tensioning force applied. A detailed list of tips for proper tightening is included in Fig 6.

Coupling-Stud Stretch Measurement Can Make or Break Turnaround Time, Dan Johnston, Riverhawk

Polyalkylene glycol (PAG)-based electrohydraulic control (EHC) fluids are compared to several different phosphate ester formulations, with pros and cons delineated for each. After 10 years of use at one site, vendor's PAG-based EcoSafe EHC S3 DU showed an impressive total acid number, a key performance index. One powerplant with three steam turbine/generators running on the same charge of this fluid reported "no issues with system pumps, servos, or actuators, no detrimental effects on fluid from temperature excursions, and fewer issues with moisture contamination."

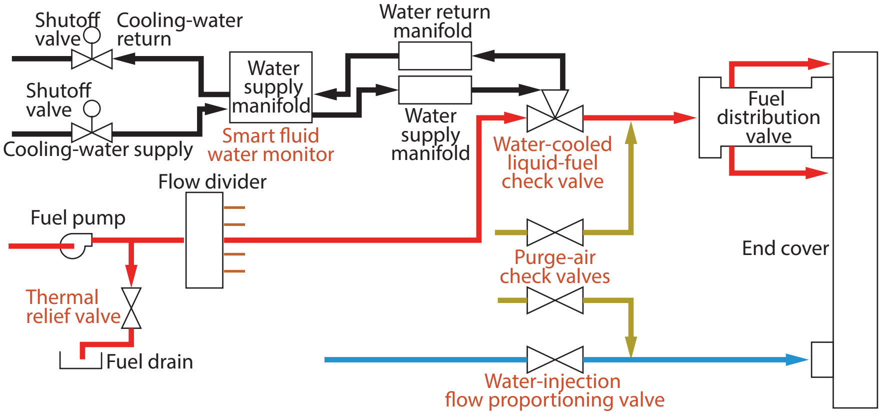
PAG-based EHC Fluid, a Sustainable Alternative to Phosphate Ester for EHC Application, Chris Knapp, Shell Lubricant Solutions

The Mobil™ turbine-oil triage chart can be applied for mitigating varnish, says presenter, after you've assessed the situation you are trying to address (extend outage intervals, correct operational issues, support future conversions) and gathered basic information and conducted a root-cause analysis. Impact photos from the use of several different Mobil products and services are included.

Mobil™ Turbine Oil Triage Guide, Chandler Rogers, Mobil

Third-generation dual-fuel water-injection system components (Fig 7) are said to have performed very well at the customer site referenced: liquid-fuel starts and transfers exceed the "industry standard success rate," purge-air check valve operates with no leakage, check valves and three-way purge valve experienced no failures over multiple years, and water-injection flow proportioning valve operated multiple years without failures, despite thousands of hours of downtime.

20 Years of Reliability: A System-Based Case Study, Dual Fuel with Water Injection, Schuyler McElrath, JASC



7. JASC's third-generation fuel-system improvements. System overview is for 6FA, 7FA, and 9FA liquid fuel systems with a fuel distribution valve. Equipment identified in color are JASC components

Comprehensive weather readiness assessment can help ensure that your site complies with latest regulatory mandates that plants provide maximum and minimum ambient dry-bulb temperatures to which units can operate without a forced outage, derate, or failure to start. Checklists for turbine/generators; fuel supply, plant air, lube oil, cooling, and water systems; and cabinets and compartments are included.

Extreme Temperature Readiness, Jason Neville, TGA Advisors

Expanding sleeve bolt technology can avoid problems like seized fitted bolts and studs, which often have to be destroyed to be removed and can lead to damage to the coupling holes themselves, extending downtime. Vendor's EZFit technology can be considered a permanent replacement for other prevalent designs.

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

Tutorial on the use of hydrogen as a fuel includes H_2 properties, sources, value-chain considerations, percentage in blends, industry experience, and challenges to adoption.

H_2 as a Fuel for GTs in the Power Industry, Gus Graham, CRDX Carbon Reduction Systems

High-pressure water-mist systems for fire suppression are explained, then compared to other options such as CO_2, Halon, dry chemical, inert gas, and low-pressure water mist. Three HP water-mist delivery-system designs (skids, fluid containers, piping) are illustrated. Meeting water quality recommendations is a must when using these systems, and design should meet the NFPA definition of water mist—99% of droplets at minimum operating pressure are less than 1 mm in diameter (layman's version).

Water Mist Fire Suppression for Power Generation, Dale Shirley, Marioff NA

Controls

Findings and observations from the perspective of an owner's engineer during the upgrade of two gas turbines from a Mark VI/EX2100/LS2100 to a Mark VIe/EX2100e/LS2100e control system are presented.

Control Solutions, Abel Rochwarger, GTC Control Solutions, a division of AP4 Group

The impact of instrument-related events on machine reliability opens this slide set, with statistics worth contemplating—for example, upgrades and maintenance would have prevented 40% of the reported failure events. Balance of preso reviews reliability assessments for exciters and load commutated inverters (LCI), component replacement intervals, maintenance and testing of on-shelf electronics, TILs associated with these components, and performance evaluation.

Exciter and LCI Controls Reliability for 7FA Gas Turbines, John Downing, TC&E, a division of AP4 Group

Reactive, proactive, and predictive M&D services have been developed around the company's digital products, primarily Autotune, now serving over 100 assets. Examples of the three types of M&D are included. Under proactive, for example, are checking combustor dynamics signals during transients and early signs of combustion anomalies. Predictive examples are based on comparing unit performance to a larger fleet of machines.

Digital-Twin Alignment Between Design Intent and Real-World Power Plant Operation, Gregory Vogel, PSM, a Hanwha company. CCJ

The value of process optimization

Challenge. Achieve world-class starting reliability.

Solution. AES Huntington Beach Energy and AES Alamitos Energy implemented robust process optimization programs to achieve close to 100% starting reliability on its gas and steam turbines since COD in early 2020.

Startup failure (SF) means an outage that results when a unit is unable to synchronize within a specified startup time following an outage or reserve shutdown. NERC defines a startup period to begin with the command to start and end when the unit is synchronized. SF begins when a problem preventing the unit from synchronizing occurs; it ends when the unit is synchronized, another SF occurs, or the unit enters another permissible state.

Both plants have 20-yr power purchase agreements with two starts daily. To meet this requirement, plant personnel were proactively involved with project construction and commissioning activities, together with the EPC contractor's commissioning team.

AES management and the EPC contractor provided all operations and maintenance personnel 10 weeks of plant-specific training. In addition to this in-person training, the team also received DCS simulator training.

At the end of commissioning, a couple of experienced contract operators were hired to fill open operator positions for a year. Contract operators and the AES operations team updated operating instructions, prepared startup checklists, reviewed and established alarm priorities on the DCS,

The team has been tracking plant operational challenges to achieve 100% startup reliability during the post-COD period. Startup-failure and plant-trip data have been well analyzed and internal RCA discussions have been carried out by the team for improving overall plant reliability.

To achieve 100% starting reliability, a pre-start checklist has been used on every startup/shutdown and signed off by a control room operator and plant equipment operator. Operators have been required to finish familiarization training, as well as to follow well-established plant startup and shutdown procedures.

In addition, plant O&M technicians have been coordinating to meet plant operational priorities and actively avoid equipment failures. Weekly planning and scheduling meetings have managed to effectively resolve plant discrepancies. Operators have been using the OEM's digital asset performance monitoring system for tracking equipment performance.

Preventive operational checks have been carried out weekly, monthly, and quarterly to prevent plant discrepancies, while predictive and preventive maintenance have been done effectively.

Performance and predictive monitoring tools—such as EtaPRO, advanced pattern recognition, and Predictor vibration monitoring—are used. To immediately resolve plant issues, IC&E technicians have been assigned in swing shifts.

After every annual outage, an effective commissioning and testing procedure checklist is followed before a plant restart. Additionally, the OEM's M&D support center has been helping and troubleshooting any unknown complications for the gas turbines.

Results. Even averaging more than 250 annual starts in the last three years of operations, plant starting reliability has been averaging 99% (bar charts). This enviable achievement is attributed to the implementation of the process optimizations programs described above.

Project participant:
Damodaran Sri Ramulu, operations manager

AES Huntington Beach Energy, AES Alamitos Energy

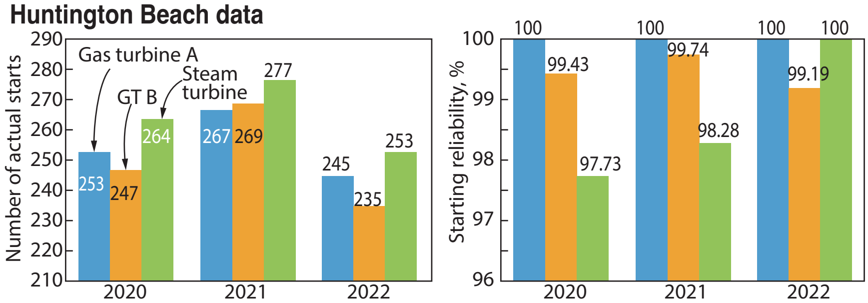
Owned by AES Southland

Operated by AES Corp

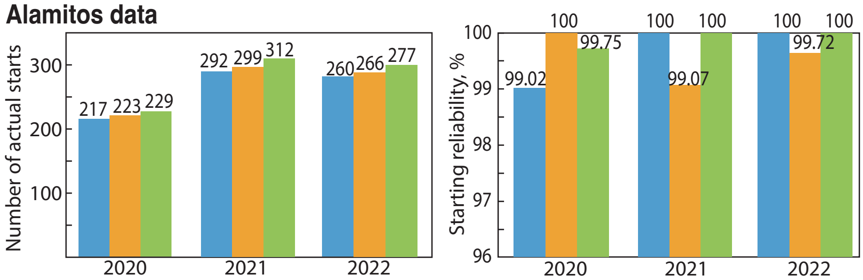
Each plant, rated a nominal 674 MW, is a 2 × 1 combined cycle powered by GE 7F.05 gas turbines and Siemens SST6-5000 steam turbine, located in Huntington Beach, Calif

Plant manager: Weikko Wirta

Huntington Beach data



Alamitos data

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Faribault

Agility solution reduces ST start time, rotor stress

Faribault Energy Park

Owned by Minnesota Municipal Power Agency

Operated by NAES Corp

265 MW, 1 × 1 7F-powered combined cycle equipped with a GE A10 steam turbine, located in Faribault, Minn

Plant manager: Shawn Flake

Challenge. Combined-cycle powerplants have changed their operating profiles to accommodate grid demands for flexible generation. Example: MISO territory has a significant amount of wind energy in its portfolio, requiring Faribault to cycle daily because of excess wind generation overnight.

Faribault Energy Park primarily covers intermediate- and peak-load requirements. Today's energy market has required the plant to provide faster starts and reduce startup costs while maintaining equipment health and reliability over its lifetime.

The cyclic profile of the steam turbine has increased rotor low-cycle fatigue which must be properly managed to reduce the unit's life consumption per start. Objective is to operate well beyond the typical 30-yr lifespan that plants typically are designed for. Historically, turbine OEMs have provided startup guidelines and ramping practices that were conservative but didn't manage stress properly.

Solution. Faribault implemented steam-turbine Agility starts for its A10 machine with the primary goal of providing faster combined-cycle starts while consuming rotor life at a rate commensurate with, or less than, baseline consumption. The ST controller calculates the optimal steam temperature to minimize startup times based on the rotor's warming profile. Rotor cyclic stress is minimized at the same time.

The calculated steam-temperature value is input to the gas-turbine control system and steam-attemperator logic. The GT acts as the primary steam-temperature controller by varying turbine exhaust temperature to the HRSG. Attemperators act as a secondary steam-temperature controller, minimizing—often eliminating—the need to use spray water during startup.

Results. Succinctly, implementing ST Agility starts has decreased fast-start time while reducing rotor stresses that consume life.

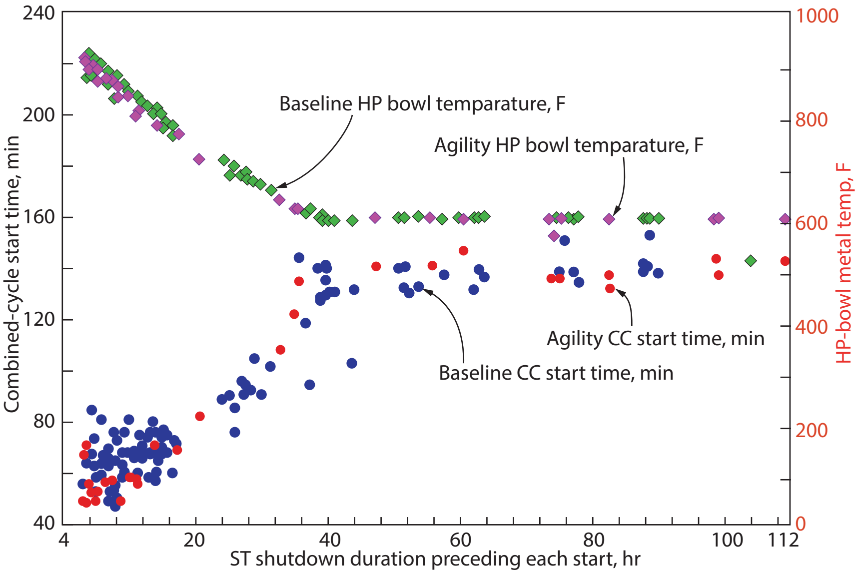
More specifically, combined-cycle start times, after a shutdown duration of 16 hours or less, have been reduced by nearly 10 minutes consistently (figure). Typically, with daily cycling, the shutdown duration is eight hours. Faster starts make the plant more responsive to grid needs while saving fuel. Shorter startup times are achieved by releasing the gas turbine at the optimal time to ramp to market based on steam-turbine rotor stresses.

Rotor stresses have been controlled by creating a stress "budget" for each startup. Stress targets, measured in kilopounds per square inch (ksi), are used to reach minimum and maximum stress limits, allowing each start to consume a budgeted amount of life.

Prior to the upgrade, rotor stress trends on warm starts had several peaks and valleys throughout the warmup phase. Controlling the steam temperature to hit plant's ksi targets has removed the peak and valley effect of a traditional warming cycle. Rotor stresses now reach the peak target, hold peak stresses through warmup, and release on the back end creating a plateau effect.

Project participants:

Shawn Flake, plant manager
Scott Lowe, operations manager
Tim Mallinger, lead operator



Faribault 1 × 1 start times from GT roll to 195-MW plant load. Data points were compiled from 238 baseline starts and 38 Agility starts

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Essential Power Newington

Owned by Essential Power Investments

Operated by Cogentrix Energy Power Management

565 MW, 2 × 1 7F-powered combined cycle equipped with a GE D11 steam turbine, located in Newington, NH

Plant manager: Tom Fallon

Flags make HV grounds visible to ensure proper installation

Challenge. During maintenance outages when conducting high-voltage (HV) activities, personnel work diligently to be sure grounds always are under "control." Site philosophy is that grounds are the last items on the LOTO and the first off it when restoration activities are conducted. A site-qualified electrical employee always will sign onto a LOTO that contains grounds so he or she can witness attachment/removal. The biggest challenge is making sure grounds are visible during installation to be sure there are no questions about what equipment is properly grounded.

Solution. Staff analyzed options for improving safety as well as visibility to the ground cables when they are installed on the 345-kV transmission lines during transformer testing or generator work (Fig 1). They found a supplier of all-weather, high-visibility reflective ground flags that can be hook- and loop-fastened to the ground clamp, or have a grommet-reinforced hole for zip-tying the connection to the clamp or cable.

Drawing attention to these HV ground connections adds a layer of protection to the LOTO process to ensure the grounds are properly removed before restoring the system. The flags also make it easier for contractors to know which piece of HV equipment they should be working on, given that all transformers look the same. This is a quick visual indicator to confirm you're at the correct location without checking markings on the units.

Results. Using visual stimuli to let electrical testing contractors, equipment operators, or other personnel in the area know that the equipment is under grounds control, helps to eliminate errors. Plant's electrical testing contractor said it hadn't seen anything like this at any of the other plants they have performed testing services for in New England. Staff submitted this as an internal best practice within Cogentrix so the entire fleet is aware of the product and its ease of use, as well as its enhancement of awareness.

1. All-weather, high-visibility reflective flags draw attention to HV ground connections

Project participants:
Chad Harrison, maintenance manager
Mike Dill, I&E technician

Enhanced thermal monitoring helps protect critical equipment

Challenge. Extreme cold weather is no stranger to Newington and the New England area. For a cycling facility, Newington was designed and constructed with less-than-adequate measures for cold-weather mitigation. Over the years, the facility has been improved in this regard with additional buildings, HVAC equipment, and heat-trace and insulation—with proven success during extreme cold weather.

It was important for plant personnel to learn from recent regional cold-weather events—such as the Polar Vortex of 2013/2014, Bomb Cyclone of 2015/2016, and Winter Storm Elliott during Christmas 2022—to better prepare for future storms. For example, having the ability to monitor remote locations and equipment from the control room was a necessity.

Use of remote temperature monitoring devices would be a beneficial freeze-protection addition and would complement the site's cold-weather plan in a pronounced way. This was particularly important given NERC's plan (at the time) to revise standard EOP-11, "Emergency Preparedness

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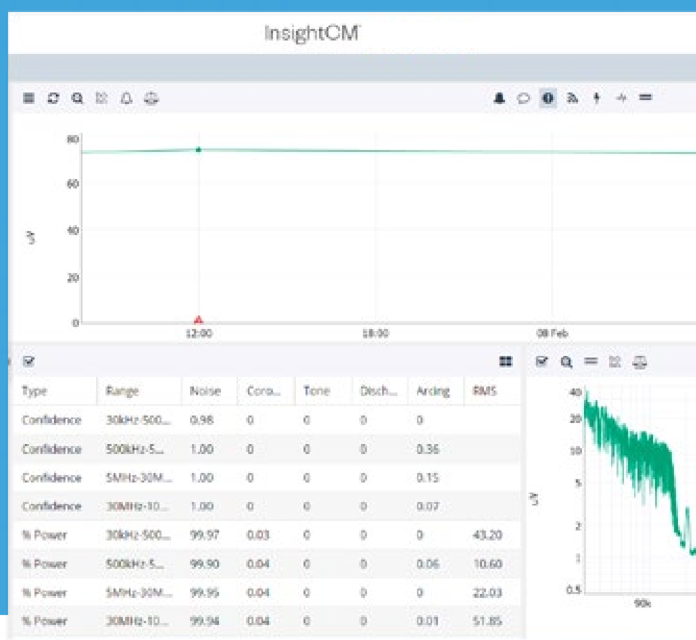

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2. Sensors installed in difficult-to-reach locations protect critical equipment against high and low temperatures

and Operations" and mandate that generation owners implement a cold-weather preparedness plan.

Solution. When sharing internal best practices with another asset in the Cogentrix portfolio, Newington personnel investigated a remote temperature monitoring solution called Monnit®. After developing an implementation plan, Monnit sensors were ordered and installed.

The sensors have the ability to check-in at any periodicity the user desires and can proactively alert others via email and text of cold/hot areas of concern. Data captured by each sensor can be trended, an important capability. With the iMonnit software and affordable licensing, users can monitor the entire network of sensors from one location—such as the control room. There also is a cell-phone app that can be downloaded and monitored as needed.

Newington purchased several lithium-battery-powered industrial-grade remote temperature sensors for temperature-critical areas (Fig 2), such as the following:

- Fire sprinkler/deluge buildings.
- HRSG internal sections.
- Critical instrumentation boxes.
- Feedwater piping susceptible to freeze-up during offline periods.
- Auxiliary equipment outbuildings.

Results. With the installation thus far of 38 sensors facility-wide, Newington has the ability to monitor and be alerted on critical areas of concern during extreme cold and hot weather events. Reports can be generated from the software and rules established to automate device concerns, battery levels, etc.

These devices were an added feature in the facility's new NERC cold-weather awareness plant in support of EOP-011-2, which became effective Apr 1, 2023.

Project participants:
Joshua Leighton, operations manager
Eric Pigman, engineering manager
Cogentrix's Hamilton Liberty staff
Cogentrix's Hamilton Patriot staff

Fuel filter enhancements facilitate O&M, improve safety

Challenge. Essential Power Newington was designed to operate primarily on natural gas, with the ability to transfer to ultra-low-sulfur diesel (ULSD) as necessary. Historically, ULSD has been burned in winter when natural-gas demand and oil prices are at their peaks.

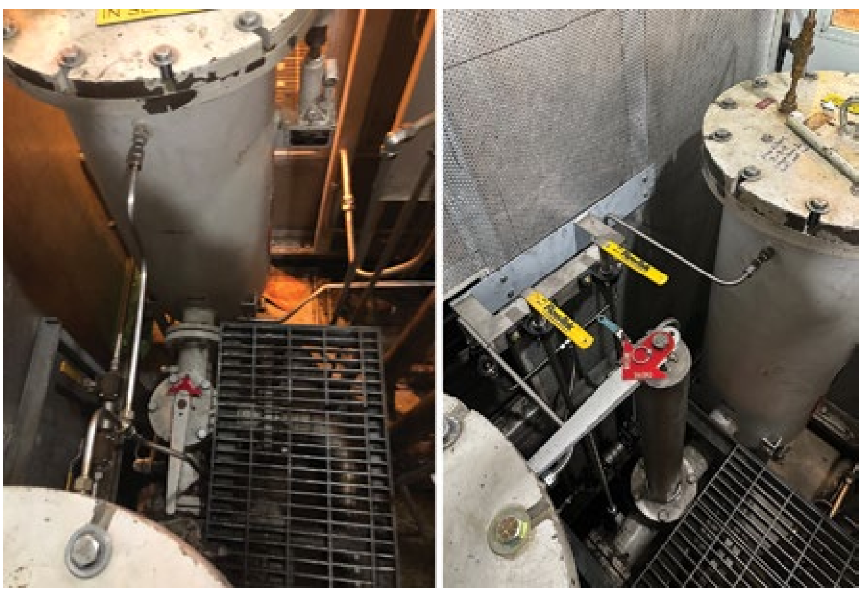
Duplex fuel filters were provided to remove particulates from the distillate fuel. A pressure gage and alarm switch monitor the differential pressure across the strainer to indicate when filter replacement is required. The filters are located in an off-package liquid fuel/atomizing air module with limited and challenging access for routine O&M. Filter-housing changeover, pressure-equalizing, and drain valves were extremely difficult to access and operate safely.

Filter replacement often was required when the unit was operating—when reliability is paramount. Operation of the various filter valves required kneeling down on a small grating platform underneath control-oil tubing with limited leverage for filter changeover and media removal. The filter was located a few feet below the grating and difficult to reach (Fig 3, left).

Solution. A site team walked down the two gas turbines and agreed on an appropriate in-house design to support filter O&M in a safe, effective manner. Valve extension handles were constructed by site maintenance employees for all drains and equalizing and filter changeover valves. The control-oil tubing for the liquid-fuel stop and bypass valves in each of the GT compartments was rerouted to improve filter access.

Results. With extension handles installed on filter drain, equalizing, and changeover valves for both units, access improved tremendously, allowing safe and effective O&M evolutions (Fig 3, right). The system was installed in fall 2022, and operated throughout the winter of 2022/2023 when liquid fuel was burned, with positive results. Avoiding a safety incident or damage to equipment by poor leverage and ergonomics was the key to this completely in-house design and improvement.

Project participants:
Scott Roy, lead plant operator
Ted Karabinas, maintenance technician
Tom Jamison, maintenance technician



3. Newington's duplex fuel filters, at left as installed, were modified to improve O&M access and safety (right)

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(e.g with Low-Speed Balance)

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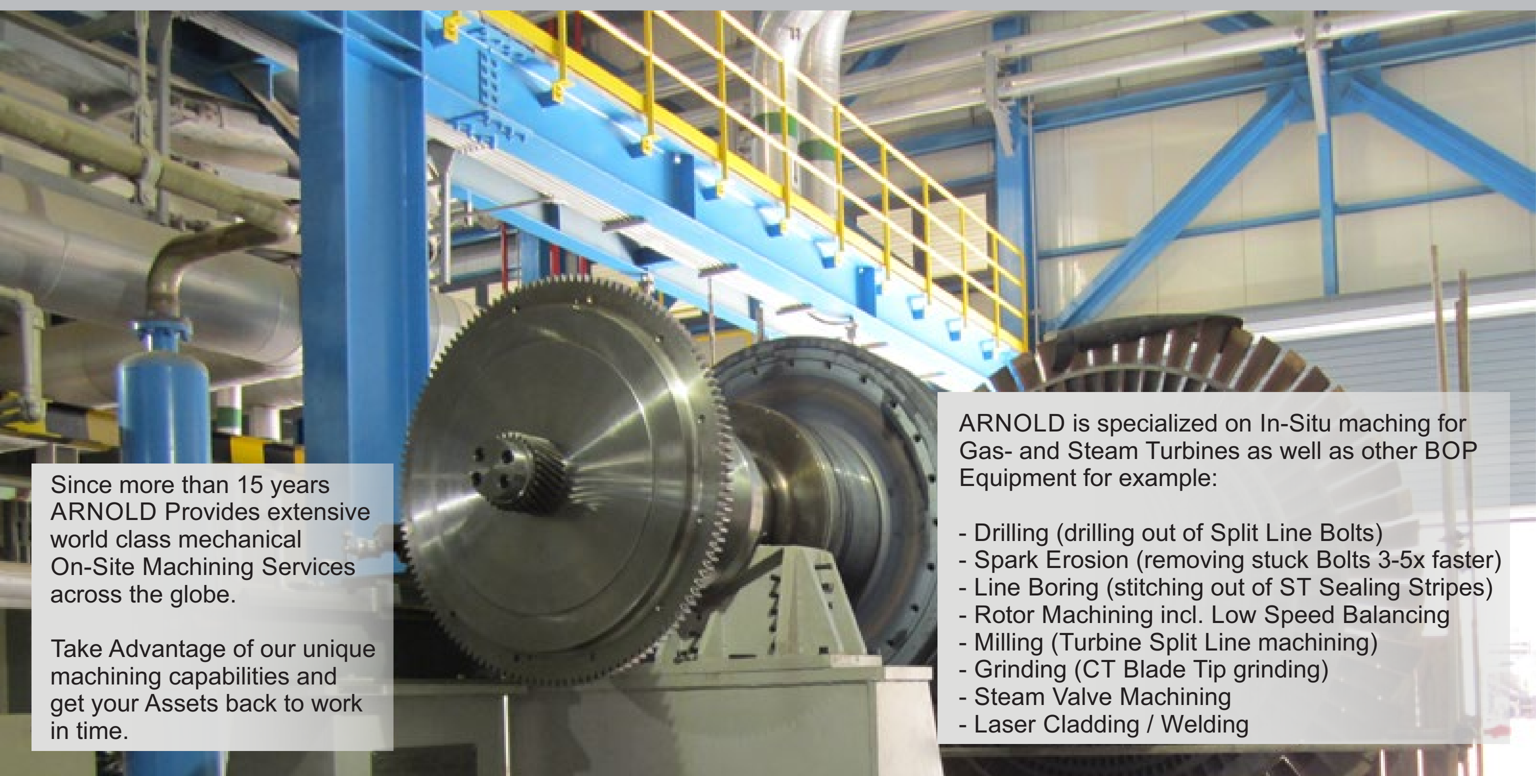

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ARNOLD GROUP

St. Charles Energy Center

Owned by CPV Maryland LLC

Operated by Consolidated Asset Management Services

745 MW, 2 × 1 7F.05-powered combined cycle equipped with a GE D11A steam turbine, located in Waldorf, Md

Plant manager: Nick Bohl

RO clean-in-place wastewater discharge mod reduces

Background. St. Charles Energy Center uses two double-pass reverse-osmosis (RO) systems with electro-deionization (EDI) skids to produce demineralized water for the plant's heat-recovery steam generators. The RO system contains a clean-in-place (CIP) feature for removing accumulated impurities to restore performance and efficiency.

The as-built plant design used a trough located in the water-treatment building to route the CIP wastewater to the plant wastewater collection sump (WCS), which discharges the CIP wastewater back to the local water treatment facility (WTF) for processing and reuse.

St. Charles's wastewater discharge permit specifies that the pH for this water must be greater than 5 and less than 10 when discharging back to the local WTF. During a CIP, wastewater pH can range from less than 4 to more than 11. Sending water with a pH in this range to the WCS during a CIP increases the chance of permit non-compliance.

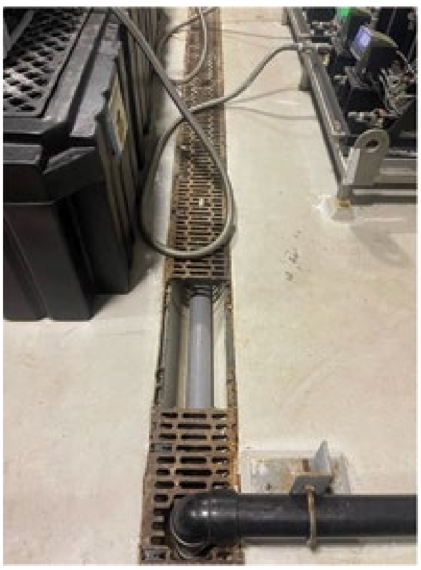
Challenge. To prevent a permit violation attributed to low or high pH, the plant would increase cooling-tower blowdown to the WCS to dilute the sump water, or use chemicals—such as sodium hydroxide or hydrochloric acid—to neutralize the wastewater in the CIP tank before discharging it to the WCS.

Both methods were inefficient, costly, and introduced a great risk of human error. Blowing down the cooling tower to dilute the sump contents uses water in the tower that must be made up to maintain proper operational level, while at the same time increasing wastewater costs because of the increase in discharge to the WTF. Plus, there is a safety risk associated with the storage and handling of sodium hydroxide and/or hydrochloric acid to neutralize sump contents.

Solution. The plant addressed these issues by hard-piping the CIP tank discharge line to the filtrate sump, thereby allowing its contents to be pumped out directly into the cooling-tower basin instead of the WCS. The new hard pipe was placed in the original discharge trough to prevent trip hazards (Fig 1). The team also manufactured a section of CPVC with a union so the piping can be assembled and disassembled easily and efficiently to discharge to the filtrate sump (Fig 2).

Results. The discharge mod has reduced the total time it takes to perform a CIP by two hours and has saved up to $700 per CIP. This gives the site greater control over the pH level in the WCS, thereby mitigating the risk of non-compliance with the site environmental permit by not discharging directly to the WCS. Additionally, this mod improves employee safety by eliminating exposure to chemicals for neutralizing pH.

Project participant:
Shawn Burnette



1. Hard pipe was placed in the original discharge trough to prevent trip hazards

2. A section of CPVC was arranged with a union to permit easy assembly/disassembly for discharge to the filtrate sump

Benefit of using Python to calculate plant performance

Background. Annually, PJM Interconnection requires all plants in its territory to perform an installed-capacity test (iCAP). It is equivalent to the claimed installed capacity in PJM eGADS, and the capability of the generating unit at the expected time of the PJM summer peak. This also is referred to as the "rated capability" or "rated iCAP" which is determined by adjusting plant capability for site conditions coincident with the dates and times of summer peaks over the previous 15 years.

Challenge. The plant had been using an Excel spreadsheet that relied on macros to calculate correction curves for the given ambient conditions of temperature, barometric pressure, and relative humidity, and the 15-yr summer condition averages for those variables.

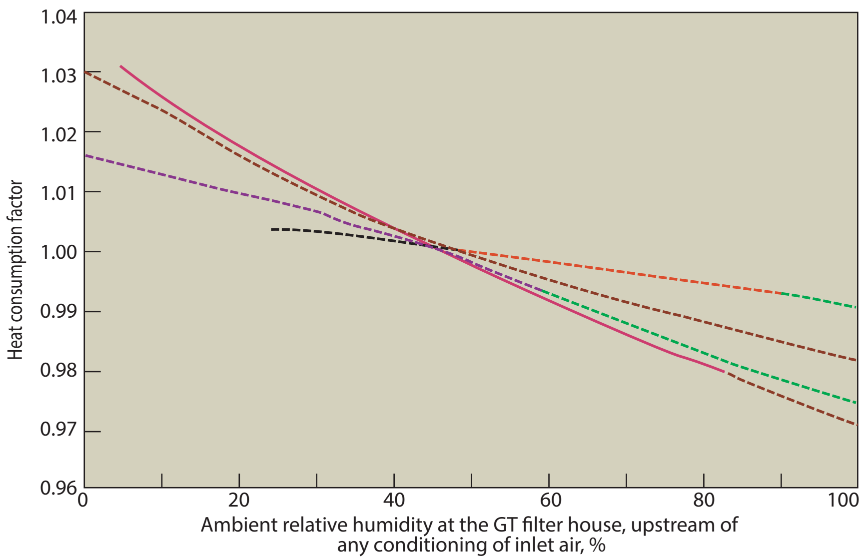
Correction curves provided by the OEM only included certain ambient conditions, and they required mathematical interpolation to obtain the proper correction factor. To illustrate, Fig 3 gives curves for ambient relative humidity with the evaporator cooler in service and ambient temperatures of 59F, 75F, 94F, and 100F.

After the iCAP testing was complete and all PI data were input to the Excel spreadsheet, site and other performance engineers would question the validity of the Excel result. The discussion related to the "correct" number to use would go back and forth for multiple weeks for each test. This resulted in numerous manhours being used for debating whether the Excel output was correct or incorrect.

Editor's note: The complex equations used to create the curves in Fig 3 were submitted with this entry, but believed to be of marginal value to most readers and not included here.

Solution. The best way to facilitate the process was to develop a written code within the computer programming language Python, an interpreted, object-oriented, high-level language with dynamic semantics. In short, it's a powerful tool to develop a proper calculator for all the curves used in calculating the iCAP net generated output. The program includes approximately 300 lines of code—including equations for interpolation.

A sample of this code was provided with the entry but not included here given its very limited value to the large majority of readers.



3. Calculating rated capability as required annually by PJM Interconnection was challenging using an Excel spreadsheet for determining correction factors. Python greatly simplified the task

The benefit of using Python for calculation of the iCAP is that it takes the human error out of calculating the iCAP value within the Excel spreadsheet, which required annual updating depending on how ambient conditions differed along with the PJM summer peaks. With Python, the only thing the site team must do is insert the numbers for temperature, barometric pressure, and humidity, and the 15-yr averages for each, into the program and press "run."

After all the required date are input, Python returns the proper correction factors used, plus the corrected net output of each unit to be submitted as the iCAP number.

Results. Since the implementation of Python and validation of the code via hand calculation, the man-hours of involvement required of management—including plant engineer, operations manager, and plant manager—to develop the iCAP number for input to the PJM portal have been reduced dramatically. In addition, the new methodology is so user friendly operators can use this tool during the iCAP test to ensure the plant is on track for hitting the target corrected net output.

Project participant:
Jacob Boyd, EIT, plant engineer

38 CC Norte III

Owned by Abeinsa

Operated by NAES México

907 MW, 2 × 1 7F.04-powered combined cycle equipped with a Toshiba steam turbine, located in Chihuahua, Mexico

Plant manager: Armando Burgueño

Successful winterization plan increases plant reliability

Challenge. 38 CC Norte III is located in a region of Mexico with one of the country's most extreme climates—very hot summers and extremely cold winters. Temperatures as low as -19C have been recorded. High wind speeds are another characteristic of the area.

High winds and low temperatures in wintertime were wreaking havoc with instrumentation—especially level, pressure, and flow transmitters, which were arranged in two of three logic. Out-of-range or lost data, typically attributed to freeze-up of sensing lines, often caused turbine/generators to trip. The result: High EFOF (equivalent forced outage factor) and financial losses.

Solution. In 2021, a year after the plant began commercial operation, diesel-oil-fired hot-air generators were installed to reduce the impact of low temperatures on critical instrumentation (Fig 1). However, this solution was far from ideal. One reason: O&M technicians had to supply diesel to the hot-air generators every couple of hours to keep them in service.

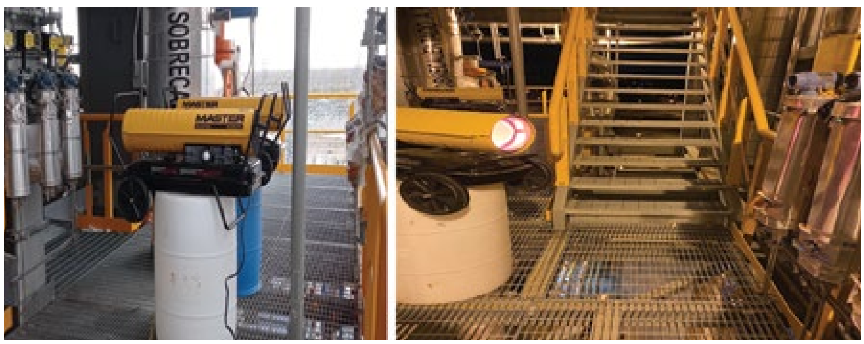
Encapsulating in thermal boxes all transmitters working with water/steam column lines was the solution, along with thermal insulation of exposed lines (Figs 2 and 3).

Results. The table tracks historical EAF (equivalent availability factor), reliability and EFOF data and shows the dramatic improvement gained by migrating from the hot-air generators to the insulated lines and cabinets. The migration was completed early in 2023 and highly successful, as evidenced by comparing the data for January and February 2023.

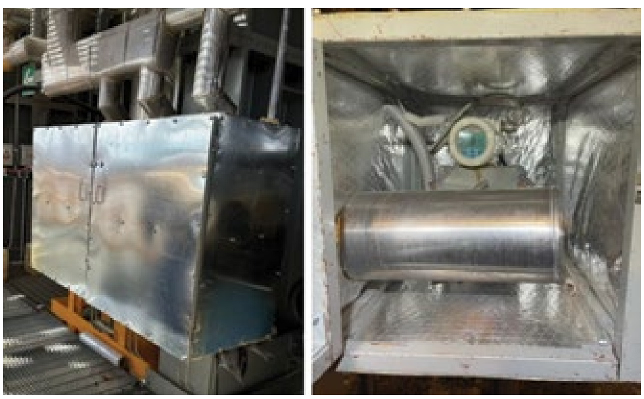
Another plus was the safety, environmental, and cost benefit of eliminating the diesel-fired hot-air generators.

Project participants:
Armando Burgueño Santacruz, Rafael Sarabia Rodríguez, Javier Ramírez Gutierrez, Francisco Javier Soqui Siqueiros, Juan Jose Carlos Contreras, María Guadalupe Valdez Zabalza, Eleazar Velderrain Alcaraz, and Flavio Cesar Virgen Rey

KPI	Feb 21	Mar 21	Apr 21	Feb 22	Mar 22	Apr 22	Dec 22	Jan 23	Feb 23	Mar 23	Apr 23
EAF, %	95.15	98.06	98.06	96.58	98.06	96.57	99.42	99.19	99.95	99.36	99.36
Reliability, %	65.60	89.60	94.60	82.90	99.99	97.20	99.55	99.40	99.95	100	100
EFOF, %	21.91	10.36	4.95	17.11	0.05	0.27	0.45	0.90	0.05	0	0



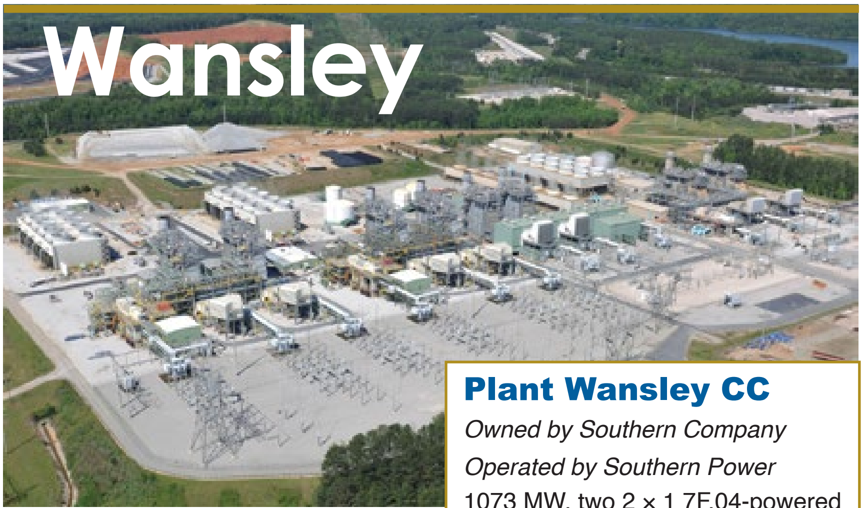
1. Use of diesel-oil fired hot-air generators for protecting critical instrumentation proved ineffective



2. Thermal boxes were effective for protecting instrumentation (at left is external view, at right internal)

3. Thermal insulation prevented freeze-up of water-steam columns

Wansley



Plant Wansley CC

Owned by Southern Company

Operated by Southern Power

1073 MW, two 2 × 1 7F.04-powered combined cycles equipped with GE D11 steam turbines, located near Carrollton, Ga

Plant manager: Mike Moro

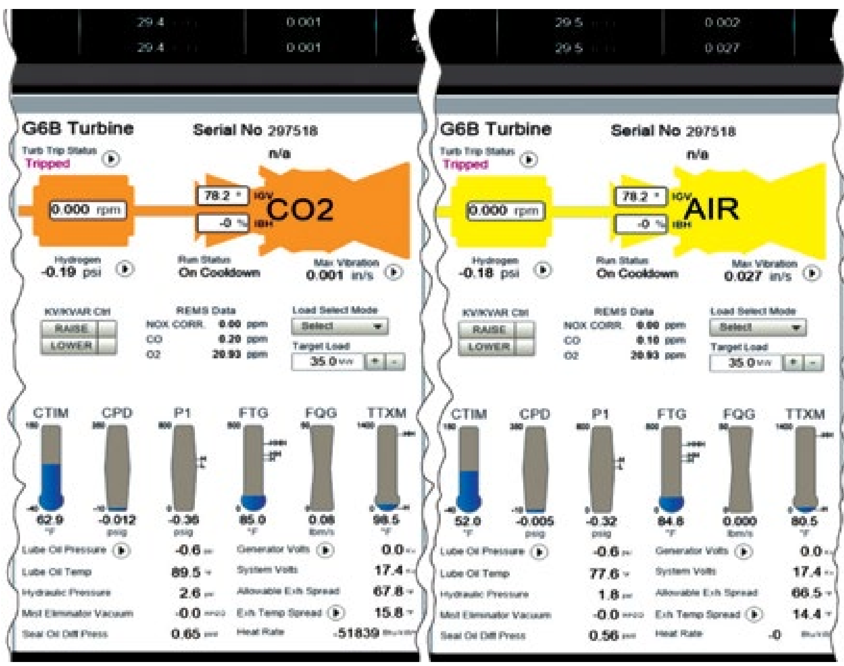
Know at a glance the gas in your generator cooling system

Challenge. During an outage, when the generator does not contain hydrogen, the control system didn't have an obvious way of indicating this critical information to people in the control room.

Solution. Install the new Cimplicity plant overview screen into the Mark VIe control system. With this modification, the color of the generator and gas turbine changes automatically on the screen when in an abnormal state (figure). This screen normally is displayed on one of the large monitors, allowing anyone in the control room to know at a glance what gas is in the generator.

Results. The logic works by using the hydrogen analyzer feedbacks to determine what gas is in the generator. Under normal conditions, with hydrogen in the generator, the analyzers are switched to "Percent H_2 in Air." When the generator is being purged with CO_2, the analyzers are switched to "Percent H_2 in CO_2." Finally, when the generator is completely purged of CO_2 and hydrogen, and contains air, the analyzers are switched to "Percent Air in CO_2."

Project participants:
Jason Justice, Ryan Biggs, Doug Burnette, Shane Cummings, and Kevin Martinez



Color of the gas turbine and generator indicates the gas present in the cooling system

Hunterstown

Hunterstown Generating Station

Owned by Platinum Equity LLC

Asset management by Competitive Power Ventures

Operated by NAES Corp

810 MW, 3 × 1 7F.04-powered combined cycle equipped with a GE D11 steam turbine, located in Gettysburg, Pa

Plant manager: Tom Hart (former), Mark Kadon (current)

Plant personnel safety: Remote racking devices

Challenge. Hunterstown's obsolete robot made racking-out breakers more hazardous than need be. The device was a headache, thereby causing a hazard for employees. This could have led to corners being cut.

Solution. NAES requires remote rack-out when incident ratings exceed 40 calories/cm^2. Many times, the old robot would indicate the device was fully racked-out but, in fact, it was in mid-travel when the operator approached. Staff selected CBS ArcSafe to provide new remote raking robots for the plant.

Results. The new robots allow employees to safely rack out any device onsite while being well outside the arc-flash boundary. Staff also purchased a magnetic camera that allows the operator to see remotely what position the breaker is in before approaching (photos).

The robots have a clutch that will disengage before over-torquing the breaker. This mitigates many of the problems experienced previously, and operators no longer have to manually break the device free before using the remote racking device. The 4160-V devices are completely wireless, the only thing that needs to be plugged in is the battery pack.

The operator takes the remote and the camera screen outside of the building and does the racking completely out of the line of fire and well outside of the arc-flash boundary. The 480-V devices do have a wire but the operators are still able to go outside of the building and outside of the arc flash boundary. The process has become exponentially safer for all plant personnel.

Project participant:
John Marino, operations manager

Hunterstown's new robots allow staff to safely rack out any device onsite while being well outside the arc-flash

Upcoming Conferences

7F Users Group
May 20-24, 2024
Marriott St. Louis Grand
St. Louis, MO

HRSG Forum
June 10-13, 2024
Marriott St. Louis Grand
St. Louis, MO

Legacy Turbine Users Group
July 15-18, 2024
The Woodlands Waterway Marriott Hotel
The Woodlands, TX

7HA & 9HA Users Group
August 12-15, 2024
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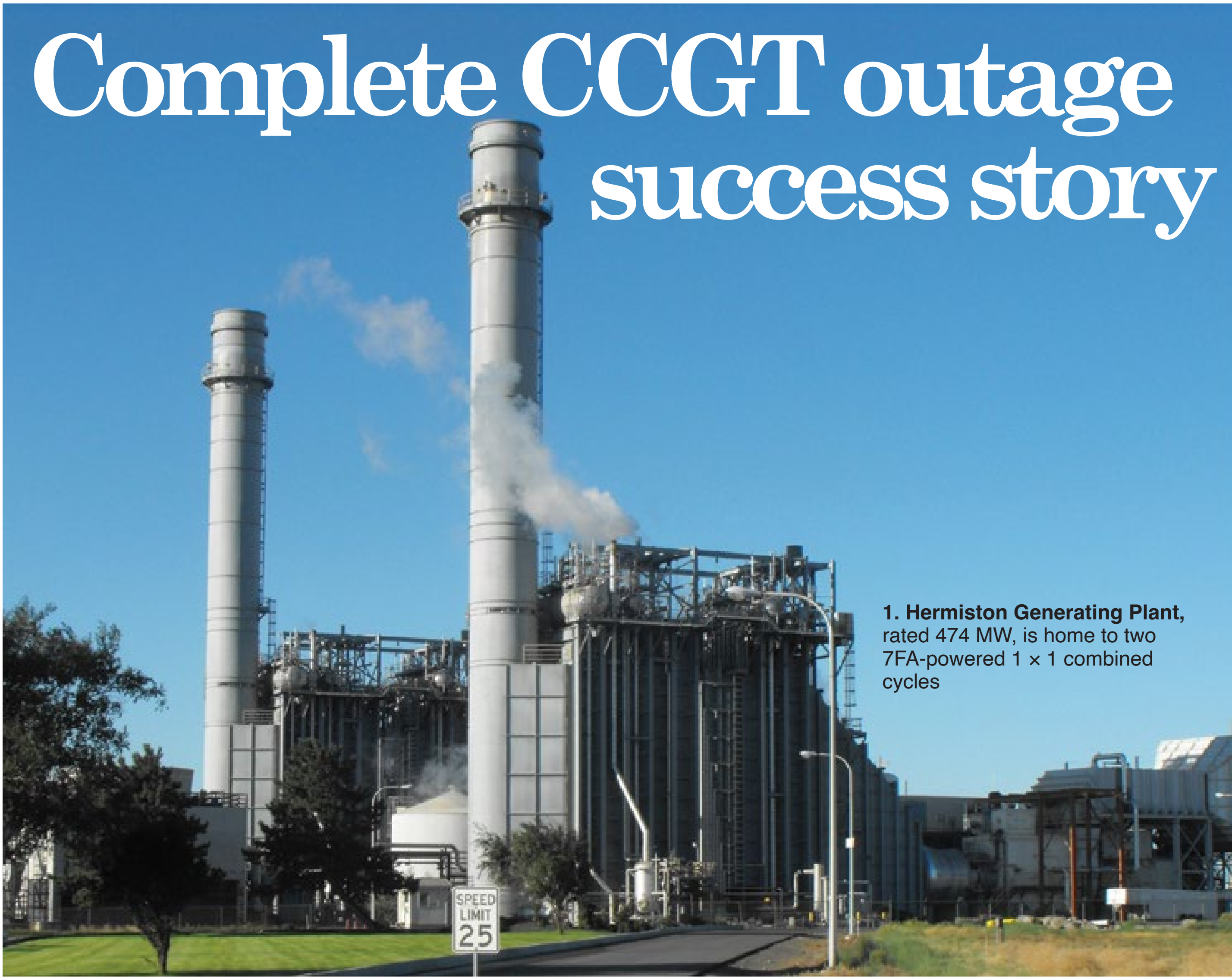


1. Hermiston Generating Plant, rated 474 MW, is home to two 7FA-powered 1 × 1 combined cycles

Mechanical Dynamics & Analysis (MD&A) recently completed the major inspection and refurbishment of a 1 × 1 combined cycle at the Hermiston Generating Plant that successfully returned the facility's turbines and generators to full and reliable operation.

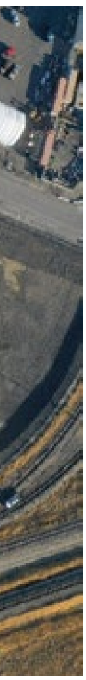
The project began with the full major inspection of a late-1990s-vintage, 170-MW 7FA gas turbine—including the robotic inspection of its 7FH2 generator. The A10 steam turbine and its 7A6 generator also were fully inspected and refurbished by MD&A in the same outage.

The plant

Perennial Power's 474-MW, two-unit Hermiston Generating Plant in northeastern Oregon (Fig 1) provides power to nearly 500,000 households in the Pacific Northwest. It also sends steam to Lamb-Weston's adjacent potato processing facility.

Both Hermiston units feature identi-

2. Limited space for contractors and equipment laydown was an added challenge in performing multiple majors



3. Team MD&A removes the 7FA gas-turbine rotor

4. First-, second- and third-stage turbine buckets were replaced (Fig 3, left end of shaft)

5. A10 steam-turbine rotor is removed for inspection and repairs

cal gas turbine/generators and steam turbine/generators, all commissioned in 1996. The plant has been recognized by the Oregon Occupational Safety and Health Division in the past for its exceptional health and safety record and to date has never experienced a lost-time injury.

The outage

Safety, planning, communication, and coordination were instrumental in the successful Unit 2 outage in fall 2022.

Plant Manager Chad Daniel takes us back to the outage and offers an insightful and educational look at what made it run smoothly.

"I can't over-stress the importance of pre-outage planning and open communication among the plant, the various technical points of contact, and all contractors," he explains. "We had 20 contractors on site, MD&A being the largest, plus additional subcontractors."

Daniel explains that pre-job planning and walkdowns are absolutely critical.

"There are things that come up during walkdowns (crane activities, for example) that may need to be altered, sequences shifted, and you are always looking for safety items. All of these are critical to a successful outage."

He continues: "With nearly two-dozen contractors onsite and within limited space (Fig 2), communicating and coordinating contractor milestone schedules and needs become crucial (competing for space, LOTO timing, equipment testing, safety concerns, etc).

"Our plant has found that by having multiple internal pre-outage meetings combined with specific responsibilities and work-order and contractor assignments, you make sure that no single person is overloaded. At Hermiston everyone shares those responsibilities, both salaried and non-salaried. Our internal meetings and reporting start several months before the outage. Meetings with contractors are also held onsite or virtually as often as needed."

"It starts with the plant," states Daniel. "I feel it is the site's responsibility to build the dialogue, the trust, and the open communication to bring up any and all questions and make it a streamlined and safety-conscious outage.

"The result," as he explains, "is that once you get rolling into the outage, you have the relationships, you know who you need to talk to, you have people that you are comfortable with and have faith in so you can walk through the issues, get them resolved quickly, and keep everyone involved and moving ahead."

Daniel also addressed weather-related scheduling, offering an important caution for outage planning. Although his part of Oregon does not routinely experience extreme weather, the climate can still be unpredictable, especially in the fall and spring. So, you need to consider temperature swings, and high winds than can impact crane operations.

"When you are planning your outage, whether it's based on the owner's needs or the hours on your machine, certainly leave a few extra days for contingency, if possible, particularly for a major inspection where you are going to be down for a substantial amount of time, are performing non-routine work, or work that poses increased risk of delays. You have to be mindful of the end timing of the outage and keep weather conditions in mind for startup. You don't want to be starting the HRSG, for example, in freezing conditions," he notes.

7FA gas turbine

MD&A mobilized and completed the disassembly process utilizing a two-shift operation (Fig 3). Detailed visual inspections began, coupled with detailed NDE, followed by the recommended refurbishments.

In the turbine section, first-, second- and third-stage buckets were replaced (Fig 4) due to rubbing wear and loss of the thermal barrier coating (TBC).

First-, second- and third-stage nozzles also were replaced because of foreign object damage, evidence of crack-

6. Main steam valves for the A10 steam turbine were inspected and repaired in MD&A's St. Louis facility

7. 7A6 generator field on its way to MD&A St. Louis for a full rewind ing, and coating loss. Inspections and similar indications revealed the need to also replace the shrouds.

In the combustion section, liners and transition pieces were replaced with refurbished sets due to TBC loss. New inner crossfire tubes and retainers were installed because of wear and outer crossfire tube packing was replaced at reinstallation.

Although no abnormal visible wear was found, forward combustion cans and fuel nozzles were replaced with customer-provided refurbished sets. Flow sleeves also showed no wear, but the flow-sleeve piston rings were replaced.

Liner caps were replaced with refurbished ones, and transition-piece bullhorn brackets were found worn and replaced with new.

For the compressor-section inlet guide vanes (IGVs), MD&A replaced gears, rack, inner and outer bushings, and spacers. IGV blades themselves will need to be replaced at the next major inspection.

Rotating and stationary blades showed no damage. R-0 inlet compressor blades were replaced with a refurbished set and shims were added to stages 14, 15, and 16. The casing and rotor showed no need for immediate action, but the discharge casing retention bars were replaced.

The inactive thrust bearing showed heavy scoring and the T-1 and T-2 bearings revealed pitting and scoring, which were subsequently replaced with refurbished bearings. The active thrust bearing was cleared for service.

7FH2 generator

For the generator, the initial scope of work was visual inspection, robotic wedge-map analysis, electromagnetic core imperfection detection (ELCID), and a full battery of electrical tests.

The borescope inspection showed substantial widespread greasing and several areas that had loose hardware. Field removal was recommended for a more comprehensive stator investigation. Following that, a core wedge map was performed that showed approximately 90% of the wedge system was loose and/or hollow, not meeting MD&A criteria. A full stator re-wedge, replacement of greasing blocking/ties, and axial support tightening was recommended and performed.

MD&A also provided and installed an improved wedge design.

Prior to re-wedging, a significant amount of time was expended cleaning the core. All slots were cleaned, including dovetails.

New filler material and top ripple springs were installed during the re-wedge. A modification was made to the end wedges to improve mechanical strength. The original flux probe was installed without issue, and a final ELCID was performed with acceptable values.

Based on modal bump testing, MD&A recommended that the entire collector and turbine ends have series blocking installed to reduce resonant frequency response. Saturated felt and ties were added to dampen the response.

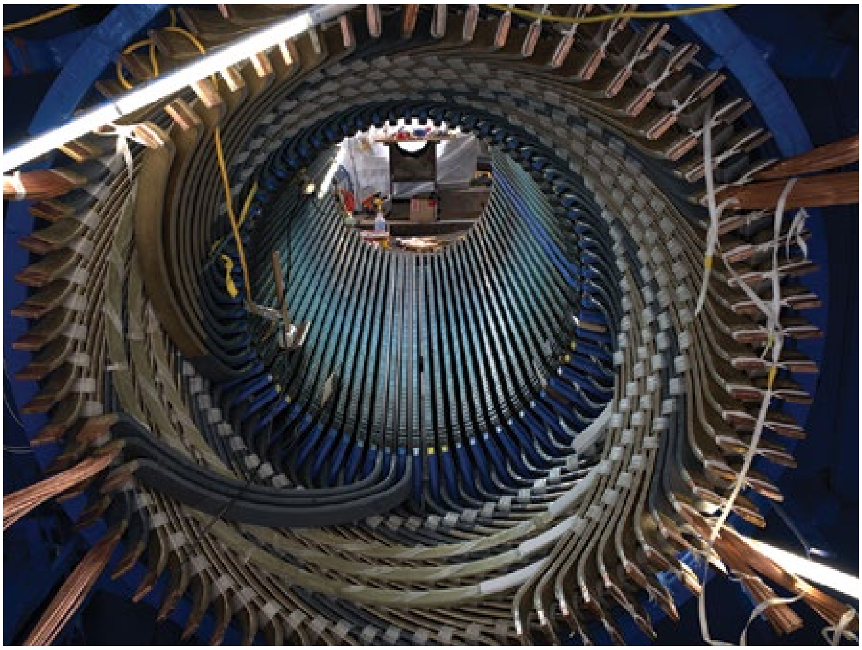
New axial support hardware was installed, replacing the loose axial supports and hardware found during initial inspections. Locking epoxy was applied on all hardware to ensure no complications during operation.

Hydrogen seals were replaced with new, and field collector rings were ground.

Successful electrical testing was performed at the completion of all work performed.

A-10 steam turbine

MD&A performed a major inspection and overhaul of the 81-MW A10 steam turbine (Fig 5) and its generator stator and field—all installed in 1996. The main steam valves also were removed by MD&A and sent to the company's St. Louis facility for inspection and repairs (Fig 6).



8. Stator rewind for the 7A6 generator was performed onsite by MD&A after a thorough inspection

MD&A specialists performed a complete steam-path structural audit of the A10 machine. Although many minor diaphragm indications could have been repaired by MD&A onsite, ILP diaphragms 9, 10, 11, and 13 were shipped to MD&A's facility for major repairs. Stages 10 and 11 also had inserts installed on the steam-seal face because of dishing.

HP and ILP rotors remained coupled and were removed for sandblasting and NDE. Minor bucket repairs were performed onsite to correct impact damage and moderate solid particle erosion.

On reassembly, MD&A performed a Topless Laser Alignment® and its On-Site Seal Services fit and installed new diaphragm and gland-steam packing.

7A6 Generator

The 7A6 air-cooled generator was disassembled and its field removed and shipped to MD&A's St. Louis facility for a full rewind (Fig 7). In addition, the company's Generator Div mobilized onsite to perform a full stator rewind.

The combined HP stop and control valve was disassembled and the cores shipped to St. Louis for inspection and repair. The Steam Turbine Repairs Div also received two reheat stop valves and two intercept-valve cores for inspection and repair.

Stator. Concurrent with the steam-turbine major inspection, an elevated workspace was constructed onsite to support the generator division in stator disassembly and reassembly work. A baseline ELCID was performed to determine integrity of the current stator core iron. No shorted laminations were noted.

The wedge system was removed, then the flex probe was carefully set aside for reassembly.

With wedges and series loop connections removed, bar removal began. Inner axial supports were left in place and prepared for the reassembly. Connection pieces were cleaned for reuse.

The stator was thoroughly cleaned to remove any contaminants from the wedge/bar removal process. A post wedge/bar removal ELCID indicated no core-iron damage during wedge and bar removal.

Each core slot was cleaned, and a detailed inspection of any abnormalities was conducted. The core compression flange and all exposed areas where the endwindings sit were painted with an epoxy paint for a uniform color on the compression flange.

After thorough cleaning, the rewind began (Fig 8).

Bar boxes were moved to the scaffolding deck with an innovative safety-conscious method of disassembling the scaffolding roof and flying the boxes to the deck with a crane following completion of a detailed lift plan.

Each of the six circuit rings were acceptance-tested, and the outside binding bands installed.

A tapered gauge from the bar manufacturer was used to ensure concentricity was achieved on the four binding bands. Concentricity of each band is a vital step that will properly align each bar and subsequentially the endwinding basket once the rewind is completed.

Two top and two bottom bars were installed to ensure alignment. Bars were fit into a shoe on the collector end and carefully transferred through the bore to the turbine end. All 72 bottom bars were installed, blocked and tied. All 72 top bars were then installed, blocked and tied, along with 12 new resistance temperature detectors (RTDs).

After all bottom bars were installed, a Hipot test was performed to ensure there was no bar armor insulation damage. Another Hipot was performed on all top and bottom bars at the completion of top-bar installation.

Wedges were then installed, and filler was adjusted at each wedge for proper radial compressive force. Axial locking pins were installed, followed by a final ELCID and brazing. The existing circuit-ring copper connection pieces were re-used and brazed to respective top- and bottom-phase connections.

Upon completion of all rewind activities, final electrical testing consisted of winding copper resistance, insulation resistance, and a final Hipot of each respective phase. Each phase produced satisfactory resistance values.

The stator rewind activities progressed as expected throughout this project. The consistent bar shapes and robust bar design aided in completing

9. Hermiston's 7A6 generator-field rewind in progress at MD&A's repair facility the project without incident.

Field. The 7A6 generator field was sent to MD&A in St. Louis for testing, disassembly, coil removal and cleaning, further testing, reassembly, and high-speed balance (Fig 9).

During initial electrical testing of the heavily dished collector rings, collector studs, and bore copper, the collector studs failed high-potential testing. This resulted in the replacement of the collector rings which included removing the old collector rings, manufacture of new collector rings, new collector-ring insulation, and reinsulating of the collector studs. Coils were removed and sent offsite for cleaning. They were then returned and checked by MD&A. After reinstallation, each coil received ac Hipot and turn-to-turn testing.

Also, during the rewind process, the blocking was upgraded to the MD&A standard block and tie design. Turn insulation was coated, requiring a rotor bake cycle.

Electrical testing, high-speed balance, acceptance testing, and shipping followed.

MD&A also provided startup and balance support of the unit, along with full recommendations on what to look for or replace at the next outage. Daniel offered the following: "MD&A has become one of our most trusted, dependable and transparent contractors to work with."

Balance of plant

Throughout the outage, balance-of-plant work was conducted using both Hermiston plant personnel and a wide variety of contractors.

Major items beyond the base MD&A scope included the following:

- Vogt 3-drum HRSG-related items:
  - Boiler feedwater pump replaced.
  - Insulation repaired and replaced on numerous HRSG piping systems.
  - NDE inspections on HRSG and feedwater piping.
  - SCR dilution-air fan motor replaced.
  - Stack-damper linkage repairs.
  - HRSG blowdown-tank modification; check valve added to quench-water line.
  - Rebuilding of HP and reheat attemperator, IP feedwater, HP feedwater and other valves.
  - Completion of state-required internal boiler inspections.
- Other items included these:
  - More than 200 corrective, demand-task, and PM work orders completed by plant personnel.
  - Instrument transmitters and switches calibrated for numerous plant systems.
  - Diesel fire pump rebuilt.
  - Cooling tower: tower basin silt removal and cleaning, routine inspections, fill-material sample cell weights obtained, minor structural repairs, replaced all circ-water-system 6-in. lateral piping grommets in all four tower cells, circ-water pipe header expansion joints replaced.
  - MCCs, SF_6 breakers, 52G, and 4160-V contactors tested/inspected/cleaned.
  - CO_2 and deluge fire systems inspected/tested.
  - Lube-oil plate-and-frame heater exchangers for the steam and gas turbines disassembled, plates cleaned, gaskets replaced, and reassembled.
  - Steam-turbine pedestal restoration; epoxy repairs.
  - Gas- and steam-turbine Mark-V control system health-check inspections completed.

Outage results

Overall performance of the gas turbine improved as a result of the outage. Corrected output increased by 4701 kW (3.1%) and corrected heat rate decreased by 185 Btu/kWh (-1.9%).

Forecasting

A forecasting note extracted from discussions with plant personnel: "One critical item that helps us prevent negative surprises at Hermiston actually starts years before the outage." Daniel explains: "We review post-outage equipment and engineering reports as soon as possible after the outage, while the information is fresh. There are always recommendations for future outages in these reports.

"Also, there can be non-critical jobs that can't be completed during the outage, and they can get overlooked as we go back to post-outage duties. So, we try to issue work orders for these items right away so they can be tracked and remain visible.

"We've found that by practicing this, our maintenance budget forecasts are more accurate, and we have fewer surprises during future outages."

Final notes

Hermiston has received several awards over the years from CCJ for both safe operations and best practices. Examples include self-performing combustion inspections, hydrogen-purge remote activation, and others searchable at https://www.ccj-online.com/

Editors' discussions with Daniel on this outage noted the overall safety theme. "Best-practice safety adjustments" and "safety communication among all personnel" were repeated and emphasized, as was an attitude of trust and respect for all organizations and personnel involved.

"Every individual onsite, whether a plant employee or contractor, regardless of pay grade or title, has Stop Work authority," he states. CCJ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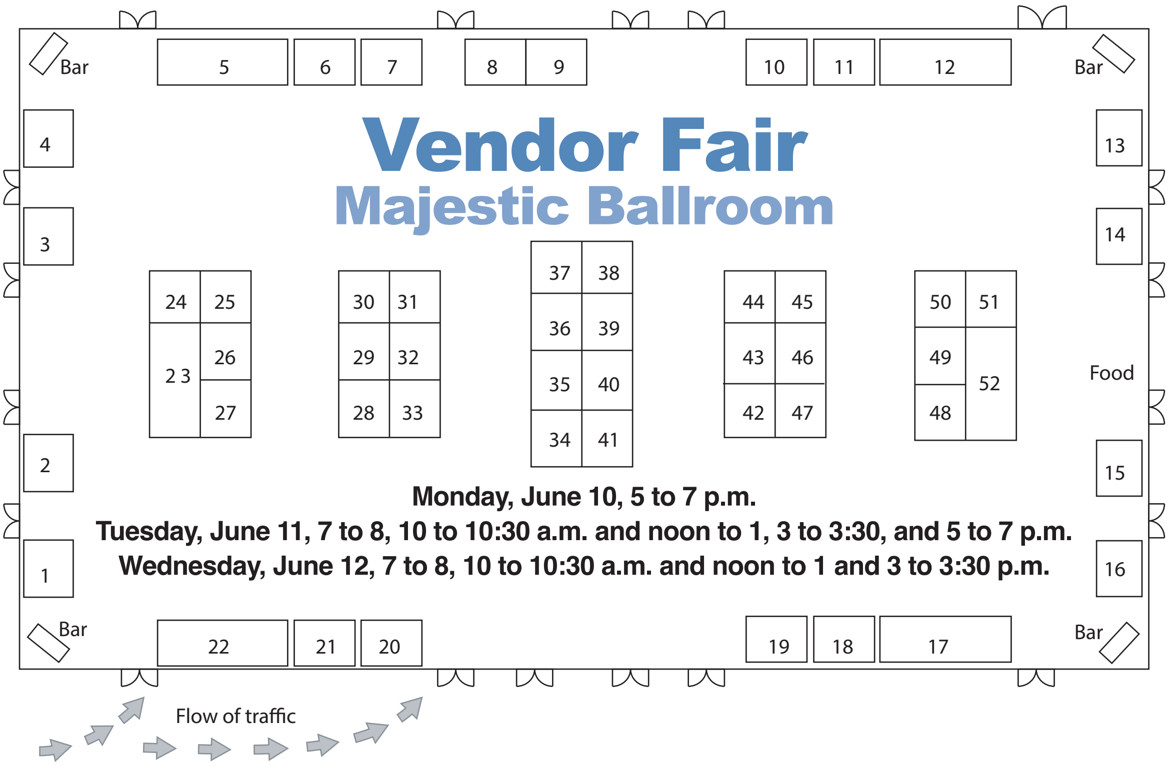

Exhibitors, alphabetical

Company **Booth**

Accurity Industrial Contractors LLC 49
Advanced Valve Solutions 10
ARNOLD Group USA Inc. 52
Babcock & Wilcox 18
Badger Industries 47
Baker Energy Group/Baker-Bohnert 6
Catalytic Combustion Corporation ...40
Clark-Reliance 21
Constellation Clearsight 39
CUST-O-FAB 42
Dekomte de Temple LLC 33
Deltak Inc. 50
Donaldson 38
EagleBurgmann Industries LP 29
Engineered Pump Services 32
Environex Inc 48
Environmental Alternatives Inc 9
EPRI 17
Eton Controls 8
Fucich LLC 30
Gas Path Solutions 41
GE Vernova 23
Groome Industrial Service Group 16
HSB 44
IMI CCI 45
Industrial Air Flow Dynamics Inc. 27
Industrial Degauss 25
InServ 46
Intertek AIM 11
KSB SupremeServ 4
Metroscope Inc 26
Millennium Power Services 24
MISTRAS Group 13
MOGAS Industries Inc 31
Nooter/Eriksen 28
Power & Industrial Services Corporation 20
PowerFlow Engineering Inc 37
Precision Iceblast Corporation 22
Questtec Solutions 35
S T Cotter Turbine Services Inc 36
Structural Integrity Associates 15
SVI BREMCO 2
Synergy Catalyst 43
TesTex Inc. 14
Thompson Industrial 34
Tuff Tube Transition by Viking Vessel 12
US Clean Blast 51
ValvTechnologies 1
Vector Systems Inc. 19
Vogt Power 7
Vogt Valves 3
ZEPCO LLC 5

Exhibitors, booth number

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2 .... SVI BREMCO
3 .... Vogt Valves
4 .... KSB SupremeServ
5 .... ZEPCO LLC
6 .. Baker Energy Group/Baker-Bohnert
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49 Accurity Industrial Contractors LLC
50 .... Deltak Inc
51 .... US Clean Blast
52 .... ARNOLD Group USA Inc

Groome Industrial positioned for growth

Groome Industrial Service Group, a recognized leader in specialty maintenance services across a broad range of industrial markets, is always working toward one goal: Provide top notch turnkey industrial services to every one of its clients, anywhere in the country. Groome took a huge step towards that goal when it recently announced the acquisition of Iowa-based W-S Companies and its entities.

GROOME
Industrial Service Group

This acquisition increases Groome's portfolio of services, geographic coverage, and equipment fleet, which will enhance its existing business, offer additional opportunities to clients, and help grow its customer base. Groome and W-S share rich histories, a strong commitment to their people and values that promote safety, integrity, and collaboration.

W-S Companies, one of the largest, privately held, veteran-owned and -operated industrial services companies in the United States, was founded in 1993. It is a multifaceted organization comprised of eight associated entities: W-S Industrial Services, W-S Mechanical Group, W-S Specialty Services, AllSouth Environmental, Ducks Paint Shop, Force Welding School, H_2O Underpressure, and Orange Industrial Services. These companies deliver high-quality services ranging from complex projects to more standard day-to-day operations. W-S and its entities' shared commitment to safety, integrity, and accountability is a cornerstone of its operations. They serve a diverse client base spanning industries such as power, food and beverage, refining, petrochemical, entertainment, utilities, chemicals, manufacturing, pulp and paper, and municipal.

The W-S entities offer industrial cleaning and maintenance services such as hydroblasting, hydro excavation, wet/dry vacuum services, media blasting, mechanical maintenance, explosive deslagging, boiler/exchanger cleaning and repair services, tank cleaning, video pipeline inspections, welding and fabrication, pipefitting and welding education, and industrial and municipal waste removal and disposal.

Groome is best known for its work in the natural-gas-fired power-generation space, focusing on catalyst maintenance and replacement, ammonia-injection-grid services, inlet-filter-house services, and most recently its patented KinetiClean™ HRSG tube cleaning service. In addition, Groome's industrial service mix ranges from painting shipyard cranes and full-scale plant clean-downs to installing aircraft hangar doors. Growth in recent years has also positioned Groome as a top maintenance provider in the coal-fired power-generation industry.

Groome also has a team of expert engineers and technicians that offer suggestions, insights, and custom specifications that help clients set realistic budgetary and time-frame goals. Their focus on safety, attention to detail, dedicated project management, and straight-forward communication is evident throughout each project from initial planning to successful completion.

Jeff Bause, President & CEO of Groome Industrial, states, "We are excited for W-S to join the Groome team, creating a bigger and better specialty maintenance company with an even stronger nationwide presence. Both companies provide a service mix that is complementary to one another while also offering unique specialty services."

Now combined, Groome and W-S have positioned themselves as leaders in industrial, mechanical, and specialty maintenance services with a continued focus on safety and value creation. Groome has significantly increased its national footprint with over 20 locations and, with a wider breadth of services, is poised to provide clients with an even higher level of turnkey solutions.

W-S Companies
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For more information about Groome Industrial Service Group and its newly expanded line of services, please visit www.groomeindustrial.com, or call 800-505-6100.

Bause

Technical program highlights

HRSG Forum 2024, less than a month away at the Marriott St. Louis Grand, June 10-13, features four days of advanced technical content and a unique balance of presentations, pinpoint education, focused discussions, and active sharing of solutions and new ideas of considerable value to owner/operators.

Each element of this important conference and exhibition is open to all attendees—including users, service and equipment providers, OEMs, and global consultants (turn back to p 53 for exhibitor list and booth locations).

Discussions and robust sharing of ideas are moderated by the well-respected experts Bob Anderson, Competitive Power Resources, the conference chair, and Barry Dooley, Structural Integrity Associates. They are supported by a steering committee of industry veterans: Eugene Eagle, Duke Energy; Albert Olszewski, Constellation Energy; Yogesh Patel, TECO Energy; and Scott Wambeke, Xcel Energy.

Sponsors of the annual meeting are identified by their company logos on p 52.

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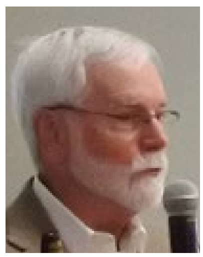

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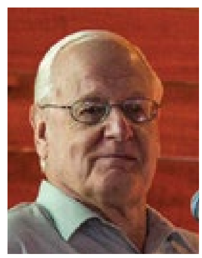


Dooley

Day One

The first day of the conference features two workshops. Andrew Toback of Environex Inc leads the morning event (8 a.m. to noon) on SCR/CO systems. His focus is on system design, chemistry, operation, and catalyst maintenance. More specifically:

- Design principles and arrangement of components.
- Chemistry—desired and undesired reactions and tradeoffs.
- Catalyst factors that impact emissions performance.
- Non-catalyst factors that impact emissions performance.
- Dual-function catalyst considerations. Which systems are a good versus poor fit?
- Ammonia/urea injection system operation—including different reagent options and their impact on system design and operation.
- Catalyst system O&M best practices.

Loyal Fischer of KSB SupremeServe North America is at the front of the room for the second workshop—a deep dive on boiler feed pumps, from 1 p.m. until the exhibit hall opens four hours later.

Highlights of Fischer's program:

- Centrifugal pump basics.
- Boiler feed pump construction.
- Pump installation.
- Pump operation.
- Routine maintenance.
- Typical overhaul.
- Performance changes.
- Troubleshooting.

A two-hour reception with adult beverages and heavy hors d'oeuvres closes out the day at 7:00.

Day Two

The lineup of morning presentations:

- Hydrostatic testing, *Ian Perrin, Triaxis Power Consulting LLC*
- TuffTube update: Regulatory acceptance and header replacements, *Marshall Hicks, Viking Vessel Services*
- Specifying replacement bypass valves, *Ory Selzer, IMI Critical Engineering*

The afternoon lineup:

- Cycle chemistry control and FAC for HRSG/CCGT plants, *Barry Dooley, Structural Integrity Associates*
- Fitness for service, *Jeff Henry, Applied Thermal Coatings* and *Jay Vattappilly, Hartford Steam Boiler*
- HRSG considerations and analysis before GT upgrade, *Vignesh Bala and Neal Holden, Vogt Power International*

The day's program closes with a networking reception in the exhibit hall from 5 p.m. to 7.

Day Three

Morning presentations include:

- CCGT plant improves demineralizer operation by optimizing clarifier coagulant, *Robert Russell, Veolia Water Technologies*

Note that the speaker program was not complete before CCJ went to press.

The afternoon presentations:

- HRSG prewarming system optimizes CCGT startup, *Norman Gagnon, Arnold Group* and *Eugene Eagle, Duke Energy*
- Stellite delamination prevention, *Richard Laukam, ValvTechnologies*
- Drum weld inspection, *Lester Stanley, HRST Inc*

A two-hour reception sponsored by EPRI completes the day at 7 p.m.

Day Four

EPRI's annual HRSG Technology Transfer Session updates attendees on the research conducted to improve combined-cycle operations. It begins with a State of the Industry presentation summarizing a few of the many challenges facing owner/operators.

The day revolves around HRSG and high-energy-piping case histories that encourage questions and discussion.

Reviews of EPRI's recent activities with both high- and low-temperature components complete the day. CCJ

Global organizations supporting HRSG Forum

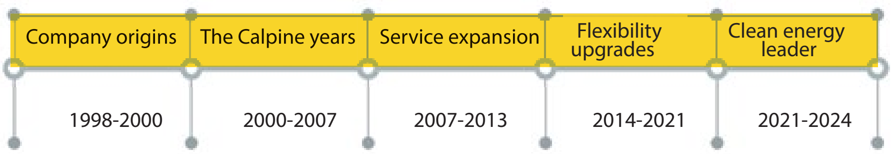
Origin story sets the trajectory towards user-focused solutions

Psychologists tell us that our personalities are largely established early in life. Some even argue that by the time you turn seven, how you behave is pretty much set for life. In other words, your origin story is really, really important.

Think about that as you read this first segment of CCJ's three-part report on PSM's 2024 Asset Managers Conference, which doubled as a celebration of the company's 25th anniversary.

With a bit of nostalgia, the first speaker used advertisements of the day to illustrate the company's historical timeline (Fig 1), showing its humble beginnings as an upstart non-OEM with some innovative ideas for improving gas-turbine performance, to one of the leading global, full-service non-OEM GT firms.

While the timeline in the latter years reveals several corporate ownership changes, the early years as a unit of Calpine Corp is most instructive. Calpine, itself an independent, non-utility generating company upstart at the time, set the pace in the industry for developing, owning, and operating combined-cycle powerplants.



1. Timeline illustrates PSM's evolution over the company's first 25 years with its core competitive distinction, technology-driven retrofits and upgrades, originating during Calpine ownership

Thus, unlike virtually all other leading non-OEM service players in the market, PSM's formative years were spent analyzing, repairing, and optimizing machines owned and operated by the leading combined-cycle-based generating company.

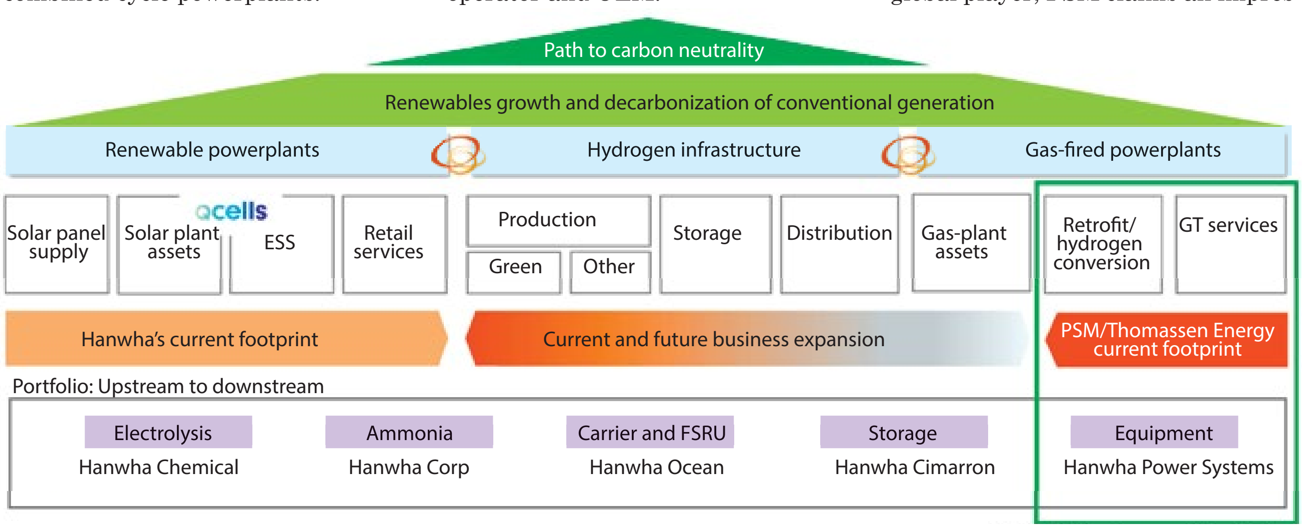
An independent Genco (as they were known then) like Calpine acquiring a machine shop spun many heads at the time. Everyone who recalls the O&M issues facing advanced GT technology users during that decade can imagine the opportunity this presented for PSM. Among other pluses, PSM was able to develop collaborative solutions as an *internal* partner, not through the often more adversarial (especially from a legal perspective) buyer-seller relationship of the owner/operator and OEM.

Thus was set the trajectory for PSM's focus on truly user-oriented solutions. As just one example, PSM's GTOP product line originated as the Calpine engine optimization program. Each of the corporate ownership periods allowed PSM to gain rich experience with most of the other gas-turbine models prevalent in the marketplace.

Today, PSM is owned by Hanwha, the seventh largest company in South Korea, with $US65-billion in total sales, and ranking 296 on the Forbes Global 500 List. Not a bad landing for a company launched by a few aeroderivative machine specialists.

In the trophy case

Along the journey from US startup to global player, PSM claims an impres-



2. Corporate parent Hanwha's growth strategy combines the supply of renewable energy systems (such as solar PV), gas turbines firing a range of new fuels to meet decarbonization targets, and new fuel supply and storage infrastructure. Note that FSRU is the acronym for Floating Storage and Regasification Unit

3. PSM is a full-scope aftermarket gas-turbine service provider with advanced technology. Robust remote M&D capability was added to PSM's portfolio of aftermarket services (list above) in recent years

sive list of "first in the industry" to:

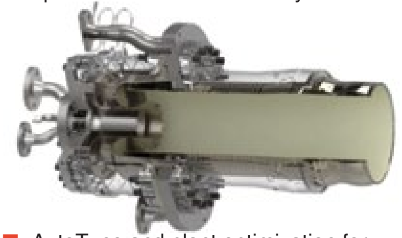
- Offer (from a non-OEM) F-class performance upgrades.
- Provide extended-interval combustors for 501F and 7F/9F machines as standard (30% lifecycle advantage).
- Offer a 7F R0 compressor blade fix.
- Develop a B/E class ultra-low-NO_x (sub-5 ppm) combustor.
- Offer extended operation down to 35% load (first and only).
- Develop an advanced F-class combustor system for a hydrogen blend.
- Commercially offer an additive-manufactured F-class turbine vane.
- Introduce an E-class combustor capable of 35% H_2 fuel blend with no diluents.
- Achieve a 60% H_2 fuel blend for a frame-type machine (dry).

Familiar brands

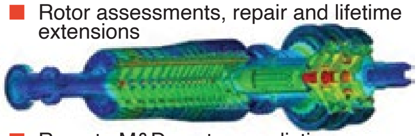
Many of PSM's branded technologies will be familiar to CCJ readers. Here is a quick review of where they stand today.

- The latest FlameSheet™ version, Gen VI, incorporates micro-mixing technology (more on this later), which has achieved sub-30% turndown (for the 7F) and allows better handling of highly reactive fuels like hydrogen, while maintaining emissions compliance. The technology is capable of firing up to 80% H_2 by volume in the fuel stream, and has been demonstrated on 60% H_2 for a 7EA machine.
- Exhaust-bleed technology, developed for the 7EA, is now available for the 7B/E/F and the 501F. Bypassing 10% of the engine's air flow, when combined with inlet bleed heat (IBH), enhances turndown by 10%.
- GTOP technology collectively has added 550 MW of capacity to units around the world. That's equivalent to a moderately sized power station.
- Compressor and turbine enhancements have led to a 2.8% flow increase without sacrificing efficiency.
- Sequential Fuel Injection (SFI) has enhanced load following flexibility up to 25% while maintaining emissions compliance.

- Retrofit combustion systems for operational and fuel flexibility



- AutoTune and plant optimization for improved reliability
- Full turbine upgrades for maintenance, performance improvements
- Rotor assessments, repair and lifetime extensions



- Remote M&D center, predictive diagnostics and maintenance
- Long-term agreements with full service coverage

4. PSM's products and services portfolio encompasses a wide variety of advanced technologies

- FlexSuite logic reduces startup periods, saving on fuel consumption and reducing CO emissions during starts and shutdowns.

60 to zero in 30

As the right side of the corporate strategy slide shows (Fig 2), PSM has a big role to play in Hanwha's carbon neutrality growth strategy. PSM's portfolio of services, upgrades, and retrofits (especially for H_2 combustion) for GTs marries up with Hanwha's current base in renewables, electrolysis, and ammonia. Both PSM and Hanwha will be aggressively expanding into H_2 infrastructure, including gas storage, LNG, and floating storage and regasification (FSRG).

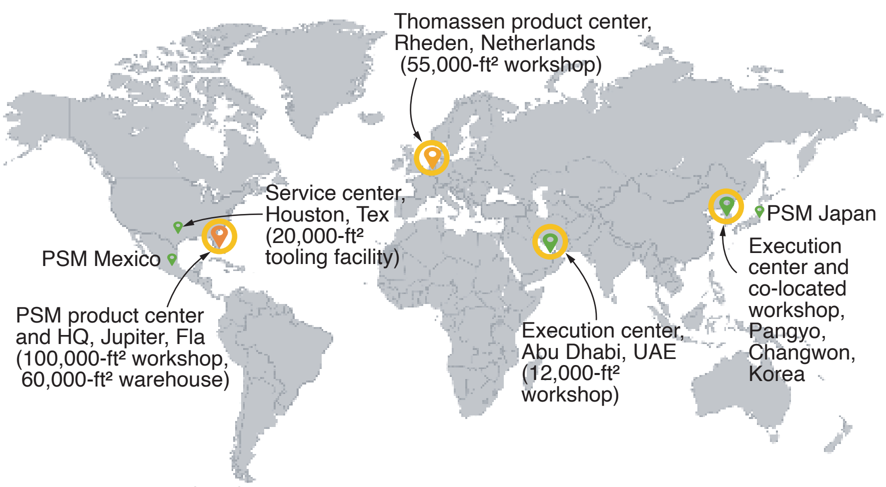
PSM's aftermarket services portfolio (Figs 3 and 4) now includes a robust remote monitoring and diagnostics (M&D) component initiated several

PSM's 25th anniversary is not just a day

Unlike married couples who may celebrate their anniversary on a specific day, the festivities for PSM include what it describes as The AMC World Tour: Retrofit Revolution – Technology to Transform. Tour dates include June 3-4 in Accra, Ghana; July 17-18 in Kuala Lumpur, Malaysia; and November in Abu Dhabi (details to come).

One of the key messages is that the race to decarbonize will be won by the early adopters. Thus, it is critical to identify and partner with companies/consortiums for a successful and timely transition to net zero.

Another key message to be delivered during the tour is that existing assets are the foundation for the energy transition and gas turbines are essential players for decarbonizing energy production. PSM has a suite of technologies expressly designed to help its customers evolve over the long-term as hydrogen plays a larger role in the transition and higher and higher H_2 blends are adopted as a gas-turbine fuel.



5. A major benefit of the Hanwha integration is the company's expanded global footprint. PSM's US and Mexico facilities now can leverage Hanwha/Thomassen Energy's strategic shop locations in The Netherlands, Korea, Abu Dhabi, and Japan

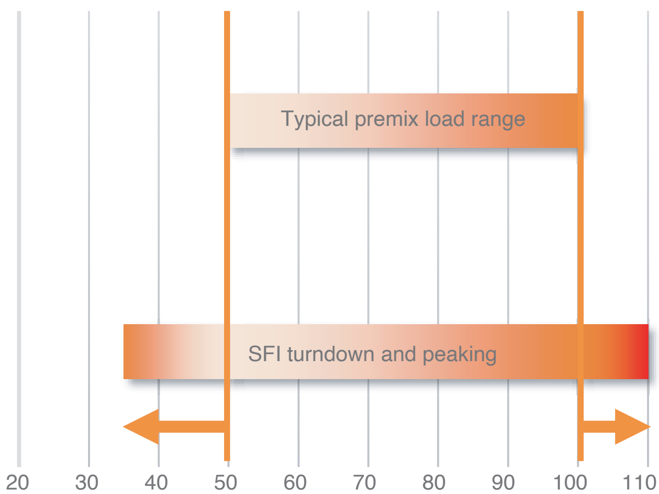
years ago, in addition to its traditional service, repair, upgrade, and retrofit of critical components. Incorporating advanced technology is considered to be a key differentiator from its aftermarket services competitors. The Hanwha integration expands its global footprint (Fig 5).

In 2023 alone, the company boasts 17 conversion projects, with some new product introductions. Among them: Nine FlameTops, three Low Emission Combustor (LEC) or SFI, two GTOP3.1, and three IBH/anti-icing. Add to that more than 250,000 field service hours clocked on behalf of its customers, including 50 large-scope outages. On the innovation front, the first-of-a-kind demonstration of FlameSheet technology with greater than 60% H_2 fuel blend rounded out the stellar look-back on the year.

Match technology to machine

If you cross-reference your machine to PSM's technologies (Table 1) you get an instant idea not only of what applies to your situation but the extent to which PSM has adapted its retrofit and upgrade products. The IBH system for expanding the turndown range is now available for the GE 6B, 7E, and 9E engines, as well as for Siemens 501 6B, D5, and F machines.

SFI (a "flameless combustion concept"), available for the 7EA, adds up to 25% load flexibility (at either end of the load range), resulting in turndown to 35% with full emissions compliance, or peaking capability for when those extra megawatts are especially precious on hot summer days. Contrast that to the typical premix load range (Fig 6).



6. Sequential fuel injection expands an engine's output regime to 110% at the top end, as well as to 35% turndown

A lesser-known technology perhaps is PSM's virtual flame detector, which addresses maintenance issues with flame detectors on B/E- and F-Class units. By using power output as a proxy for flame presence, PSM's FlameSheet logic eliminates the need for secondary optical flame detectors. For B/E units, the technique serves as flame detection in the secondary zone from lean-lean mode and above. For F-Class units, flame detection occurs at startup to allow engine to enter its warmup phase.

Add all of this to the company's suite of hot-gas-path (HGP) and rotor upgrade solutions across the model range. The speaker ran through the dizzying array of hardware improvements available to owner/operators of legacy GE engines (visit www.psm.com to see/learn more).

FlameSheet™ platform

PSM's FlameSheet technology, introduced a decade ago, has racked up an impressive list of milestones (Table 2)— including the first application to an E-class unit last year and the first Frame 5 commissioning this year. Recall that FlameSheet was developed for general operational flexibility, including up to 100% H_2 firing (depending on GT model), turndown to 30% with no sacrifice in emissions compliance, and a 32k-operating-hour/1250-start inspection schedule.

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

The technology comes equipped with 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. It has been demonstrated on the 7F and 501F. It also avoids hardware damage, outages, and trips from poor-quality fuel.

The latest generation of FlameSheet incorporates "micro-mixer" technology to better handle highly reactive fuels like hydrogen. Generically, micro-mixing refers to the goal of decreasing the "scale" of the fuel/air mixture, reducing flame length and residence time (for combustion reactions to take place), and making the mixture as uniform as possible.

This can be accomplished by reducing the size of fuel nozzles and using a larger number of smaller nozzles. PSM's micro-mixing technology achieved sub-30% turndown in a 7F machine.

Described as a "combustor within a combustor," FlameSheet comprises four fuel circuits—pilot, pilot tune, main 1, and main 2. Subsystems include combustion dynamics monitoring, flashback monitoring, ignition, and AutoTune. Other salient features include these:

- Aerodynamic trapped vortex for

7. "Navigating Industry Trends and Challenges," the opening panel discussion on Day One of the conference, was chaired by Brian Micklos, PSM's director of strategy (left). To Micklos' right, in order, are Claude Couvillion, Middle River Power; Lee McFalls, Kindle Energy; Steve Kellogg, ExxonMobil Low Carbon Solutions; Tom Long, Calpine; and Jeff Benoit, PSM's VP for clean energy solutions

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.

Navigation tools

The conference included a panel, "Navigating Industry Trends and Challenges," with heavy hitters representing a broad swath of the owner/operator community: Claude Couvillion, senior VP, operations and development, Middle River Power; Steve Kellogg, hydrogen strategy advisor, ExxonMobil Low Carbon Solutions; Tom Long, senior VP, asset management and outage services, Calpine; and Lee McFalls, COO, Kindle Energy (Fig 7).

There was broad concurrence on the need for regulators to remain technology-agnostic and give industry players the flexibility they need to achieve the proper balance among technology selection; federal, state, and local policies; and market forces which vary considerably from ISO to ISO and region to region.

Limitations on energy-storage solutions and carbon capture and storage (CCS), while presenting opportunities for development, mean that the firm power produced by GT-based power stations will

1. B-to E-Class upgrades/conversions address individual market needs

Upgrade	Emissions	Turndown	Output	Fuel flexibility (H_2)	Availability	7EA	6B	F5
LEC III™/ NexGen combustor	X			X		X	X	
FlameSheet™ combustor	X		X	X		X	X	X
Inlet bleed heat (IBH)		X				X	X	
Inlet / filter anti-icing (IBHAI)		X			X	X		
Exhaust bleed (ExB)		X				X		
Sequential fuel injection (SFI)		X	X	X		X	X	
AutoTune	X	X	X	X		X	X	X
Peak fire			X			X	X	X
Wet compression			X			X	X	
Fast start/fast ramp (FS1/FS3)	X				X	X		
Exhaust cooling upgrade		X	X			X		

2. FlameSheet™ key metrics

Number of units (under contract by 2026	30
Number of 7FAs.	22
Number of 501Fs.	6
Operating hours (since 2015)	More than 250,000
Fleet leader, hours	More than 60,000
Fleet leader, starts	More than 330
First E-Class commissioning	2023
First Frame 5 commissioning	2024
Number of units burning H_2	4

always be critical. Aging infrastructure presents a separate challenge.

Calpine's Long noted that the company operates 26,000 MW in 22 states and is the world's largest geothermal plant owner/operator. Calpine, which prides itself on its innovation culture, has 700 MW of battery storage facilities operating or in development in California, as well as other solar and thermal projects. It considers CCS a "critical" piece of future infrastructure and has secured funding for two major CCS projects in Texas and California. Long briefly mentioned H_2 as a solution percolating back two decades.

It may be surprising to learn that a huge "fossil fuel" extraction and production company like ExxonMobil (which also operates a fleet of 330 gas turbines) has reorganized into three primary business segments, one of which is "Low Carbon Solutions." The company is supporting the segment with a projected $20-billion of investment by 2027.

Kellogg lists the company's net-zero ambitions as (1) to reduce GHG (greenhouse gasses) intensity by 20% to 30% by 2030, (2) to achieve net zero for its Permian Basin assets by 2030, and (3) to achieve net zero for Scope 1 and Scope 2 emissions by 2050. ExxonMobil sees supplying hydrogen and ammonia fuels to the power market and CCS services as two key areas for growth.

Note that Scope 1 emissions are direct GHG emissions that occur from sources controlled or owned by an organization; Scope 2 emissions are indirect GHG emissions associated with the purchase of electricity, steam, heat, or cooling.

Couvillion lamented the "lack of foresight" on the part of regulators, and called out New Jersey in particular, for forcing the shut down of plants without due consideration of economic and environmental impact. Middle River is a private equity firm which manages investments in distressed assets. They are adding battery storage assets in California and expanding in the PJM market.

Batteries are a diversification strategy, even though large-scale battery additions could compromise the lifespan of its GT assets. Batteries help the company secure long-term contracts with community choice aggregators (CCA) and utilities and stabilize revenues under varying market scenarios.

Kindle Energy is responsible for 10,000 MW of power, primarily in PJM. McFalls was especially proud of a significant new project in Louisiana, the Magnolia Power Generating Station, a 700-MW 1 × 1 combined cycle powered by a 7HA.03 gas turbine and scheduled for completion next year. McFalls also underscored the company's resilience in Ercot during the most recent winter storm.

Other notable gems distilled from the panel discussion:

- The CCA program in California has enhanced competition among suppliers.
- PJM is experiencing significant "market constraints," exemplified by its request for 200 MW by June.
- Scarcity of manufacturing resources creates long lead times for new units, so current focus is on preserving and upgrading existing assets, especially GTs.
- While developers of new GT projects in California typically experience protracted approval times, the state has been able to expedite approval for "energy infrastructure upgrades" to respond to crises.
- PJM is receptive to carbon-capture projects, especially when integrated into existing CO_2 transport and delivery infrastructure.
- The pros and cons of pre-combustion (natural gas reforming, for example) versus post-combustion (amine-based stripper processes) carbon removal proved to be a hot topic, especially regarding siting, available space, process complexity, costs, and long-term contract pricing for captured CO_2. CCJ

A proven method for improving operational reliability

By Rishi Velkar and Todd Robison, NV Energy

Combined-cycle plants built during the construction boom of the late 1990s/early 2000s are now about 70% through their 30-yr design lives. Although not originally designed to cycle, ever-increasing amounts of solar energy readily available on the grid, especially in the Southwest, make it economically prudent for these plants to cycle off completely from time to time throughout the year.

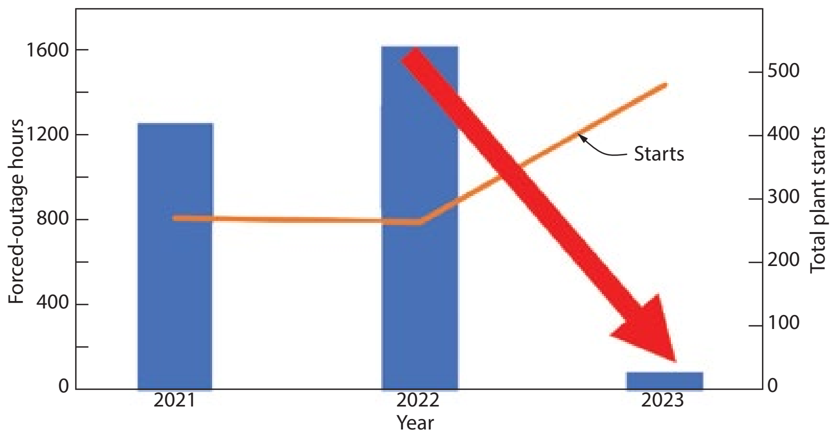
However, cycling and plant age contribute to premature equipment failure, negatively impacting reliability and increasing operating costs. It's important for plant personnel to be proactive to properly address issues affecting availability and avoid outages of long duration.

Lenzie was one of the largest combined cycles in the nation when completed in spring 2006. Its two 2 × 1 7FA-equipped power blocks share a common 100-cell air-cooled condenser, believed to be the largest in North America at the time

The following case history concerns NV Energy's Chuck Lenzie Generating Station, a 2 × 1 natural-gas-fueled combined cycle located about 30 miles north of the Las Vegas Strip. The plant has two power blocks, each equipped with two 7F gas turbine/generators and one D11 steam turbine/generator.

Rishi Velkar and **Todd Robison**

Lenzie, which went into service in 2006, achieved an equivalent availability factor (EAF) of 98.6% in 2023, its highest ever. While the number of starts doubled from about 63 per turbine in 2022 to more than 140 per turbine in 2023, the Lenzie team was able to reduce the plant's forced-outage hours to only 153 compared to more than 1000 hours from the prior years. This was achieved primarily because of Lenzie's strong adherence to NV Energy's work management policy/practices (figure).



Work management policy and practices boost Chuck Lenzie Generating Station's equivalent availability factor to 98.6% in 2023—the highest level since commissioning in 2006

Recall that the primary purpose of work management is to recognize, define, prioritize, and document the maintenance effort required to restore and preserve system function for reliability. Work identification encompasses both reactive (corrective) and proactive (preventive) work and requires cooperation between the operation and maintenance staffs. The outcome is quality work that improves plant reliability and availability.

Process plants typically have a Computerized Maintenance Management System (CMMS) incorporating work orders that can build up over time if not properly maintained. Lenzie started 2023 by reviewing, with representatives from both operations and maintenance, each work order in backlog.

Result: The backlog of corrective maintenance orders was reduced from 600 to 120, the preventive work orders from 100 to 20. Note that NV Energy refers to a storage place for work orders that have not been closed as "The Backlog."

An accurate Backlog is necessary to continually evaluate maintenance requirements and successfully perform work planning and scheduling activities. Duplicate work orders, and jobs that had become irrelevant or impractical, were purged from the Backlog; they divert attention from real priorities and make it impossible to accurately gauge the workload.

The next step in the work-management process is a critical one involving the work planning done by way of scheduling software. Work scheduling is the process of work management that enables the plant to improve the effectiveness and efficiency of the maintenance effort by doing the right work at the right time using the right resources.

The process of work scheduling is essentially determining the when and who of the work-management process by prioritizing the work backlog and then matching it to the available resources. This is conducted using the principle of joint prioritization—the collaborative prioritization of work among key stakeholders.

Another critical piece of the puzzle is to maintain the Short Notice Outage Workorder list (SNOW), a list of work orders that take an outage to complete. It is vital to plan the work in advance so when an opportunity presents itself during an outage, forced or planned, the work can be completed, not put off until the last minute. At Lenzie, the SNOW list is reviewed and modified/updated multiple times annually.

However, the most important practice that a powerplant should adopt is to have constant communication between its operations and maintenance organizations. Since operations is the most important customer at any plant, it is the eyes and ears in the field and the first alert to issues. But these must be communicated to maintenance and it is vital for management to provide a platform to support these discussions. At Lenzie knowledge is transferred during the morning meeting at 6:10, after the shift change. This is where operations makes maintenance aware of any issues that present a reliability risk.

Also, as power companies plan to retrofit and upgrade legacy equipment and processes as plants approach end of life, one topic often left out of the discussion is the importance of stocking critical spare parts. Having critical spares on hand can reduce downtime significantly. During 2022-2023, Lenzie personnel identified and stocked more than 200 spare parts in the warehouse.

Finally, keep in mind that Lenzie was able to exceed its EAF goal by adopting a proactive maintenance approach. Given that combined cycles likely will be cycling more in the future, this might be a good time to review your plant's mode of operation and method of maintenance planning. CCJ

Impact of Code changes to Gr 91 allowable stress values

By Cesar Moreno, HRST Inc

Gr 91 material is named after its main components: 9% Cr and 1% Mo-V. It was developed in the late 1970s, with the focus of its use in the nuclear power industry. The material is part of the Creep Strength Enhanced Ferritic (CSEF) steels group, which includes its predecessor, Gr 9. One of the main factors supporting the creep resistance of CSEF materials is their microstructure. This is why it is critical to maintain proper fabrication procedures to obtain the full capabilities of the material.

Module	Material (SA-213)	Design pressure, psig	Calculated ASME design temp, F	GE DLN2.6+ (2 x 1 CC, GT 90 MW, 59F ambient)
SHP4	T91	2301	1084	1133
RHT3	T91	653	1094	1090
RHT2	T91	653	1094	1023
SHP3	T91	2301	1029	1018
SHP2	T91	2301	1051	947
RHT1	T91	653	1094	924
SHP1	T91	2301	760	862

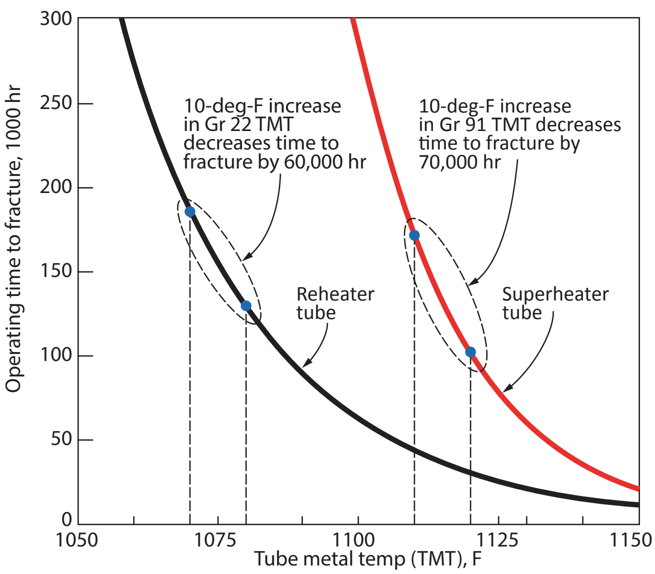
1. Tube metal temperatures calculated by HRST engineers for various operating conditions reveal that the highlighted values exceed the design temperatures used prior to the Code changes

Shortly after its development, Gr 91 material soared in popularity. It offered many significant benefits—including reduced minimum wall thickness (up to about 40%) for the same creep life as traditional boiler steels. In addition to the reduction in MWT, Gr 91 boasts up to a 12-fold increase in fatigue life. Additionally, it has about an 18% lower coefficient of thermal expansion than Gr 22, making it especially attractive for applications in cycling units that frequently experience transient conditions.

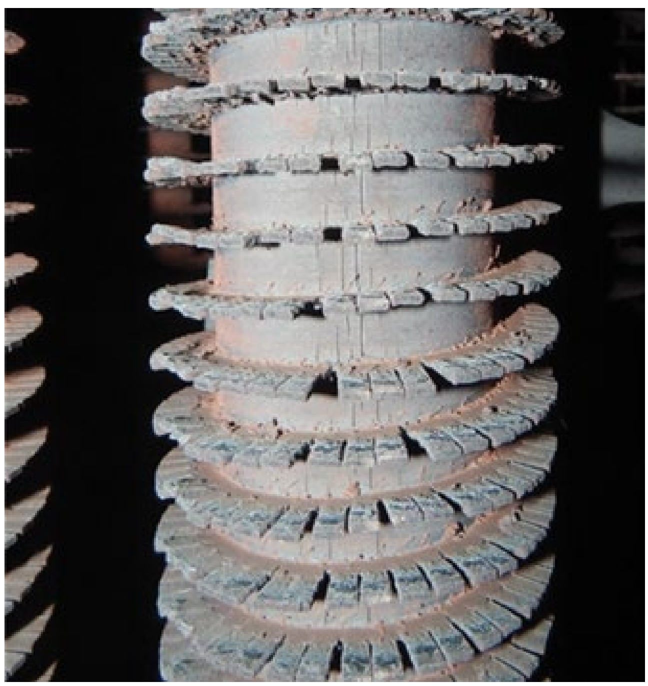
As the industry continued to develop, and new equipment required more demanding operating conditions, the market for Gr 91 grew quickly. This encouraged the mass production of Gr 91 material which often led to producers maintaining only the minimum requirements in the chemical composition and fabrication process.

Some of the cost-saving measures applied in production—such as lean chemical composition, application of minimum guidelines for heat-treatment cycles, and varying production processes (strand casting versus ingot)—lead to measurable variations in the final compositions of different heats. The combination of these variables is detrimental to the final characteristics of the material.

Given the wide use of Gr 91 material in the industry and the vast amount of data collected over several decades of in-service applications, there is now information available to provide more accurate results for design limitations and life expectancy of the material.



2. Estimate remaining life in your boiler tubes based on tube metal temperature. T91 superheater tube specified for 1800-psig service is 1.5 in. diam with 0.12 in. minimum wall; T22 reheater tube for 500-psig service is 2.5 in. diam with 0.12 in. minimum wall



3. Overheating of this Gr 91 tube is in evidence

Predicting creep life for Gr 91 generally has a high degree of uncertainty and extrapolating from (relatively) short tests is not reliable. The availability of long-term data (over 30,000 hours in operation) allows for more realistic estimates of the material's life.

In the 2021 revision of the ASME Boiler and Pressure Vessel Code, the allowable stress values (ASVs) for designs using Grade 91 materials were reduced. This decision was based on a combination of factors, but seemingly driven primarily by the significant differences in the material's capabilities when produced under ideal production conditions versus those produced following the absolute minimum requirements.

The material is now classified in two categories, Type I and Type II, differentiated by their chemical composition. Type II Gr 91 has the stricter requirements of the two, producing a higher-quality material which more closely resembles the composition used during the original development and testing.

The reduction of ASVs has a direct impact in HRSG design considerations. At a typical operating condition with a tube metal temperature (TMT) of 1100F, the new ASVs for Type I and Type II materials see a reduction of 15.5% and 11.6% respectively. This directly results in a higher MWT requirement for the same operating temperature; conversely, it reduces the allowable TMT for existing designs.

In addition, there are many other industry changes that add to the considerations of the Code change. Many plants have implemented GT upgrades which often create more demanding conditions for the HRSG. Operating profile changes, especially more frequent operation at lower loads also have a significant impact on the expected life of systems using Gr 91 material. Other issues such as non-uniform flow distribution in the burner duct area, increased firing temperature, missing baffles that create bypass lanes, and internal oxide growth can exacerbate the problem.

Most HRSG designs employ Gr 91 material near its limits, which creates a situation where a small increase (15 to 20 deg F) in TMT could have a drastic reduction in the expected life of the material (Figs 2 and 3).

HRST has performed analyses of specific cases using the Larson-Miller Parameter (LMP) for creep-life approximation and found up to a 40% reduction in expected operating hours for an 11-deg-F TMT increase. Given the possibility for these types of situations, consider putting steps in place to evaluate the current condition of your Gr 91 systems.

ASME B31.1 provides requirements for monitoring the condition of external high-energy piping (HEP), also commonly referred to as covered piping systems, or CPS. Inside the HRSG, the design limits should be reviewed using the new ASVs to determine if there are any concerns. Following this review, if the values are not ideal, the evaluation can be repeated using the actual operating conditions of the plant.

Once this has been done a condition assessment can be developed. It should include an individual assessment of each system, stress analysis for the concerning areas, and NDE. Finally, if problems are identified during the assessment, they can be used to determine specific locations of high risk. Destructive assessment can be performed for the material to determine its chemical composition and heat-specific strength, which would help guide the appropriate actions to take at that point. CCJ

Premature failures of formed tees

***Editor's note:** Jeff Henry, Applied Thermal Coatings (ATC), and Jayaram Vattappilly, Hartford Steam Boiler (HSB), conducted a webinar Jan 24, 2024 on "Premature failures of formed tees [tee intersections] in high-energy piping systems," a topic introduced at the 2023 HRSG Forum (https://HRSGforum.com). Use the QR code nearby to access the hour-long event.*

Webinar highlights

Recently, there have been several premature pressure-part failures in both conventional and combined-cycle powerplants involving formed tees of various sizes that met the requirements of ASME B16.9. These failures have occurred in high-temperature steam systems where the specified material is Grade 22, 91, or 92.

Henry and Vattappilly explain the possible causes of the failures and outline a structured program to identify tee intersections that might be at risk.

For formed tees in the US alone, there have been multiple failures in multiple units. The Electric Power Research Institute (EPRI) estimates the number of tees potentially at risk to be in the thousands.

Watch the webinar to:

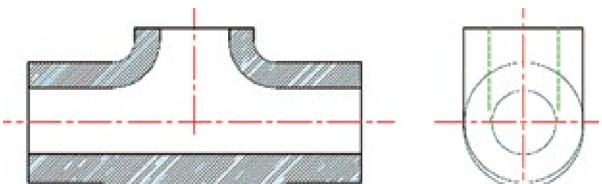
- Learn the history of ASME B16.9 tee failures involving material Grades 22, 91, and 92.
- Understand construction code requirements when using tees in a power boiler or in power piping systems.
- Review the details of a program designed to mitigate the risk of premature failure based on design, materials of construction, and operating conditions.

Note that EPRI has a program in place for this topic which was issued as an alert in 2023.

What is happening?

Henry leads off with premature failures of formed tees, stressing that we are looking at intersections designed and fabricated according to ASME B16.9 standards, *Factory-made wrought steel buttwelding fittings*.

The webinar focuses on the branch-type configuration commonly used in power boilers and power piping. These are geometrically complex components (crotch, branch, etc). During manufacture, it is absolutely critical to keep geometry and thickness consistent (Fig 1).



1. Tee, formed as an integral component, is commonly used in power boilers and power piping

A review of EPRI case-study data reveals 14 plants that experienced leaks in Grades 91 and 92 materials with operating hours between 39,000 and 78,000. A key issue is that expected life should be around 300,000 hours, or longer.

Case study

Attention turns to a failed 10-in. tee in a South Carolina coal-fired plant after 80,000 hours. This occurred at just over 25% of the expected life of a P91 tee.

Primary areas of damage are a through-wall crack at the crotch position and cracks at the toes of both the run and branch girth welds (Fig 2, left). The through-wall crack at the crotch position is ID-initiated. Cracks at the toes of both the run and branch girth welds are OD-initiated.

Henry stresses that the plant experienced similar damage in multiple tees on two units. Material specification for all was Grade 91.

He then reviews details of the cracking on both the OD and ID surfaces, and specifics of damage profiles and crack development (Fig 2, right). He emphasizes wall thicknesses and notes the "short leg length" for both the runs and the branch.

Discussion then moves to chemical composition of the steel. The as-tested composition was not as specified, but neither was this

2. This 10-in. tee failed after only 80,000 hours. A through-wall crack is visible at the crotch position on one side of the tee (left). Another crack, partially through-wall at the crotch position on the opposite side, is shown in the two photos at the right the real problem. Henry explains that although composition was not the root cause, this does indicate a problem with quality control in manufacturing.

He also discusses minimum wall thickness according to Code. In this case, the center of the crotch position had the thinnest wall of the tee (Fig 3) and right at the specified minimum wall thickness of 44 mm according to B16.9.

Vattappilly then offers a detailed discussion on ASME Section 1, ASTM, and various specifications and rules.

He reiterates that in the case discussed, the primary damage mechanism is "creep-driven and creep-dominated damage in response to the operating conditions." Vattappilly also states that the component was supplied by what is considered "one of the premier OEMs in the world."

He explains, with examples, the stress intensification resulting from a hole (a/k/a opening) made in the pipe, and tells us why the stress pattern is important information.

In short runs, the stresses from an opening normalize (attenuate) as you move away from the opening. There is high stress as a result of the opening—so the run length is a critical factor. The stress pattern at the crotch/opening is important as well.

3. As produced tee wall thicknesses are in millimeters. Note the short leg lengths for both the run and branch

Vattappilly then reviews thickness and area calculations for a tee that failed, and offers a detailed discussion on Area Reinforcement Rules, ASME Section 1.

Knowing the risk

Henry next points out the benefits of assessing inherent weaknesses.

Investigations should verify dimensional measurements and geometry, chemical analysis, hardness profiles, and details of heat treatments—all focusing on creep resistance.

An effective assessment program should include:

- Wall-thickness measurements at multiple locations to define overall tee configuration, with emphasis on the crotch position.
- Chemical analysis by positive material identification (PMI) testing, or removal of material to obtain more accurate laboratory analysis.
- Hardness testing to verify processing condition.
- PT or MT of girth welds and crotch of tee.
- Volumetric inspection for cracking, focusing on the crotch position.

If damage is not found, tees should still be ranked based on relative risk.

If damage is found, repair options will be needed to assess operation until a replacement is available. CCJ

Vattappilly

Henry

Design considerations for SCR, ammonia equipment

By Vaughn Watson, Vector Systems Inc

The efficiency and long-term performance of an SCR system is largely dependent on several key design considerations for its various components. When complex NO_x reductions on heat-recovery steam generators (HRSGs) are required, there are critical aspects of the system that must be addressed to ensure success. While the catalyst often gets all the credit, *and all the blame,* when performance declines, careful attention to system design can mitigate or prevent many of the top factors contributing to SCR issues.

Catalyst design itself is crucial to the effectiveness of the emissions control system. Catalyst volume, formulation, and pressure drop must consider the totality of operating scenarios the boiler will encounter. This evaluation should include all load levels, including the minimum emissions-compliant load (MECL), that the boiler will operate within.

All ambient conditions also should be considered. This is especially important for boilers firing multiple fuels or blended fuel streams. Your evaluation must include all operating cases from the HRSG OEM, but also interpolation of DCS data trends, if evaluating an existing unit for catalyst performance.

Additional testing to ascertain the NO/NO_x ratio is important because high NO_x speciation can be a major issue to SCR efficiency and require specific SCR catalyst formulations to achieve desired NO_x reductions. Be sure to consider boiler turndown as well because the NO_x produced typically is higher, and the decrease in exhaust temperature will limit catalyst efficiency.

SCR catalyst should be inspected at every outage to ensure the catalyst face is not blocked by rust or insulation (Fig 1). This can majorly affect SCR catalyst performance by masking the SCR's active pore sites.

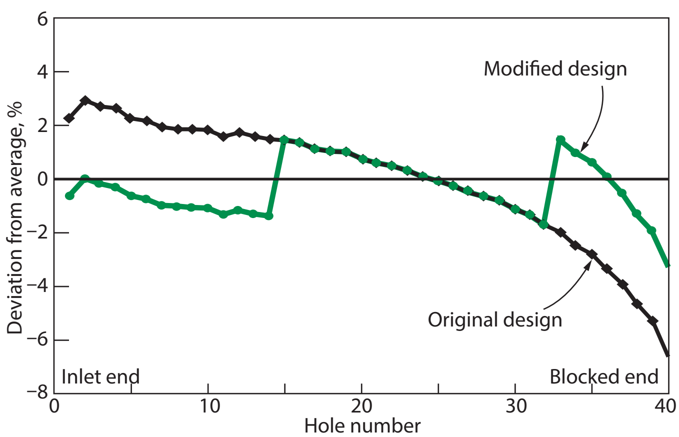
Bypass can greatly affect NO_x and ammonia slip. The catalyst support structure, as well as the perimeter seals, should be inspected to ensure there is no bypass of exhaust gas and ammonia. Assure catalyst modules are well packed to prevent ammoniated exhaust gas from passing unreacted through gaps around the catalyst bed. On a high-performance SCR, small amounts of bypass can drastically add up to the inability to meet objectives.

Ammonia distribution within the exhaust-gas cross section is a major factor in the catalyst's ability to properly reduce NO_x levels. This important part of the system falls on the design of the ammonia injection grid. AIG design must consider the amount of ammonia and diluent required for the reaction, as well as the ability to inject and mix the ammonia with the NO_x present in the exhaust gas (Fig 2).

1. Inspect SCR catalyst at every outage to ensure the catalyst face is not blocked by rust or insulation

Give careful consideration to injection pressures, mass flow, and density change along the length of each AIG lance. Injection-grid design for advanced NO_x control will carefully vary injection orifice sizing, spacing, and angle of injection necessary to ensure the $NH_3:NO_x$

2. Ammonia distribution within the exhaust-gas cross section is a major factor in the catalyst's ability to properly reduce NO_x levels



3. Deviation from the average mass flow rate through injection orifices with a single-zone reagent lance (original design) compared to results for a three-zone lance with different injection-hole diameters in each zone (modified design) distribution is matched to the volume of catalyst (Fig 3).

Inspect the AIG every outage to ensure there is no significant plugging, which could have a huge impact on catalyst performance. Clean the AIG if you find plugging, then determine the root cause. Often, the design of the AIG can be improved to achieve better performance and provide some resilience against frequent plugging issues.

Avoiding many SCR performance issues begins with the ammonia supply. Work with a reputable and accountable chemical supplier to ensure you are getting the reagent purity necessary for your system. Avoid ammonia contamination in transit to the plant by requiring dedicated trucks for each haul.

Also, require certificates and test reports before offloading to help protect the system against such contaminants like chlorides and calcium. These impurities can damage and plug the various components of the ammonia system.

Specifying the correct purity grade of ammonia is critical for aqueous ammonia systems; reagent-grade ammonia is the best option. The key differentiation is the purity of the water content of the solution which may contain soluble minerals that can plug, foul, erode, and damage SCR system components.

Such impurities in the reagent solution can lead to vaporizer fouling, AIG plugging, and potential catalyst performance problems. Keep in mind that it only takes one bad load of ammonia to experience the headaches associated with ammonia impurity.

By ensuring the foregoing factors are considered in the SCR and ammonia-system design, and addressing problems when they are discovered, are essential to an efficient SCR system capable of advanced NO_x reduction. CCJ

Real-time damage monitoring of HRSG components

Editor's note: *During the main-session presentations at HRSG Forum 2023, Duke Energy and Structural Integrity Associates Inc (SI) jointly presented on an online "HRSG damage monitoring system," which is highlighted in CCJ's summary report of that conference (Issue No. 77, p 65).*

At the same Forum last June, Jacob Boyd presented "Wireless high-energy-piping monitoring program," recently implemented at his plant, CPV's St. Charles Energy Center in Maryland (Issue No. 77, p 68).

Both topics were expanded during the two-hour webinar reviewed below, "Real-time damage monitoring of HRSG components," held Nov 7, 2023. Connect to a recording of that event, coordinated by CCJ, via the nearby QR code. What follows are selected highlights of what you will see and hear in this webinar.

Monitoring at Duke Energy

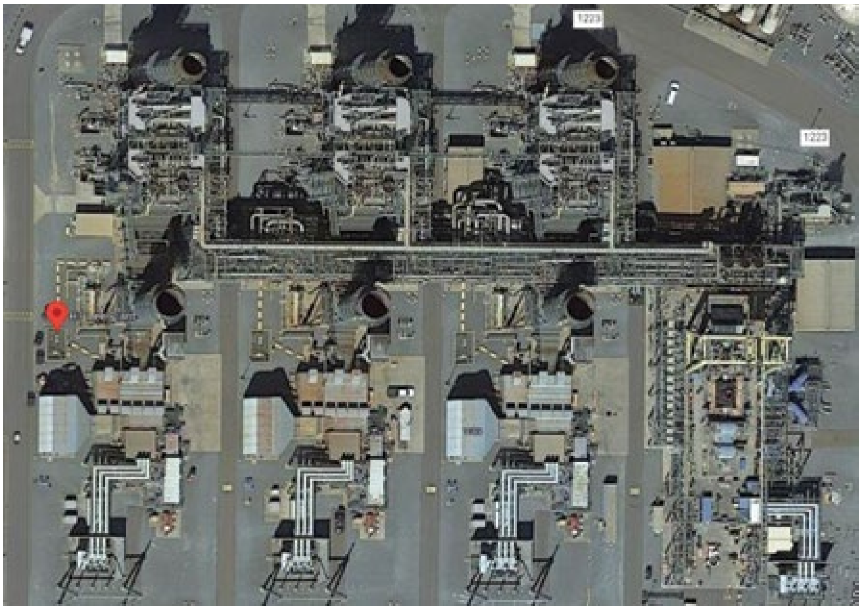
Structural Integrity's Kane Riggenbach introduces the webinar while Duke's Eugene Eagle reviews for listeners his company's damage monitoring system. They offer a real-time assessment of system performance and component integrity for both HRSGs and high-energy piping (HEP). The webinar focuses on Duke's goals, implementation, significant results, and future plans.

The online monitoring system begins with existing plant monitoring equipment for temperatures, pressures, steam flows, and valve positions. Duke and SI then add specific temperature instrumentation (in this case, 64 thermocouples per unit). All data feed into Structural Integrity's PlantTrak™ software, relayed to SI through a secure VPN connection. Company analysts then look for indicators and trends that affect creep and fatigue life, and monitor high-temperature alerts and other abnormalities specific to the HRSG components.

The reference plant (Fig 1) has three triple-pressure HRSGs behind Siemens F-class gas turbines that have accumulated 70,000 service hours since 2012. Currently in baseload, the plant is moving into cycling operation, expected to increase wear and tear on the units.

The purpose of the new monitoring system is to look more closely at these high-temperature components susceptible to creep, fatigue, corrosion fatigue, oxidation, and exfoliation:

- Interstage attemperators.
- Bypass superheaters.



1. Duke Energy's H F Lee 3 × 1 combined cycle tracks damage to HEP and HRSG components in real time

2. Pipe-hanger position monitor (arrow) helps predict high-stress locations within the piping system

- Intermediate headers and tubing downstream of attemperators.
- Branch connections.
- Final-stage outlet headers.
- Drums.

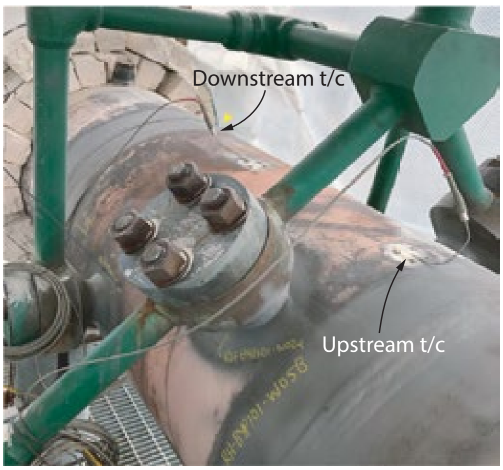
As Riggenbach summarizes, this "allows you to dig deeper into what might appear to be acceptable results."

The webinar offers data comparisons for operating modes, comparisons between units and sites, the effects of low-load operations, operating with and without steam sparging, and the impacts of startup time changes.

One key benefit discussed is help in targeting inspections, setting inspection times and budgets, and basically, states Riggenbach, "finding the problems before they find you."

As Eagle explains, "These are big and important units for Duke. They are highly efficient, and if we can get maximum life out of them while ramping them a bit harder, or cycling them more, we can get the most value out of these assets."

Kane then addresses specifics of instrumentation which he says are "now more specific to component life management than simply process variables." He explains that detection (instrumentation) is now looking at both magnitude and frequency of events. Such monitors look at temperature differentials, ramp rates, over-temperatures, and other items. This leads to trending, analysis and diagnostics, and setting priorities.



3. Thermocouple locations in the hot-reheat bypass system

At this point in the webinar, some questions and answers are monitored by Co-chairs Barry Dooley, Structural Integrity, and Bob Anderson, Competitive Power Resources.

An interesting caution for older HRSGs: Historical operating data could be difficult to obtain and verify. Also, system and component changes over the years might not be well documented.

Other questions discussed include benefits to parts supply and storage, fitness-for-service predictions, and benefits to control-logic changes.

High-energy piping

Jacob Boyd then discusses wireless HEP monitoring at the 2 × 1 St. Charles Energy Center, a program implemented with SI. This plant, commissioned in 2017, has fast-start 7FA.05 gas turbines, a D-11A steam turbine, and CMI HRSGs. The plant cycles 140 to 170 times per year.

In late 2019, the site experienced a through-wall leak at the girth weld of a hot-reheat (HRH) bypass line. Root cause was thermal fatigue. Plant personnel worked with SI to install local thermocouples to better assess thermal transients during operations.

The presentation includes descriptions of data collection nodes and e-mail notifications, highly valued at St. Charles because of limited engineering and walkdown staff.

Cycling concerns led to wireless monitoring of the HEP system, again working with SI (Fig 2). HEP monitoring examples highlight a growing area of concern at many plants.

At this point in the webinar, questions are again coordinated by Dooley and Anderson.

More data

SI's Wes Bauver, follows with various case-study examples of other damage monitoring systems.

This includes discussion of HRH bypass thermocouple locations (Fig 3), circumferential data with thermocouples at 12:00, 3:00, 6:00 and 9:00 locations, and results of data over time.

Bauver looks at a specific HP-to-CRH bypass event, and data indicating non-uniform attemperator spray and indications of possible bypass-valve leakage.

Next is an interstage attemperator thermocouple arrangement recommended for older units: specific locations relative to spray nozzles, elbows, and liners. Discussions cover lessons learned through comparing spray flows and steam flows on two units over time.

He shows a bypass system with thermowell instrument locations relative to valves, and discusses temperature differentials relative to elbows, bypass valve, and bypass piping. Data plots show differentials recorded during startups from 2016 to 2022, and unit comparisons.

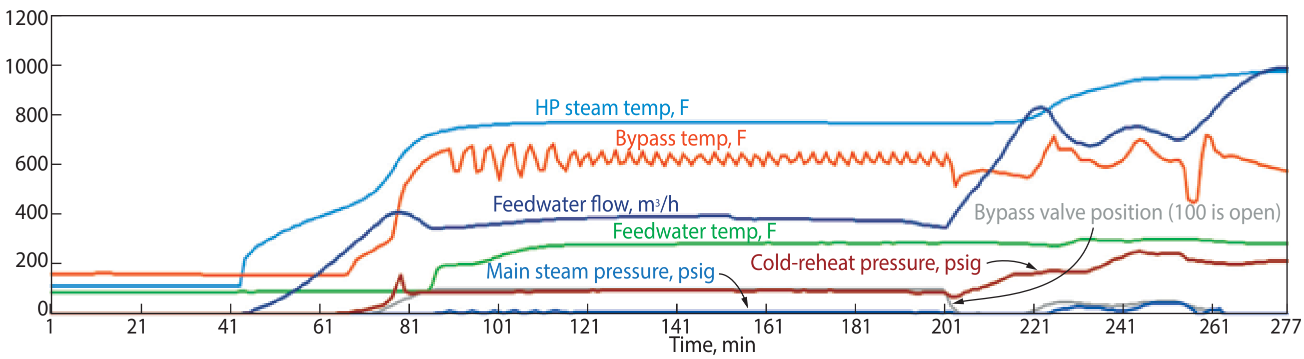
Bauver ends with a look at typical cold starts and graphic evidence of valve hunting (Fig 4).

The fundamental point for all of the above: the more data, the better.

The webinar then offers a recap of the primary benefits of online monitoring:

- Targeted inspection locations and intervals.
- Extended inspection intervals or delayed inspections.
- Expedited fitness-for-service evaluations.
- Optimized component life management.
- Improved confidence in unit reliability.

This ends with a discussion on future use of monitoring technology, including the use of various ultrasonic transducers to monitor metal thickness during operation. CCJ



4. Valve hunting is in evidence for this cold startup. It's possible this was caused by the one spray nozzle found stuck in the open position during the outage

Legacy Turbine Users Group

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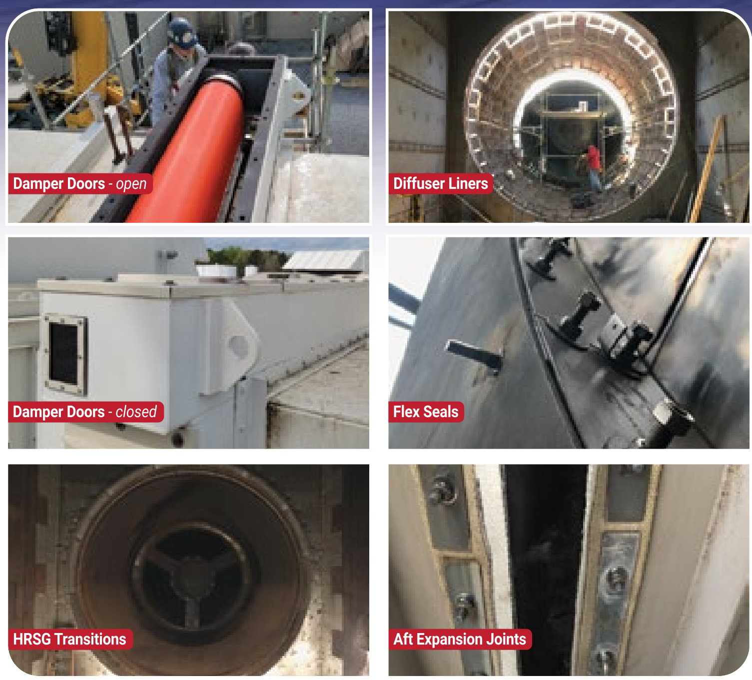

Inlet Systems

- *Fabric Inlet Expansion Joints*
- *Acoustical Liner Repairs & Replacement*
- *Inlet Dampers*
- *Inlet Silencer Panels & Ducts*
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Vendor Fair

Exhibitors, alphabetical

Company	Booth
Advanced Turbine Support	38
AGT Services Inc.	22
Allied Power Group	6
Alta Solutions Inc	52
AP4	16
Avail Infrastructure Solutions	47
Baker Hughes Energy Services	11
Baseload Power	33
Bearings Plus	28
Camfil Power Systems	19
Chentronics	46
C L Williams LLC	20
Crown Electric Engineering & Manufacturing LLC	41
CTTS	45
CUST-O-FAB	9
DEKOMTE De Temple LLC	55
Digital Reality	27
Donaldson	66
Doosan Turbomachinery Services Inc	1
Durr Universal Inc	7
Emerson	5
EMW filtertechnik GmbH	14
Entrust Solutions Group	51
EthosEnergy	17
Gas Path Solutions	12
Gas Turbine Parts & Services Inc.	49
GE Vernova	15
Global Energy Services Alliance LLC	35
Gulf Turbine Services	63
Hansen Turbine	24
HILCO Filtration	82
HPI Energy Services LLC	68
Hy-Pro Filtration	78
IC Spares	62
IEM Energy Consultants LLC	83
Industrial Air Flow Dynamics Inc.	39
Integrity Power Solutions LLC	76
ISOPur Fluid Technologies Inc	81
JASC	23
K Machine	77
Koenig Engineering Inc	58
Liburdi Turbine Services Inc	75
MD&A	61
Mee Industries Inc	59
Miba Industrial Bearings	70
National Electric Coil	72
Nederman Pneumafil	43
Oilquip Inc.	42
ORR Protection Systems Inc.	48
Paragon	26
Parker Hannifin	84
Petrotech Inc	64
Philadelphia Gear Power Systems by Timken	50
Pinnacle Parts and Services	32
Power House Resources	67
Power Services Group	30
PowerFlow Engineering Inc.	37
Powmat Ltd.	73
Prime Turbine Parts	29
PSM	79
Republic Turbines	13
Riverhawk	34
Rochem Fyrewash Inc	69
Schock Manufacturing	71
SISO Engineering	74
S T Cotter Turbine Services	18
Stork Turbo Blading Inc	56
Structural Integrity Associates	53
Sulzer Turbo Services Houston Inc	54
SVI BREMCO	10
TesTex Inc.	36
TOPS Field Services LLC	4
Toshiba America Energy Systems Corporation	65
Trinity Turbine Technology	21
TRS Services	3
TTS Power	80
Turbine Resources	40
Turbine Services Ltd	85
TurbinePROs	57
Veracity Technology Solutions LLC	60
Voith US Inc	44
W L Gore & Associates	2
World Wide Gas Turbine Products Inc	25
Young & Franklin	31

Tuesday, July 16, 5 p.m. to 8:30

Exhibitors, booth number

Booth number	Company
1	Doosan Turbomachinery Services Inc
2	W L Gore & Associates
3	TRS Services
4	TOPS Field Services LLC
5	Emerson
6	Allied Power Group
7	Durr Universal Inc
9	CUST-O-FAB
10	SVI BREMCO
11	Baker Hughes Energy Services
12	Gas Path Solutions
13	Republic Turbines
14	EMW filtertechnik GmbH
15	GE Vernova
16	AP4
17	EthosEnergy
18	S T Cotter Turbine Services
19	Camfil Power Systems
20	C L Williams LLC
21	Trinity Turbine Technology
22	AGT Services Inc
23	JASC
24	Hansen Turbine
25	World Wide Gas Turbine Products Inc
26	Paragon
27	Digital Reality
28	Bearings Plus
29	Prime Turbine Parts
30	Power Services Group
31	Young & Franklin
32	Pinnacle Parts and Services
33	Baseload Power
34	Riverhawk
35	Global Energy Services Alliance
36	TesTex Inc
37	PowerFlow Engineering Inc
38	Advanced Turbine Support
39	Industrial Air Flow Dynamics Inc
40	Turbine Resources
41	Crown Electric Engineering & Manufacturing LLC
42	Oilquip Inc
43	Nederman Pneumafil
44	Voith US Inc
45	CTTS
46	Chentronics
47	Avail Infrastructure Solutions
48	ORR Protection Systems Inc
49	Gas Turbine Parts & Services Inc
50	Philadelphia Gear Power Systems by Timken
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52	Alta Solutions Inc
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54	Sulzer Turbo Services Houston Inc
55	DEKOMTE De Temple LLC
56	Stork Turbo Blading Inc
57	TurbinePROs
58	Koenig Engineering Inc
59	Mee Industries Inc
60	Veracity Technology Solutions LLC
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62	IC Spares
63	Gulf Turbine Services
64	Petrotech Inc
65	Toshiba America Energy Systems Corporation
66	Donaldson
67	Power House Resources
68	HPI Energy Services LLC
69	Rochem Fyrewash Inc
70	Miba Industrial Bearings
71	Schock Manufacturing
72	National Electric Coil
73	Powmat Ltd
74	SISO Engineering
75	Liburdi Turbine Services Inc
76	Integrity Power Solutions LLC
77	K Machine
78	Hy-Pro Filtration
79	PSM
80	TTS Power
81	ISOPur Fluid Technologies Inc
82	HILCO Filtration
83	IEM Energy Consultants LLC
84	Parker Hannifin
85	Turbine Services Ltd

2024 technical program highlights

The Legacy Turbine Users Group's third annual conference and vendor fair is two months away as CCJ goes to press with our last issue before that meeting. With the steering committees for the 7EA, Frame 6B, and Frame 5 Users Groups (sidebar) still working on their agendas and lining up speakers, there aren't many program details to share at this point. Key aspects of the conference follow to encourage your attendance. Our electronic CCJ ONsite will publish program updates in the coming weeks as they become available. Access to this information also is available on-demand at powerusers.org; each group has a section of that site for its activities.

The following is what the three user groups shared with the editors as of May 1:

Monday, July 15

Morning. Introduction to legacy GE frames, presented by Consultant John F D Petersen, a long-time contributor to the industry's collective knowledge, originally focused on the Frame 6B and was expanded by Petersen to serve 7EA and Frame 5 owner/operators as well. This primer/workshop prepares all conference attendees—newcomers and experienced engineers/technicians alike—for a productive experience during the coming days.

A two-hour controls workshop, conducted from 8 to 10 a.m. by John Downing of AP4, runs in parallel with the first half of Petersen's session. Jamie Clark of AGT Services follows Downing from 10:00 to noon with a special generator session. The Downing and Clark workshops, new to the program this year, feature content of value to Frame 7EA, 6B, and 5 users alike.

Afternoon program features two tours—both 1 p.m. to 5 and sponsored by Allied Power Group. One focuses on the company's Combustion Center of Excellence at its Farrell Rd facility; the other tour is of APG's Mills Road Facility. Participation is limited so reserve your seat on the bus ASAP.

Tuesday, July 16

Morning:

7EA. Presentations include the following:

- Troubleshooting a legacy turbine, *Donald Melsheimer, GT-DLM LLC.*
- Air filtration and extreme weather, *Rob Reinhardt, Donaldson Company.*
- Extreme cold-weather preparation for generator owners and operators, *Rachel Williams, Entrust Solutions Group.*
- Compressor vane looseness: What to look for and what to do, *Rich Armstrong, CTTS.*
- Extending service life of 7EA components, *José M Quiñones, MD&A.*

Frame 6B. GE presents on the topics listed below, followed by relevant discussion.

- Critical updates, new TILs, RCA results, etc.
- 6B AGP updates, changes, fleet-leader information, *Kevin Elward.*
- 6B combustion systems overview, capabilities, recommendations, *Mihir Lai.*
- Rotor life-extension trends and recommendations, *Mardy Merine.*
- Open discussion on capital parts challenges.
- Introduction to FieldCore's live outage, *Tim Evans.*

Frame 5.

- Turbine controls upgrade case history, *Emerson.*
- Hydraulic starter motor solutions, *S T Cotter Turbine Services Inc.*
- Baker Hughes tour

Afternoon:

7EA.

- Gas turbine performance evaluations and instrument calibration, *John Downing, AP4.*
- Torque converters in starting packages: Long-term wear and failure modes, *John Baciak, PowerFlow*

LTUG steering committees, 2024

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Dale Anderson, *East Kentucky Power Co-op, J K Smith Power Station*
Tracy Dreymala, *EthosEnergy Group, San Jacinto Peakers*
Jeff Hansen, *Old Dominion Electric Co-op*
Tony Ostlund, *Puget Sound Energy*
Mike Vonallmen, *Clarksdale Public Utilities*
Lane Watson, *FM Global Chemical Operations*
Tyler Wensel, *Luminant*

Past members:
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Guy LeBlanc, *IHI Power Services Corp*

Frame 6B
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Kevin Campbell, *Chevron*
Robert Chapman, *Chevron*
Ryan Cordero, *Baytown Engineering Services*
Jonathan LaGrone, *Formosa Plastics Corp*
Doug Leonard, *ExxonMobil Technology and Engineering*
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Zahi Youwakim, *Indorama Ventures*

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Josh Edlinger, *Alpha Generation LLC*
Johnny Lanthorn, *Butler Warner Generation*
Michael Maris, *ExxonMobil, Baytown Refinery*
Matthew Pazanski, *ExxonMobil, Baytown Refinery*

Engineering Inc.

- Impacts of increased cycling on GE gas-turbine critical components, *Ravi Annigeri, EthosEnergy Group*.

Frame 6B. GE Day concludes with a series of breakout sessions geared to user interests—including combustion/hydrogen systems, capital component planning, generator, rotor, controls/instrumentation, Live Outage, and repair technology.

Frame 5. Baker Hughes tours fill the afternoon. Get details at the conference registration desk.

Wednesday, July 17

Morning:

7EA. GE Day presentations begin with a brief state-of-the-industry review by Jay Bryant followed by "things you should know" regarding new TILs, RCA updates, etc, by Kevin Elward. The three presentations below take the group to the first breakout session at 11 a.m.

- Fuel capability case study and open discussion of hydrogen/bio-diesel fuel projects, *Mike Cocca and Frank Glasgow*.
- New things to consider based on the OEM's recent development and implementation projects, *Jay Bryant*.
- Reliability ideas based on user case studies and the OEM's recommendations, *Will McEntaggart*.

The lineup of breakout sessions running from 11 a.m. to 4 p.m., including lunch: Peaker roundtable, cogen roundtable, Live Outage, LNG roundtable, generator 101, controls/software, repairs, 7E 101, DLN, accessories/BOP reliability, and asset management with a focus on rotors and casings.

Frame 6B. No program details were available for Day Three at press time.

Frame 5. Only two presentations

on the day's program at press time, both in the morning: Electric valve upgrade for the Frame 5 by Young and Franklin, and technology and applications of GT coatings by Liburdi Turbine Services.

Thursday, July 18

There are two all-day (7:30 a.m. until 5 p.m.) tours pertinent to the activities 7EA, 6B, and 5 owner/operators alike on the program—one sponsored by Doosan, the other by Sulzer.

2023 conference report: Users share how to make aging machines 'ageless'

Many vitality-product purveyors, surgeons, pharmaceutical firms, and others want to convince you that "age is just a number." The adage may be even more true for older gas-turbine models. A surgeon may reconstruct your knees and hips, and brain-health pills might make you feel sharper, but you still may die of cancer or heart disease. Turbines, on the other hand, don't suffer from diseases, just wear and tear, which can be addressed.

As evidence, vintage machines are being life-extended to go from 200k operating hours, thought to be an original end-of-life point, to 300k, and perhaps more.

The second annual Legacy Turbine Users Group (LTUG) Conference, held in Phoenix July 17-20, 2023, brought together, under one roof, owner/operators of Frame 5, 6B, and 7E machines. The dominant theme was how to keep these units running until, well, until they can't. That goal is made more difficult, experts say, not only by the unavailability of some parts, especially auxiliaries, and/or the lead times to get them, but also by the dearth of experience and expertise available in the community these days, and by seemingly little-related events like extreme weather.

For example, one leader of a LTUG generator/exciter discussion group pointed out that a rewind could cost almost as much as a new unit, but the lead time for new may be prohibitive. A control system HMI upgrade for a 7EA site is around 50 weeks, he said, and it's a "resourcing, not a computer chip, issue." The lead time "right now" for Frame 5 combustor hardware from the OEM is 60 weeks,

1. Turbine auxiliaries, such as the inlet-air filter house, should have their own mini-maintenance plans as the plant ages said another expert. In fact, one participant commented, "lead times for everything are ridiculous."

Maintenance, inspection, and inventory protocols have to adapt as machines enter the "ageless" realm. That's as true for auxiliaries as it is for the gas turbine itself. One discussion leader said that there must be an inspection plan for every outage for the inlet air filtration housing (Fig 1). Why? One small leak, such as during a super heavy rainstorm, and all the untreated water gets sucked into the HEPA filters, the pressure drop begins to rise "within hours," and salts become entrained in the compressor flow.

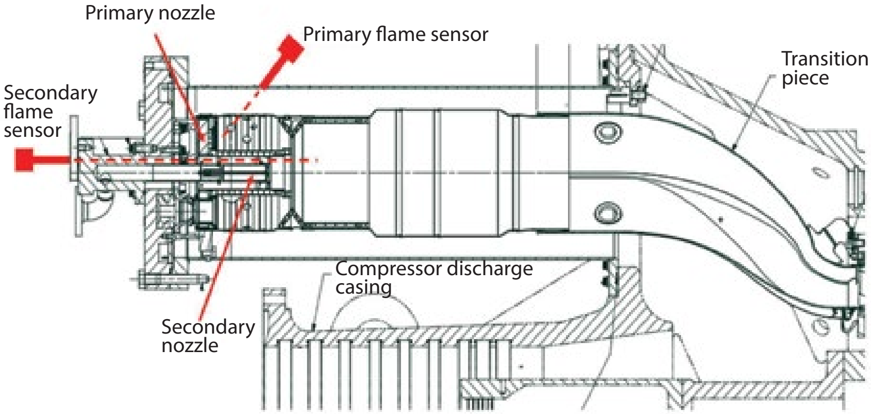
Some users are seeking tailored maintenance strategies for black-start, peaker, and emergency units that may run less than 50 hours per year. Most of these sites' "operating hours" are for testing only.

Nevertheless, the ingenuity displayed by the community of owners/operators, OEM, and service providers clearly shows that where there's a will, there's a way. Several service providers offer what they say are vastly improved rotors, blades, and vanes compared to the original OEM design. One went as far to say that the company was able to "transform a 7B into a 7EA" through significant changes to the rotor, compressor blades, vanes, fuel nozzles, liners, transition pieces, exhaust gas path, and diffusers, among other components.

Another company claims to have created its own "standard" (compared to an "industry" standard) for a combustor (Fig 2) by sub-optimizing each component. The company further states that the redesign reduces the temperature-spread variation on a set of combustor fuel nozzles from 10% to less than 0.5%. Idea is to work to a standard that includes flow-test and turbine operating data, in addition to dimensional fit-up data.

According to material from one service provider, TIL 1576 ("Gas Turbine Rotor Inspections") and GER-3620 ("Heavy-Duty Gas Turbine O&M Considerations") suggest that the life expectancy of a Frame 5 rotor is 200k hours or 5000 factored fired starts. Its life assessment/extension techniques can add up to 100,000 factored fired hours. One machine analyzed by this firm's shop had 300k operating hours before TIL 1576 was even issued! Life extension is paramount because it may take multiple years to procure a new Frame 5 rotor and these machines are being "called back into service across the country."

Reflecting this trend, and the broad theme of the conference, is the presentation on a Frame 5 life-extension proj-



2. Optimizing each component of the combustion system—shown here is a Frame 5 DLN1—can substantially improve parameters important to performance, such as temperature-spread variation ect. Two 20-MW 1976-vintage Frame 5 diesel-fired peakers, laid up in 2015, were fully restored, upgraded, and life-extended for operation well into the future. Deliverables included 98% start reliability, 98% availability, and remote operation. As a indication of the vintage and current technology levels, the control system was upgraded from a Speedtronic™ Mark II to Emerson Ovation™. You can imagine that these 40 megawatts must have been pretty critical to the utility which undertook such a project.

Highlights of the project include major electrical rework, new auxiliary and exciter transformers; control system replacement, including exciter, new fuel metering valves, upgraded flame scanners, and vibration monitoring system; generator rotor rewind; complete rebuild of the diesel starting engine/generator; new fuel skids; and extensive concrete rework. The slides are in outline form, so you may have to contact the authors for additional details which may be relevant to your site.

Also consistent with the general conference theme, but illustrating a different approach, an industrial cogeneration site in Alberta, Canada, did a flange-to-flange replacement of a 1999-vintage 7EA machine, rather than overhaul the rotor, to ensure another 20 years of reliable service.

Other major aspects of the project include a generator field rewind, controls upgrade to a Mark VIe and EX2100e, replacement of turbine exhaust plenum and expansion joint, replacement of lube- and hydraulic-oil ac and dc motors, and rebuild of gas-turbine/generator gas valves and actuators. The slides include a photo montage of the work and a video of the project.

3. Trip of the fire suppression system, such as a CO_2-based system, when there is no fire may be more common than you think

Safety, a topic that pervades all user conferences and rightly so, got plenty of air time at the LTUG. One important topic in the Frame 5 room was entry requirements for turbine enclosures. The OEM says don't open enclosure doors during cooldown. Discussion leader suggested checking wheel-space temperatures during cooldown, and opening doors when they are below 150F, keeping the fans on.

Recent turbine and accessory house enclosure designs include alarms on the doors, ventilation checks, control system trips on low ventilation air and/or an opened door, and permissive for the door to be closed. The Mark VI has a bypass that allows one to enter once every 24 hours, with a 20-min warning, and 30-min limit to exit. Another consideration for an entry protocol may be indicators outside to limit the frequency of entry.

A safety discussion in the 6B room kicked around TIL 1577 addressing precautions for inlet-air filter-house ladders and internal safety gates. Although this qualifies for confined space entry, there is essentially only one means of escape in the event of a fire. Filters and evaporative cooler media can burn from welder sparks or a light falling down. Users argued that there should be multiple ways to exit the housing.

A big caution with CO_2 fire suppression, still pretty common with these machines, was not to get complacent. Turbine compartment entry at these sites was described as "one of the really scary things in the plant." Keep the doors open and have a second person outside.

Older CO_2 systems may not have some of the safety features of new plants, such as lockable ball valves with installed safety pins blocking the discharge piping valves tied to the control system so there's no way to trigger a CO_2 release which will immediately kill someone in the compartment. Be especially vigilant during unplanned maintenance activities, when the CO_2 system may not be part of LOTO, says one participant.

Hazardous gas detectors for the turbine compartment and fuel enclosures are included in DLN upgrades. One user noted that, in a Mark VI, the detectors go into a failed state after 360 days as a way to force the site to calibrate the detectors. Normally, these detectors should be calibrated at least every half a year.

About five attendees out of 60 or so noted that they have experienced a trip of the fire suppression system with no fire (Fig 3). Others noted that the wires to heat detectors break down from age or fail from vibration. All this is evidence that fire suppression systems require regular attention. Even the latest water mist systems, standard on new 6B units, are "a pain in the butt." High-pressure air cylinders always go empty. Lots of fittings have little leaks, which empties the bottles, and then you have to hydrotest them before refilling.

Another topic sucking much oxygen out of user conference rooms, this one no exception, is extreme-weather operation and/or compliance with new standards from NERC, CAISO, Ercot, PJM, and others. Some of the alerts and recommendations generated from one talk on extreme temperature readiness include the following:

- A plant as far south as Louisiana suffered air-piping freeze-ups when temperatures hovered around 15F for five days.
- Insulate CO_2 tanks like they are steam drums.
- Blowdown lines in normally hot compartments froze up at a plant in north Georgia when temperatures plummeted to 8F.
- Weather-event planning should account for operating and idle plant status.
- Lube-oil cooler performance can be limiting during extreme hot ambient temperatures.
- An inlet air heater may mitigate icing in the compressor bellmouth when ambient conditions are extremely cold and humid.
- Little valves mean big problems in really cold weather. Make sure all critical valves, large or small, are identified and protected.

With respect to 6B sites, what keeps an OEM leader up at night? Generators, exciters, and exhaust systems, that's what. This person noted that 6Bs have lots of different generator models coupled to them depending on who packaged the unit. And why the exciter? According to one excitation system expert, there were 17 exciter forced outages between July 1 and September 2022, with the average time to recover around 30 hours. Even scarier, seven of these outages involved items that "most likely would not have been exposed during routine maintenance."

Speaking of brain health, control-system frustrations seemed to especially animate users. Much of this stems from "infighting between the hardware and software sides of the OEM." Although the OEM has tried to resolve this by creating a single controls group within the power business unit, complaints still abounded, such as:

- OEM pushes customers to the Mark VIe even when the customer doesn't want it.
- We paid one side of the house to put in the system, and then the other side of the house to fix it.
- The OEM screwed up the software, then charged the customer to fix it (on a Mark V to VIe migration project).
- OEM missed some logic changes in the overspeed-trip software which led to mistrust of all the software logic.
- Customers are not allowed to make changes to the system.
- There's not enough autonomy in the field to get things done.
- Age of existing engineers, lack of new engineers in the pipeline, is not healthy.

Generally, these five control-system issues were identified in the session, in order of severity: Lead times for hardware and software, QA/QC support and responsiveness, problems with switches, obsolescence issues, and chip supply. Message: Users need to be proactive and engaged in longer term lifecycle planning.

Don't be that guy

Some outage causes may seem like one-offs, but you still don't want to be the next guy to suffer from the same thing. One well-regarded expert delivered outage lessons learned and then several case studies which are worth your time. Access the slides at www.powerusers.org in the section retaining the Monday 7EA presentations. The lessons learned included the following:

- Incorrect alignment of a generator with a 9FB turbine.
- 7EA compressor casing bore misalignment caused by heavy-handed dowel installation (a/k/a hammered) in dowel holes which did not align properly.
- S17 blade migration on a 9FB, because of inconsistent staking (it took three outages before the site had a decent fix).
- Purge valves installed backwards on a 9E DLN1 system.
- Elevated NO_x emissions because dilution holes from a removed liner set were significantly different from the newly installed set. The moral of this story: Flow-test liners when installed.
- Generator vibration on a LM6000 after a major inspection caused by temporary coupling braces (for shipping) still attached to the rotors.

The lessons learned, which the speaker declared are "basic blocking and tackling," have to do with communication, such as preparing work lists for the incoming shift; check-

4. Generator wrecks in 2021, one in February and another less than a year later, were caused by out-of-spec pole bolts and wedges ing for technical errors resulting from the "experience deficit" with "skilled" outage workers; making LOTO procedures more consistent; attending to the minute details of logistics (stuff like welding gases, toilets, scaffolding, forklifts, lighting systems, office space and furniture, and fuel for engines); contingency planning and scheduling; and preparing a lessons learned doc after every outage to inform the next one.

For your consideration

Under the category of, if it was brought up at a user conference, it's probably something to at least be aware of. Below are some general recommendations, cautions, alerts, etc, by subsystem from the user-driven discussions in the three engine tracks conducted in parallel.

Inlet air house:

- If piping is on the outside, consider upgrading from PVC to stainless steel. One user experienced leaks in PVC piping almost immediately.
- Conical-type filter elements will sag as they get dirty, which can open a gap between the filter media and the filter sheet, allowing air to pass through.
- Change pre-filters every six to eight months, coalescers every four to eight months, or as needed.
- Fog can be a huge factor in HEPA filter performance. Have filters tested for conditions specific to your location.
- Housings may need to be recoated every outage.
- Inlet foggers (for output boosts) may eke out a few extra megawatts but over years of service, allow dirt to pass into the compressor.
- Silencer baffles made of galvanized carbon steel can rust and allow zinc to carry through the unit, clogging up the first-stage nozzle cooling passages.
- Check water-wash spray nozzles and test them every time the unit is down. Gaskets on the demin water inlet piping can become brittle and fail.
- Make sure you are consistent in how you measure inlet-guide-vane angles; get inside and use the right tools to measure.

Compressor rotor:

- Clear all extraction passages after a "crash."
- Soaps used to clean compressor blades can become a foulant. Make sure to test soaps for your site. You may fill the rinse tank five to 10 times before you get all the soap out after an offline wash.
- Use of HEPA filters greatly reduces the need for water washing. Units without HEPAs should consider coating the first seven rows of compressor blades.
- Buy rolls of coalescer material and make sure it is clean, fresh, and dry.

Combustor:

- Crossfire tubes are burning out, especially on Frame 5s. This may be associated with coking, leading an irregular flame pattern after dual-fuel testing. The 9/10 location is especially susceptible. Consider the tubes a "consumable" and keep plenty of spares handy.
- Leak- and flow-test fuel nozzles. They can start leaking after you stake them. Fuel nozzles also should be considered consumables. Make sure the mesh isn't left in.
- Check that liner repairs are correct: The floating collar can be out of position and damaged easily when you put the cap on.
- Igniter cables can degrade after many years of service, and burn out.
- Flame detector (non-fiberoptic) cooling tubing can leak; plan to replace every HGP major.

- Flow-test combustion liners: The louvers inside can get damaged over time.
- Pressure-test standard combustion cans and piping during outages. Check for leaks around the flange using tape that changes color when exposed to H_2.

Generator:

Finally, some gruesome photos of an "unfortunate event" are included in the slides used by the 6B group leaders in their Thursday session on generators. The generator in Fig 4 was wrecked in February 2021 and, after repairs and a stator rewind, wrecked again in December 2021. A failed wedge bolt was responsible for the first one, a failed pole bolt for the second. NDE examination revealed that some of these bolts did not meet specifications. Moral: Know your supply chain and all aspects of the manufacturing process, including base stock, forging, heat treating, painting, and cleaning.

Vendor presentations

What follows are summaries (where appropriate) of presentations from the three engine sessions conducted in parallel at LTUG 2023 (7EA, 6B, and 5). Most presentations by vendors other than GE are available on the conference website at www.powerusers.org. Access GE presentations by logging on to your MyDashboard account on the OEM's website.

Frame 7E (7EA)

GE Day. A multitude of slide sets are contained in the master file for this track, given there were four parallel sessions throughout most of the day, beginning with trends, outlook, and investments. Among the last are advanced secondary fuel nozzles (validated in 2021), high-output robust combustor (field validation in 2023), hydrogen fuel capability, and 7E advanced gas path (coming in 2025).

Following these were new TILs (Technical Information Letters) and RCAs (root cause analyses), hydrogen capability, and new things to consider—such as flange-to-flange replacements; 7Extend package, updated rotor life-extension guidelines; 7EA high-output robust compressor performance summary; dual-fuel DLN1+; and troubleshooting.

Breakout sessions tackled peakers/simple cycles, cogen/combined cycle, field-services live outage demo, LNG users, generator 101, generator lifecycle (including the A6/A35 core exchange program), maintenance and cyclic duty, controls, 7E101, combustion, accessories, and BOP reliability, and finally, asset management, rotors, and casings.

DLN Hydrogen Combustor, *Walt Steimel, Shell.* Mentions a collaboration between Shell and GE for decarbonizing LNG, and includes some basics about hydrogen and H_2 combustion.

Compressor Stator-Vane Looseness, *Rich Armstrong CTTS.* Reviews stator-vane looseness issue and describes a new solution.

20 Years of Dual Fuel Reliability: A Case Study, *Schuyler McElrath, JASC.* Reviews third-generation fuel-system components leading to higher reliability, many aimed at preventing system temperatures from exceeding 200F, avoiding coking of stagnant fuel. Includes a case study.

7EA OEM Stage-2 Bucket-Tip Shroud Material Loss, *Aaron Frost, AP*G. A classic presentation offering a compelling learning experience.

7EA Turbine Upgrade Solutions, *Andrew Koonce, MD&A.* Vendor purchased and reverse-engineered a 2009 7EA with zero operating hours, then proceeded to redesign and upgrade virtually all of the components—including rotor, compressor blades and stator vanes, fuel nozzles, liners, transition pieces, turbine buckets, nozzles and shrouds, and exhaust frame diffuser. And that's just for starters. Improvements for each subcomponent are listed and described.

Generator Balancing, *Keith R Collins, MD&A.* Describes an 7A6 rotor field balancing and testing program including component balancing (exciter, main body fans, retaining rings, and collector end balance caps; operating testing, overspeed test, balance provisions, IR tests, speed induced shorts, and other topics.

Case Studies on CT Exhaust-System Gas-Path Upgrades to Improve Safety, Reliability, and Performance, *SVI Dynamics.* Covers simple -cycle aerodynamics and acoustics of a 2001-vintage peaker plant with Westinghouse 501FD2 machines (presumably same techniques and procedures and potential improvements available for 7Es) and a 7FA simple-cycle plant, with sections in both case studies on site engineering and modeling.

FlameSheet Deep Dive, *Jeff Benoit, PSM, a Hanwha company.* FlameSheet™ is part of company's H_2 technology roadmap. First FlameSheet components for 7EA and Frame 5 machines began validation testing in 2023, both with 50%+ H_2 capability, in Korea. Also included: Some history of the gas turbine and more details on the FlameSheet design.

Frame 7EA Annual Update, *Mike Hoogsteden, Advanced Turbine Support.* Covers many issues with associated OEM TILs, and company's findings, pointing out discrepancies between the two and differences with OEM recommendations: Compressor rotor blade-tip distress (first stage not addressed by TIL 1854), compressor clashing, compressor S1 cracking (TIL 1980), compressor stator vane shim (TIL 1562), and turbine second-stage tip-shroud deflection (TIL 1067 rev 4).

Vibration: What's Wrong with My Turbine? *Scott Cavendish, Independent Turbine Consulting LLC.* Among the objectives of this presentation is to demonstrate the importance of looking beyond amplitude and phase angle, since most vibration issues have other underlying causes.

Turbine Outage Lessons Learned and GT Maintenance Case Studies, *Scott Cavendish, Independent Turbine Consulting LLC.* See description in Frame 6B section below.

Planning for a Controls Upgrade, *David Ciccone, Emerson.* Three areas this presentation dives into are application-specific solution advantages, turbine control enhanced features, and solving typical problems, like flame detection, fuel control valves, and generator metering. Projects typically take 12 months from purchase order to equipment shipping, with an additional three to four weeks for site installation. Otherwise, every aspect of a controls upgrade is reviewed and touched upon.

The Importance of the 7B/E Fleet: Combustion and Intelligent Data Solutions to Meet Energy Grid Demands, *Katie Koch, PSM, a Hanwha company.* Asks and answers the question, "What does decarbonization really mean?" then presents upgrades and conversions to decarbonize your 7B/E-based plant.

Rotor Life Extension by Design,

Jeff Schleis, EthosEnergy Group. Reviews TIL 1576 on rotor life, then details company's work to develop the condition-based life-assessment methodology and process and the Phoenix Rotor design, which company states can achieve same hours (200k) and factored fired starts (5000) as the OEM original.

A Bump in the Night, *Jim Neurohr, Sulzer.* Takes you through an imaginary journey of an emergency 7EA trip and everything that has to happen to inspect, assess, ship, evaluate, repair, etc. Plus, it illustrates the benefits of a single-source evaluation and repair shop to best recover from the outage.

Extreme Temperature Readiness, *David Butz and Jason Neville, TG Advisors Inc.* Reviews recent extreme weather events in North America, new compliance standards resulting from them, and the company's extreme weather readiness assessment approach. Specific areas addressed include turbines and generators; lube-oil, cooling, and water systems; cabinets and compartments; fuel system, gas-turbine inlet and bellmouth; plant air, valves, and instrumentation; winterization methods; and wind effects. Plants need to have and maintain both hot- and cold-weather plans suitable for their geographical region and type of plant and should account for both running and idle status.

Frame 6B

GE Day. The master file includes slide decks for the following presentations: "Introduction and Trends," Erik Hilsaki; "New TILs and RCA Discussion," Dave Cihlar; "AGP Updates, First Hot Gas Path," Kevin Elward; "Combustion Technology Refresher," Mohan Bobba and Sarah Cleveland; "Rotor Technology & Life Extension," Mardy Merine; "Hydrogen Trends and Capabilities," Michael Cocca; and "Introducing 'Live' Outage," Tim Evans.

Live Outage is "being gradually implemented" and is anchored by digitized work procedures and the BOB, or "big orange box," one "part" sent to the site that includes all the tools and parts needed for the field work. Live Outage has been implemented on 150 outages, says the OEM, but is only now ramping up for the 6B machines.

Exciter Reliability and Maintenance, *John (JD) Dowling, TC&E/AP4 Group.* A must-view if you are, as many in the industry are, worried about your aging exciter. There are dozens of OEM TILs (Technical Information Letters), PSBs (Product Service Bulletins), and "hot list" items associated with exciters. One big recommendation: Testing of cards, capacitors, resistors, and other "shelf" items sitting around for over 10 years is paramount.

Turbine Outage Lessons Learned and GT Maintenance Case Studies, *Scott Cavendish, Independent Turbine Consulting LLC.* The case studies included here are invaluable evaluations of what happens when mostly "avoidable" errors are made in repair, maintenance, and upgrade work. Also, one easy tip for getting better results during outages: Provide adequate lighting, especially in dark compartments and during the night shift.

Gas Turbine Failure Analysis, *Doug Nagy, Liburdi Turbine Services.* A primer on prevalent damage mechanisms and analysis procedures for turbines and combustors. Presentation is a chapter from a one-day course offered by the vendor. Part of the message is that suitable coatings are now available to mitigate against many of the damage and failure mechanisms identified in the second- and third-stage buckets in 6B machines.

Frame 5

Back to Basics: Generator Testing, *Jamie Clark, AGT Services.* A pictorial journey into various findings from comprehensive generator inspections, with close-ups of specific damage—such as insulation wear from loose bar ties, heavy greasing on connection-ring blocking, connection-ring tie wearing into insulation, endwinding broken ties, failed conductor, damaged laminations, overheated iron, and many more, along with repairs, fixes, and information on testing.

Vibration Monitoring, *Cascade Machinery Vibration Solutions.* A primer on vibration monitoring and diagnostics, including hardware and positioning, and typical graphs and plots under different operating conditions.

Influence of Alignment on Frame 5/Compressor Train, *Cascade Machinery Vibration Solutions.* Case study reviews actual versus desired alignment targets, accounting for thermal growth; dial indicator versus laser; and effect of resetting alignment.

Frame 5 Life Extension (Unionville Case Study), *Marty Magby, Allied Power Group (APG) and Ken Lance, AECI.* Slides lay out details of scope for life-extending two turbines pushing 50 years of age.

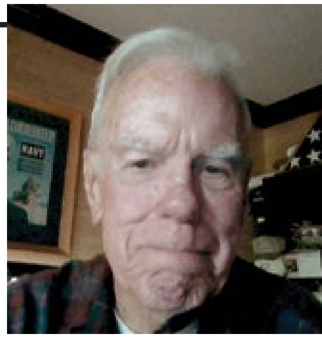
Modernization of an FS-5 Exhaust System to Eliminate Maintenance and Reduce Pressure Drop. By *not* specifying an in-kind replacement of the exhaust system, you can improve the performance of your plant. CFD modeling, in particular, can point to appropriate design modifications. Significantly lowering pressure drop (from 9 in. $H_2$0 to 2 in. in an example given) can lower operating costs by tens of thousands of dollars.

Combustion System Optimization, *Jim Neurohr, Sulzer.* Each component of the combustion system can be optimized and redesigned to create a new standard for performance and extended life, states the presenter, leading to lower fuel costs and more consistent fuel use.

Thermal Block Overhaul, *Jim Neurohr, Sulzer.* Component repair, upgrades, and enhancements are reviewed for numerous Frame 5 fleet issues. Multi-axis digital x-ray live viewing machine is identified as a competitive distinction for repairs, along with vacuum heat-treatment furnaces. In-shop overhauls can be done in about the same time frame as in-field, noted the presenter, based on experience from at least 10 Frame 5 projects.

Rotor Life: Evaluations to Continue Operation of Legacy Units, *Jim Neurohr, Sulzer.* Company has performed 44 Frame 5 rotor life assessments. Slides take you through all the steps, from removal and disassembly, initial inspections, detailed inspections and procedures, findings, reports, repairs and upgrades, and return to the site. One key message: Rotor wheels must be de-bladed to appropriately map defects.

Are your GE B/E-Class hot parts and rotor really near 'end of life'?



By Luke Williams, PE, Consultant
www.geLegacyGasTurbineSupport.com

Editor's note: *Luke Williams and his business partner, Don Melsheimer, have decades of experience supporting owner/operators of GE gas turbines (MS5001, 6B, 7EA, F, and FA frames, plus LM2500 and 6000 aeros) requiring troubleshooting assistance with their control systems (Fuel Regulator through all versions of the Speedtronic™ from Mark I through the VIe).*

Williams recently penned this article to make plant management aware that sometimes gas-turbine rotors and other hot parts are not as far into their lifecycles as you might think, or be led to believe. The possible benefits to owner/operators of not having to do NOW, a combustion or hot-gas-path inspection based on traditional thinking, might include deferring expenses to a more convenient time, extending maintenance intervals, building flexibility into your outage schedule to take advantage of market opportunities, etc.

Williams relies on equations and logic readily available in GE documentation to walk you through the arithmetic to determine how much flexibility your plant's operating profile might allow. You could learn that an operational tweak here and there might make a measurable difference on the bottom line. Williams' goal is "not to leave any money on the table." Another thought: If operators are more cognizant of how they might add value to their plant's mission there could be financial rewards for them.

If you plan on attending the upcoming Legacy Turbine Users Group annual conference, July 15 - 18, at the Woodlands (Tex) Waterway Marriott Hotel, and want to learn more, stop by Booth 20 during the vendor fair to chat with Williams and Melsheimer.

"Gas Turbine Rotor Inspections," published as GE Technical Information Letter (TIL) 1576 in June 2007, discusses the requirement of GER-3620, "Heavy-Duty Gas Turbine Operating and Maintenance Considerations," that rotor inspections be performed at specific intervals recommended by GE. These intervals, unless otherwise specified, are 5000 factored starts or 200,000 factored hours.

The revision of GER-3620 when TIL 1576 was released was "K" (October 2004). The latest revision, "P," was published in January 2021. O&M discussions in GER-3620 are generally applicable to all GE heavy-duty gas-turbines—Frames 3, 5, 6, 7, and 9. Managers and technicians with O&M responsibilities for these engines should consider having copies of both documents at the ready and be knowledgeable as to their content.

The section of GER-3620K on firing temperature (p 9) describes the relationship of firing temperature to maintenance factor thusly:

- Each hour at peak-load firing temperature—that is, baseload firing temperature +100 deg F—is the same as six hours of operation at baseload. "This operation will result in a maintenance factor of six."
- "It is important to recognize that a reduction in load *does not always* mean a reduction in firing temperature." The text then explains that the IGV (inlet guide vane) temperature control and DLN turndown affect firing temperature by reducing air flow to maintain high exhaust temperature for combined-cycle and DLN stability. The key phrase was italicized by the editors.

The relationship between firing temperature and turbine exhaust temperature is nearly 1.66:1. For base to peak operation, an exhaust-temperature increase of 60 deg F results in a firing-temperature increase of 100 deg F. Conversely, an exhaust-temperature decrease of 60 deg F results in a firing-temperature decrease of 100 deg F.

Reference to firing temperature related to peak load was introduced in GER-3620 Revision F (November 1998). The paragraph in Rev F continued to be part of GER-3620 until Rev N in October 2017.

GE indicated that an increase in maintenance interval could be expected from part-load operation on p 9 of GER-3620 Rev L, dated November 2009. Industry experience has shown that operation at less than base or peak load has extended the on-condition maintenance of gas turbines. Units that are baseload but operate at less than the base rating, such as part-load dispatch, also have exhibited extended life.

Note that "on-condition" is an aero term for a preventive primary maintenance process that requires periodic inspection of a system or component to determine if it can continue in service. The idea is to avoid a failure during normal operation.

GER-3620 provides calculation criteria for determining factored starts and hours. Calculations are based on turbine operating procedures such as hot, warm, and cold starts, trips, load condition, and turning-gear operation. The hours-based rotor-life oequation presented in Rev K is

$MF = [BLH + (2 \times PLH) + (2 \times TGH)] \div BLH + PLH$ (Eq 1), where:

MF is maintenance factor,
BLH is baseload hours,
PLH is peak-load hours, and
TGH is turning-gear hours.

Note to Frame 6B users: The typical MS6001B DLN1 is not peak capable and does not have a turning gear.

If the unit was operated at peak load 100% of the time, the MF would be 2.0. The rotor-life calculation allows a reduction in the MF as it applies to the rotor structure itself (for hot-gas-path parts, the MF is 6). Thus, as Eq 1 shows, if the unit did not operate in peak mode and did not have a turning gear, the MF would be 1, and result in an hours-based rotor life of 200,000 hours.

It follows that if the unit operated in peak mode 100% of the time with an MF of 2, the rotor-life maintenance interval would be 100,000 fired hours. That a given, operation at part load with the firing temperature 100 deg F less than the design value should increase the interval.

The rotor-life maintenance interval would be 200,000 plus 100,000 fired hours or 300,000 fired hours. The part-load maintenance factor based on 100 deg F less than design firing temperature would be:

$MF = 200{,}000 \div$ rotor maintenance interval of $300{,}000 = 0.667$ (Eq 2).

Real-world example. An MS6001B-powered plant in the Midwest has an operating condition that limits gas-turbine output to an average of 84% of its baseload rating. The limit is based on the ability of the steam customer to accept the baseload steam generated. In 2013, the unit had reached over 50,000 hours without a major inspection. The 2013 inspection found very few problems with the compressor and hot section.

Data were retrieved from the data acquisition system over the span of one year, January 2021 to December 2021. The compressor discharge exhaust temperature control curve, TTRXP, was calculated using the compressor discharge pressure (CDP). The exhaust temperature, TTXM, was subtracted from the CPD exhaust temperature control curve, TTRXP, thereby allowing a comparison of the turbine maintenance factor based on the 200,000-hr limit to the maintenance factor adjusted for the hours the unit was operated at temperatures less than baseload.

Results from the data compiled for year 2021 are as follows:

- Median turbine exhaust temperature, 1015.63 deg F.
- Median compressor discharge exhaust temperature control, 1046.79 deg F.
- Median delta exhaust temperature, Tx = 30 deg F.
- Median delta firing temperature, Tf = 50 deg F.

The part-load MF for ΔTf is the following:

0.667 + [(1 – 0.667) × (Tf deg F ÷ 100)] (Eq 3)

Thus, the part-load MF for 100 deg F is 0.667 + [(1 – 0.667) × (100 ÷ 100)] = 0.667 + [0.333 × 1] = 1.

Using the same methodology, the part-load MF for 50 deg F would be 0.835. And, the part-load maintenance interval, 200,000 ÷ 0.835 or 239,952 fired hours. Or, 10,048 hours less than the 250,000-hr design life of the rotor and 39,808 hours greater than the baseload maintenance interval.

The results are based on one year's data and was done to evaluate the effect on maintenance interval of continuous operation at less than baseload conditions. The unit has been operating for over 25 years. The next step would be to obtain data back to initial operation and repeat the calculation to verify that the overall operation has been at firing temperatures below the limit of the compressor discharge pressure and megawatt temperature control curves. "Local knowledge" is that 2021 was representative of operations in prior years.

In June 2023, timers were installed in the plant's Speedtronic™ Mark V control system to record the fired hours from 1.0 to 15 deg F below base reference, 15 to 30 deg F below base reference and more than 30 deg F below base reference. Results of data taken in March of 2024 are presented in Table 1.

1. March 2024 data

Run time	Fired hours	Percent of total hours	Median Tx	Median Tf
Total fired hours	6840	100	–	–
Hours 1 – 15 deg F below base	2420	35.4	7.5	12
Hours 15 – 30 deg F below base	3376	40.4	22.5	36
Hours more than 30 deg F below base	337	4.9	30	48

Next step: Calculate the part-load maintenance intervals (PLMI) using the actual median firing temperatures (right-hand column in Table 1). For the 1 – 15 deg F case (second line in Table 1) with a Tf of 12, Eq 3 reveals:

0.667 + [(1 – 0.667) × (100 – (12 ÷ 100))] = 0.667 + (0.333 × 0.88) = 0.667 + 0.266 = 0.933.

Thus, the PLMI = 200,000 ÷ 0.933 = 214,362 fired hours.

For a Tf of 36 (third line in Table 1), the part-load maintenance factor (PLMF) is 0.880 and the PLMI, 227,272 hours.

For a Tf of 48 (third line in Table 1) the PLMF is 0.807 the PLMI, 247,831 hours.

Applying the percentage of fired hours to the three data points gives the result in Table 2.

2. Applying percent fired hours to the data points

Data point, Tx	PLMF	PLMI	PLMI - 200,000	Part-load hours
1 – 15 deg F	0.933	214,362	14,362	5051
15 – 30 deg F	0.880	227,272	27,272	13,457
Over 30 deg F	0.807	247,831	47,831	1864

The original data collected in 2022 estimated a part-load rotor maintenance interval of 239,952 fired hours. The actual data collected in 2024, considered more accurate, produced an interval of 220,372 fired hours, or 18,580 hours less than estimated two years earlier.

As noted above, GER-3620 Revision L, says that an increase in maintenance interval could be expected from part-load operation. Plant experience confirms that operation at less than baseload or peak load extends the on-condition maintenance of gas turbines. Baseload units that operate at less than the base rating also have shown extended life. The OEM could be approached to allow an increase in part-load maintenance intervals.

Plus, the part-load data can be applied to other maintenance intervals—such as combustion, HGP, and major inspections. The basic calculation of maintenance interval as given in GER-3620P, February 2021, is the following:

Maintenance interval = Baseline combustion inspection ÷ Maintenance factor.

Further, Maintenance factor = Factored hours ÷ Actual hours, and factored hours equals K × Af × Ap × ti, where K is the injection factor, Af the fuel factor, Ap the load factor, and ti the operating hours at load.

Important for users tending legacy GE engines:

- K normally is 1.0 for most non-DLN1 units, which generally are not injected.
- Af is 1.0 for gas fuel.
- Ap and ti are made up of part load, baseload, and peak.

Note that peak hours are recorded by a peak-load timer in Speedtronic control systems; DLN1 units typically are not peak-rated.

K, Injection Factor, normally is 1.0 for most Non-DLN I units. DLN I units are generally not injected.

Af, Fuel Factor, is 1.0 for gas fuel.

Ap Load Factor and ti, Operating Hours, is made up of part load, base, and peak.

Peak- and part-load hours are recorded by dedicated timers installed in Speedtronic control systems. Recall that DLN1-equipped units normally are not peak rated. The calculation procedure above for part-load operation could be applied to the calculation of part-load Ap.

Here's a sample calculation for a 12,000-hr combustion inspection, following the same procedure as for the rotor-life calculation earlier:

PLMF = [(Combustion inspection hours ÷ Maintenance factor) – CI hours] × % Tx hours. For the part-load 1 -15 Tx deg F portion of the calculation, [(12,000 ÷ 0.933) – 12,000] × 0.354 = 305 hours.

Using the same methodology for part-load calculations of 15 -30 Tx deg F and over 30, the part-load hours for this combustion inspection would total 14,441. The ability to run more hours between combustion inspections than recommended by the OEM—in this case, 2441—may offer significant financial and operational benefits. CCJ

MIMA-3 conference targets sustainable power

By Steven C Stultz, Consulting Editor

The third conference on Materials, Inspection, Monitoring, and Assessment (MIMA-3), conducted by UK-based European Technology Development Ltd (ETD) last October (2023), in London, focused on sustainable power generation. Discussions and presentations addressed challenges associated with fossil and nuclear power generation, low- or no-carbon fuels, and renewables technologies.

Highlights of the two earlier meetings—held in October 2020 and October 2022—were published in CCJ. Use the nearby QR codes to access information of interest.

2020

2022

The 2023 event was coordinated by EDT Consulting's Ahmed Shibli and chaired by Staf Huysman of Belgium-based Engie Laborelec, an organization similar in many respects to US-based EPRI. Note that ETD Consulting is a trading name of European Technology Development Ltd, Leatherhead, Surrey, UK.

As stated by Shibli, managing director of ETD, "The aim of this international conference is the exchange of knowledge and experience related to various plant issues including decarbonization, materials, inspection/monitoring, safe operation and condition/life assessment."

MIMA conferences are attended by plant operators, owners, designers, fabricators, insurance companies, and service providers along with research institutes and universities from various countries.

Below are selected highlights from MIMA-3. Not all content is reported. The agenda and further details are available through enquiries@etd-consulting.com.

Hydrogen

Sessions began with the keynote presentation, *Long-term impact of hydrogen combustion on gas-turbine hardware,* by Kurt Boschmans, Engie Laborelec. The subtitle of this increasingly relevant topic was *Building decarbonization pathways for Europe: Engie's scenario*.

Boschmans began with the basic concept: "By replacing methane with hydrogen, gas turbines can potentially be converted into low-carbon-, or even zero-carbon-, emitting assets. The CO_2, formed during combustion of methane, is replaced by H_2O."

There is, of course, much more to the story, as he explained.

Some fundamentals from Engie's perspective:

- Co-combustion of 30 vol% H_2 can reduce carbon emissions by 10%.
- 80 vol% H_2 can cut carbon emissions in half.

Boschmans then outlined Engie's perspective on what he called "a few values," which he supported with these examples:

1. Higher adiabatic flame temperature of hydrogen will lead to higher NO_x emissions, when combustion occurs in stoichiometric conditions (1:1).
2. In gas turbines, the combustion system is typically based on dry-low-NO_x (DLN) burner technology, in which acceptable NO_x levels are achieved by combustion of a lean, premixed fuel/air mixture.
3. The lower flammability limit for hydrogen suggests that even leaner fuel mixtures could still be flammable, in contrast with methane.
4. The much wider flammability limits also clearly illustrate the importance of safety when dealing with hydrogen.
5. For an existing burner design, the higher flame speed associated with hydrogen will make a flame burn closer to the burner (as it becomes richer in hydrogen).
6. Difference in volumetric energy density suggests that the required volumetric flow of hydrogen to get the same power output as methane is nearly 2.5 times higher.

One example: Co-combustion of hydrogen up to 30 vol% was tested in Belgium operating an SGT-600 gas turbine. Looking closely at flame positioning, flame anchoring, and flashback, this suggests the need for burner design changes, with potential adaptation of DLN technology. He suggests a move toward modifications in size, shape, and/or number of injection ports, among other items.

Boschmans then looked closely at the influence of hydrogen on gas-turbine hardware, suggesting that "increased amounts of water vapor in the flue gas have a negative influence on the stability of the protective oxide scale formed on superalloy materials."

Engie in Belgium is working with Cranfield University in the UK on various materials and environments.

He then turned to a few pilot projects operating in Europe, working with Siemens, John Cockerill, and others including—Ansaldo and GE.

His conclusions:

- Based on available information, hydrogen combustion in gas turbines is feasible. Co-combustion of hydrogen up to 30 vol% can be achieved without any noticeable negative influence on gas-turbine hardware.
- First demonstrator plants with industrial gas turbines are currently running to test production on pure hydrogen.
- Hardware to allow combustion of pure hydrogen in large F- or H-class heavy-duty gas turbines has not yet been fully developed. However, there is a clear commitment of the OEM suppliers to be ready by 2030.

This was followed by *Materials for H_2-fired industrial gas turbines* by Cranfield University, then by *Technology adoption in fossil-fuel powerplants in the decarbonization era* by TNB Power Generation, Malaysia. Fred Star, ETD consultant, also discussed *Hydrogen: the backup for wind power*.

Hong Wei Wang, ETD, wrapped up the session with *Opportunities and technical challenges of H_2 in combined-cycle gas turbines*, an in-depth technical look at hydrogen production, storage, and transmission; hydrogen effect on materials—including pipelines, storage tanks, and CCGT systems; and a review of the opportunities and challenges.

Secondary steam separation in bottles outside drum

Multiple inside downcomers, expansion loops in evap feeder, and bundle spring support

1. DrumPlus™ features secondary separation (left) and expansion flexibility (right)

Selected concluding remarks:

- Great potential but not there yet.
- Handling infrastructure needs to be developed (at scale).
- Increased capacity of water electrolyzers above 100 MW needed.
- Repurposing required for existing pipelines and gas turbines.
- Need research on new materials.
- Need new engineering codes and code-case materials as basis.

HRSGs

Keynote for Session 2 was *Hydropower and integration of renewable energy* by Maryse Francois, NFX Consulting, France. The presentation discussed how hydro power, including pumped storage, can contribute to grid stability. She used examples from China, Israel, Australia, Switzerland, and Portugal.

The second keynote was *Flexible and future-proof HRSGs* by Sebastiaan Ruijgrok, NEM Energy, The Netherlands, featuring NEM's DrumPlus™ fast-start and cycling design work.

He first looked at lifetime impact of low-cycle fatigue and the impact of component expansion differences where dissimilar metal components are joined. DrumPlus features secondary steam separation in bottles outside the drum. Multiple inside downcomers, expansion loops in evaporator feed, and spring bundle supports enhance expansion flexibility (Fig 1).

Some lifetime improvement predictions were included for numbers of cold, warm, and hot starts. Two case histories were reviewed: El Segundo in California, and Lordstown Energy Center in Ohio. He ended with a look at HRSG readiness factors for hydrogen combustion.

ETD's Shibli followed with a detailed review of *ETD's studies of fossil powerplant flexible operation in Europe, North America, and Asia: Technical and cost issues.* This presentation, available through enquiries@etd-consulting.com, discusses the technical and financial benchmarking of conventional and combined-cycle plants operating in the cycling regime through statistical analysis, and assesses the relative impact of startups on a range of plant sizes, configurations, and age.

Nadeem Ahmed, ETD, followed with development of a reliability management framework and practical implementation ideas, including maintenance program adjustments and performance monitoring techniques.

Session 2 included Ahmed's *Powerplant cost impacts, cycling, and reliability issues,* discussing "an embedded approach including integration of risk-based inspection and reliability-centered maintenance within an asset performance-management system."

Wind

Session 3 focused in part on wind-turbine inspection and damage analysis. Sarinova Simandjuntak of Anglia Ruskin University, UK, opened with an overview on wind-turbine blade, column, and base inspections—including new sensor development.

Ilosta Ltd (UK) offered *Enhancing the reliability of wind-turbine-blade inspection procedures using AI.* This was supported by other turbine-blade evaluation discussions and the use of hyperspectral imagery for damage assessment by the University of Portsmouth and St. John's Innovation Center, both UK.

Tee intersection and other failures

Session 3 then focused on materials development for creep modeling, material failures, and P91 inspection in fossil and Gen IV nuclear plants.

CCJ recently reviewed a January 2024 webinar featuring Jeff Henry, ATC, on premature failure of formed tees in high-energy piping (see article elsewhere in this issue). Also, EPRI has cautioned us about premature failures of these tee intersections, primarily because of creep damage. This topic was included in MIMA-3.

ETD's David Robertson led a discussion on the consultancy's Group Sponsored Project for early-stage creep cavitation detection in P91 tee pieces.

The premise: "Thick-section components generally have failed by Type IV cracking at the heat-affected zone (HAZ) of the welded components. The damage/cracking tends to start subsurface and can only be detected by traditional NDE techniques at about 70% to 80% of consumed life, which means the damage cannot always be detected in time by standard inspection techniques (such as replication). This makes the structures potentially liable to failure before the next inspection."

This is consistent with Henry's webinar, and the topic continued in Session 4 (see below).

Specific Session 3 papers also included:

- *Creep lifetime prediction method using the cavitated volume fraction approach*, University of Huddersfield, UK.
- *TP304H reheater-tube failure attributed to sigma-phase embrittlement*, TNB Research, Malaysia.

Materials

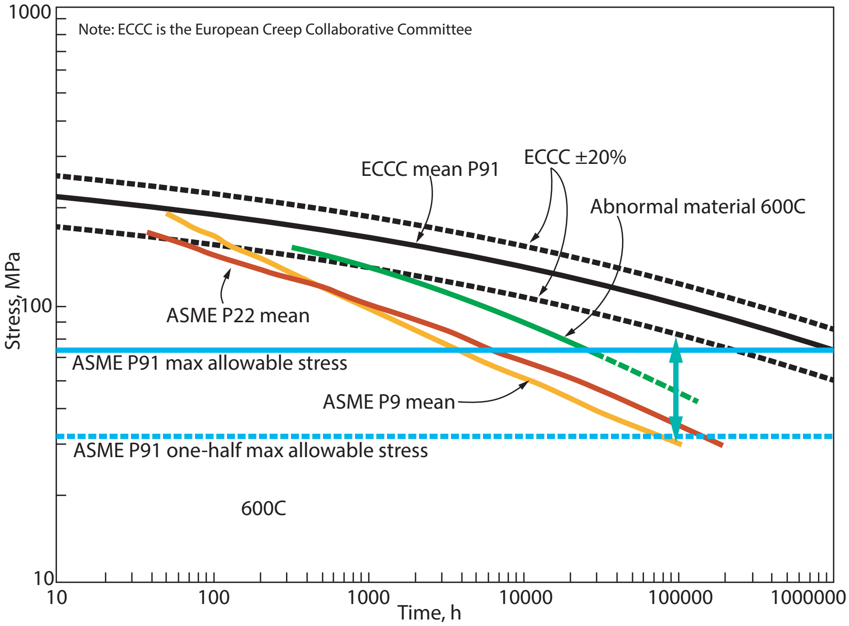
The keynote for Session 4 was *Enhancing integrity of P91 steel pipe in a supercritical thermal and Generation IV nuclear power plant* by the Korean Atomic Energy Research Institute, followed by *Transfusion: A project to transfer high-temperature materials technology from fossil to fusion energy* by ETD's David Allen and others, including the UK Atomic Energy Authority.

Robertson, along with Engie Laborelec, Belgium, and the Central Research Institute of Electric Power Industry (CRIEPI), Japan, then presented *Long-term creep testing of aberrant P91 materials for component life prediction.*

This offered an investigation of different abnormal heat treatments, welding procedures, and repeat weld repairs commonly experienced globally.

Robertson's starting points:

- Many utilities worldwide have been discovering abnormal (aberrant) P91 base metal and welded joints



2. How creep rupture strength of abnormal P91 might compare with ASME P9, P22, and P91 steels

in their plants.

- Heat treatment is critical to achieving full strength in high-Cr martensitic steels, but many material suppliers, manufacturers, and welding companies have failed to realize this criticality.
- Hardness below the acceptable limit and/or the microstructure was not in the correct, fully martensitic condition.
- Deviations from optimal chemical composition can also result in abnormal microstructural conditions.

■ Many abnormal P91 components/welds have only been found some years after entering service.

- Not all abnormal components/welds can be replaced immediately; some may have to remain in service.
- Plant owners/operators do not know how to manage these components in the absence of long-term creep strength data for aberrant materials (Fig 2).

This project offers a comprehensive review of test programs with creep rupture test data of up to 40,000 hours and beyond, produced from project sponsors in Europe and Japan. Additional sponsorship opportunities can be discussed through enquiries@etd-consulting.com.

The University of Science & Technology, Beijing, discussed life evaluation of 9Cr steels in ultra-supercritical powerplants followed by the KTH Royal Institute of Technology (Sweden) looking at creep at very low stresses.

Huddersfield University offered a cavitation-based method for creep lifetime prediction using Cu-Zn-2PB material followed by a modeling method from its School of Computing and Engineering.

CLP (Hong Kong) presented *Dosing-layer quality monitoring in condenser tubes*.

Next was *Challenges and parameters effect of wire-arc additive manufacturing (WAAM) of nickel-based alloys* by the Belgian Welding Institute and Engie Laborelec. Altrad Babcock (previously Doosan UK) followed with a discussion of cracking in 15NiCuMoNb5 marine- and power-boiler drums.

TNB Research, Malaysia, followed with *TP304H finishing reheater tube failure due to sigma phase embrittlement* and the University of Huddersfield ended the session with *Creep damage and creep lifetime prediction: Correlation or causation?*

3. Portable scanning force microscope on vertical pipe

Inspection, monitoring

The keynote for Session 5 was *DX (digital transformation) of plant maintenance with online monitoring and AI,* by Japan's Best Materia Co.

Portable scanning force microscopy (SFM) for early-stage creep and fatigue damage then was presented by Andrea Tonti of Italy's INAIL and ETD's Cheng-Jung Lin.

SFM can detect creep cavities from a few nanometers to microns in size, allowing detection and monitoring of early-stage creep in martensitic steels using this portable device (Fig 3).

ETD has used SFM onsite in Italy, France, Poland, Malaysia, and Philippines for early-stage creep detection in P91 martensitic and low-alloy steel components. One recently tested application is onsite NDE and life assessment of gas-turbine blades, significantly reducing owner/operator inspection costs.

A few conclusions:

- Creep damage in P91 components can be detected at a very early stage (about 20% to 30% of life), quantified, and used for life assessment.
- Damage detection is of much higher quality than replication.
- Portable SFM can also be used for in-situ nondestructive microstructural damage deterioration and life assessment of gas turbine blades.

Kobe Material Testing Laboratory (KMTL) and CRIEPI, both Japan, followed with a discussion of ultra-miniature specimens for life assessment in older powerplants, followed by EDF Energy (France) looking at more effective use of plant inspection and monitoring data.

Further developments in ETD's CrackFit software for the assessment of cracks in boilers and turbines was discussed by Stuart Holdsworth of Switzerland's EMPA, working as ETD's consultant and with other ETD experts. Defect-assessment procedures and software are applied to defect assessment of components and welds. CrackFit is now being enhanced for turbine rotor steels, gas-turbine blades, and disc forgings.

CrackFit includes extensive creep and fatigue crack initiation and growth data for most commonly used plant materials, including base and weld metals and HAZ.

Scanning electrical pressure drop (S-EPD) for online and offline NDT determination of remaining life in P91 pressure vessels and welds was shown by Adam Wojcik, Matelect, and University College London (offline component testing), working with ETD.

Magscan-2 is a rapid scanning electromagnetic tool for quality assurance of P91 and P92 plant components and scanning for aberrant microstructure. Its background, fundamentals, and use were described by the University of Manchester and ETD. Some of the samples presented were supplied by EPRI.

Daniel Omacht, Vitkovic (Czech Republic), discussed a portable instrumented indentation machine and software for more accurate interpretation of test results for fracture toughness and other properties. This work is conducted jointly by Vitkovic, Kema (Netherlands), and EPRI (Shenyang, China).

Ilosta ended the session with an *Advanced data-analysis procedure for improving failure assessment of cracks in pipes,* also covering pressure vessels and crack growth over time.

Sponsors for MIMA-3 included Altrad, Matelect, AGTec (Austria), and Spectrographic (UK).

Future conferences

Discussions on the last day of MIMA-3 considered several topic possibilities for future consideration by the conference organizers–including renewables, nuclear power, drones, robots, hydrogen updates, ammonia plants, decarbonization–with added emphasis on the economics and political drivers of new developments. Thoughts? Please share by writing to enquiries@etd-conculting.com. **CCJ**

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