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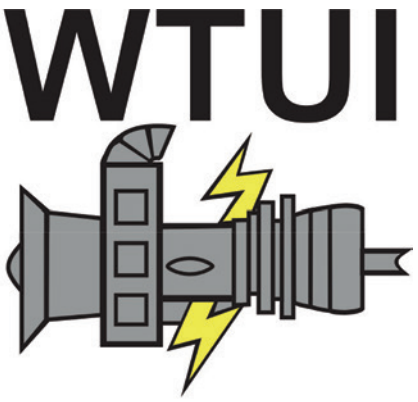
CCJ COMBINED CYCLE Journal

Expanded Aero Coverage

HRSG Forum, 2024 preview (p 60)



Western Turbine Users

Aero Best Practices

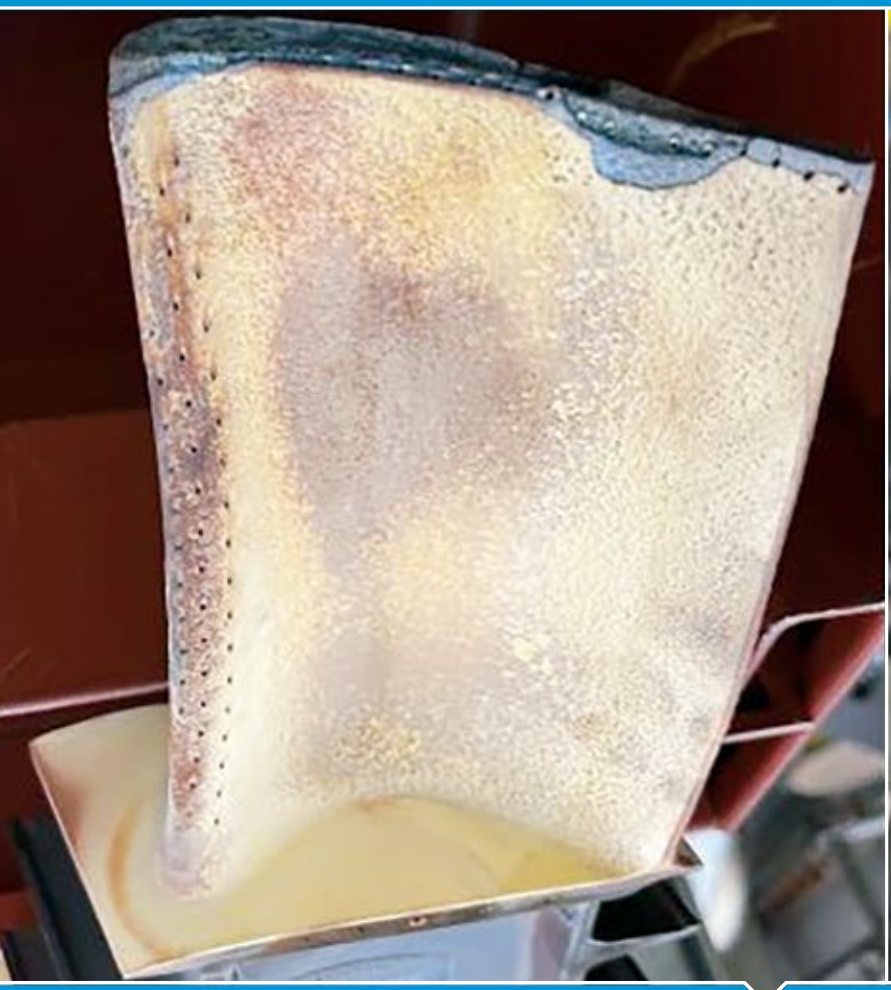
HRSG Forum

ProEnergy 23

GTEN 2023 symposium

Miscellany

7FA.04 Gas Turbine Component Repairs



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Eight Bells: Robert Threlkeld

Robert Threlkeld generally called after receiving his copy of CCJ, "to catch up." Sometimes he had questions on the content, other times an article triggered an experience that he thought worthwhile sharing. The last time we spoke, in mid-May, he was torn between attending the HRST Academy in Avon, Colo, and the HRSG Forum in Atlanta—only a week apart in June 2023.

Threlkeld had attended the Forum several times over the years, but never the Academy. He was trending in favor of the latter given his association with HRST Inc as an external advisor to the company's board of directors since retiring as a Tenaska Inc plant manager a couple of years ago. Plus, the meeting's Rocky Mountain location would beat a trip to Atlanta any day. A possible vacation in Greece also was on his mind.

That Robert didn't call after CCJ No. 75 mailed in late August, our assumption was he was on vacation or busy helping a school or hospital near his home cope with the demands of operating and maintaining their energy systems. "Assuming" was a terrible error in judgment. We didn't know his cancer had returned with vengeance until long-time Tenaska colleague and Navy brother, Dr Robert Mayfield, called to tell us of his death November 28.

Mayfield remembers, "The first time I met Robert was at Lindsay Hill where he was plant manager. Both of us were graduates of Auburn University and naval-officer commanders. He was dedicated to his family, friends, and country. During the last two decades we chatted weekly. Our conversations touched on topics such as the Navy, Auburn football, families, and helping each other when things were hard at work. Vitality and life characterized him; he will not be forgotten."

Threlkeld will be remembered by the editors and the electric generation community for the many best practices he and his O&M teams at the Lindsay Hill and Central Alabama Generating Stations—both 3 × 1 combined cycles powered by 7F gas turbines—published over the years in the pages of CCJ. Both plants are among the industry leaders in Best Practices Awards earned since the program's introduction in 2005—Lindsay Hill and Central Alabama each receiving three Best of the Best Awards over the years (photo).

Threlkeld's presentation, "Developing best practices," at the 2004 Maintenance Workshop conducted by the HRSG User's Group, is a classic for encouraging owner/operators to participate in programs such as CCJ's to avoid having to relearn lessons and to encourage continuous process improvement.

In that presentation he stressed operational consistency. The tools used at his plants included grading of heat rate, ramps, excess energy, and availability. Experience taught him that best practices help in training of new operators; reducing heat rate and long-term maintenance; saving in fuel-gas, back-feed, and imbalance costs; plus other benefits.

Robert Threlkeld receives one of the two Best of the Best Practices awards earned by his plants at CCJ's first BP awards ceremony in 2005

Threlkeld retired from the US Navy in 2001, having served for 20 years. Much of that time was spent at sea on warships, including the USS Carr, a guided-missile frigate, and USS John Rodgers, a Spruance-class destroyer. The Carr's XO touted his considerable abilities as the ship's chief engineer. Speaking to his character, the XO noted Robert's "bravery" in speaking the truth to power with reports not always welcomed, but necessary when one serves the greater good.

Another shipmate remembered him this way: "He was as good of an officer as there ever was, and even a better man." Yet another said, "The Carr's motto was 'Courage, Will, Determination.' For some people those are nothing more than words, but for Robert they were a way of life."

Bob Schwieger

COMBINED CYCLE Journal

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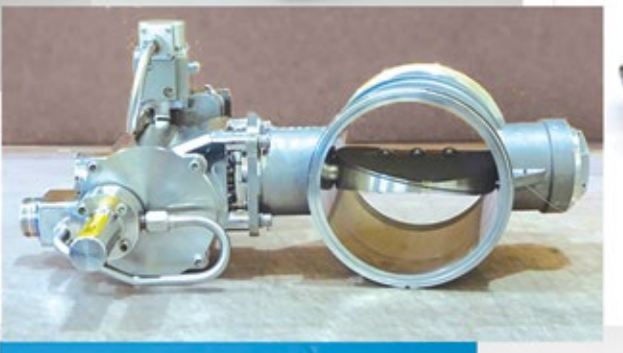

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WESTERN TURBINE Users

PALM SPRINGS
March 2024

33rd Annual Conference and Expo

President's welcome

On behalf of the board of directors, officers, breakout-session chairs, and support staff, welcome to the 33rd annual conference of the Western Turbine Users.

In the late 1980s, a handful of brave investors purchased some early model LM2500 and LM5000 gas turbines for service in California. Their O&M personnel quickly realized the common issues and advantages of the LM engine, gathering in small groups to compare experiences and provide solutions to present to the OEM.

Western Turbine Users was born. Incorporating in 1990, the small group of plant representatives grew to 50, doubled to 100, then 500, and now is over 1000 members strong. Be proud to associate with our organization's legacy, rich history, and worldwide influence as you collaborate with other industry professionals. Little did our predecessors imagine their forethought would result in something as meaningful, relevant, and influential as WTUI.

Join me in celebrating 34 years of the evolving aeroderivative gas turbine industry. Users like you have challenged equipment suppliers to improve their products, as we demand new uses and extend the lives of our gas turbines and all support equipment. As a WTUI member, your conference contribution is the root to our success. You are a vital element of the volunteer organization as we move forward.

Ed Jackson
President, WTUI

Highlights

Sunday, March 24

7:30 Golf tournament at the Indian Canyons Golf Club

10:00 Bowling tournament at Palm Springs Lanes

2:00 Conference registration opens

3:30 Welcome to WTUI/ Conference Familiarization

5:30 Welcome reception, exhibit hall opens

Monday, March 25

8:00 General session

8:45 Presentations by the Authorized Service Providers: IHI, MTU, TCT

10:00 GE Services/new products review

11:00 Mark Axford's worldwide gas-turbine business update

12:00 Lunch/exhibits

1:30 Women in power

2:30 Breakout meetings for LM2500, LM5000, LM6000, LMS100 users

6:30 Monday night reception

Tuesday, March 26

8:00 Breakout meetings for LM2500, LM5000, LM6000, LMS100 users

12:00 Lunch/exhibits

2:30 Special technical presentations

5:30 Presentations conclude

Wednesday, March 27

8:00 Breakout meetings for LM2500, LM5000, LM6000, LMS100 users

11:45 Wrap-up and adjourn

What's inside this special section:

33rd Annual Conference & Expo

March 24 – 27, 2024
Palm Springs Convention Center

Western Turbine Users Inc, the world's largest independent organization of aeroderivative gas-turbine owner/operators, celebrates 34 years of service to the industry at its annual conference and expo, March 24-27, 2024, in the Renaissance Palm Springs Hotel and Convention Center.

The last several years have been especially challenging for the user-managed group. The 32nd annual conference, at the San Diego Convention Center, March 12-15, 2023, was its first in-person meeting since the state of California stopped WTUI from conducting its annual event at the Long Beach Convention Center in March 2020 because of Covid-19 concerns.

In its place, a brief update on the organization's activities was presented a few months later to keep the membership informed on what the OEM and its four licensed Authorized Service Providers—MTU Power, TransCanada Turbines (TCT), IHI Corp, and Air New Zealand Gas Turbines were doing. Recall that ANZGT exited its LM power and marine businesses as 2022 came to a close.

Robust virtual conferences, simulating the group's traditional in-person meetings, were conducted in 2021 and 2022 because of the ongoing pandemic. These online events were produced in collaboration with CCJ, each over a period of three weeks, in 10 highly focused half-day sessions (11 in 2022).

Summaries of the 2023 presentations follow the 2024 conference overview, immediately below. Presentations from the 2023 meeting, as well as those from early conferences, are available at https//wtui.com/forums for WTUI members wanting to dig into the details. For access, email Wayne Feragen, treasurer and webmaster, at wferagen@wtui.com.

WTUI 33 (2024)

The Palm Springs in-person conference offers the opportunity to reconnect with colleagues, some of whom you may not have seen in a couple of years. WTUI organizers provide plenty of time to fulfill this objective.

Prime examples include a golf tournament Sunday morning at the Indian Canyons Golf Club (7:30 start), the vendor sponsored Sunday evening welcome reception from 5:30 to 8:30 in the exhibit hall, and the Monday night reception in the Convention Center lobby.

For WTUI first-timers, it's not necessarily about connecting with colleagues, but rather meeting new people with professional needs and concerns that align with theirs. The best place to begin this process is at the Sunday afternoon session (3:30-5:00), "Welcome to WTUI/Conference Familiarization." The floorplan for the hotel and convention center on p 12 will help you navigate the venue.

The Sunday session is chaired by Andrew Gundershaug, plant general manager, Calpine Corp, who has years of experience in the design, operation, and maintenance of GE aeros, gained both on his day job and as the organizer and discussion leader of Western Turbine's LM5000 and LM6000 breakout sessions.

Gundershaug is a patient instructor who will help newcomers maximize the benefits of participating proactively in the engine-specific technical sessions on Monday, Tuesday, and Wednesday. Plus, he will provide valuable guidance on how to assure units under their purview operate safely and at high reliability.

In his opening remarks on Sunday, Gundershaug will explain the conference arrangement, how to organize your participation, and how to navigate the 2024 sessions for maximum effectiveness. Then he will review the progression of the LM product line from the 2500 to the 5000, to the 6000, and finally to the LMS100. The philosophy of each turbine variant will be discussed and how the turbine/generators are arranged—for example, gear or direct drive.

The slide deck for Gunderhaug's 2023 presentation, updated for 2024, contains many very instructive drawings and photographs useful in plant-breakroom training sessions.

A quick read through the technical program (p 10) will remind you of WTUI's value to your professional growth and development. Highlights include the following:

- Presentations by the OEM and the ASPs focusing on shop findings and solutions. Important to have CCJ's acronyms sidebar handy (p 20) while listening to these experts because they tend to speak in shorthand—HPCR for high-pressure compressor rotor, FPI for fluorescent penetrant inspection), RPL for replaced part, etc. You don't want to disengage from the speaker to figure out what an acronym means.
- Access to the industry's top technical talent Sunday evening through Tuesday afternoon in the vendor fair (floorplan and exhibitor listing starts on p 16) to help you solve plant problems. Think of this as free consulting.
- Experience with upgrades to boost output, availability, and/or reliability, and to reduce emissions.
- Special technical presentations by consultants and third-party solutions providers invited by the organization's leadership team (p 22).
- Open discussions in user-only sessions that provide insights you'll find valuable for improving the performance of your engines.

(Continues on p 20)

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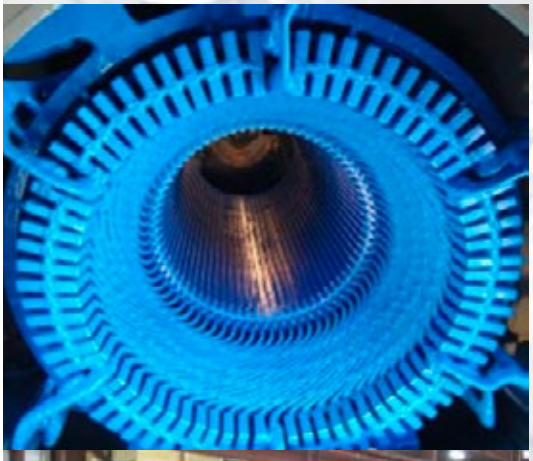

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Technical Program

As of January 31, 2024

Where to go (see floor plan, p 12)

Registration:	Renaissance Ballroom Foyer
Exhibit Hall:	Convention Center
Breakfasts:	Renaissance Ballroom Foyer/Terrace
Luncheons:	Exhibit Hall, Oasis 4
LM2500	Breakout Meetings: Renaissance Catalina Chair: Garry Grimwade, Riverside Public Utilities
LM5000	Breakout Meetings: Renaissance Mojave Chair: Perry Leslie, Wellhead Electric Co
LM6000	Breakout Meetings: Renaissance Madera/Pasadena Chair: Dave Fink, Onward Energy
LMS100	Breakout Meetings: Renaissance Sierra/Ventura Chair: Jason King, Onward Energy

Sunday, March 24

AFTERNOON

2:00 to 7:30	Registration
3:30 to 5:30	Welcome to WTUI/Conference Familiarization, Mojave Chair: Andrew Gundershaug, Calpine Corp **All new registered conference attendees**

EVENING

5:30 to 8:30	Exhibitor-Sponsored Welcome Reception, Convention Center All registered attendees and spouses/guests

Monday, March 25

MORNING

7:00 to 4:00	Registration
7:00 to 8:00	Breakfast All registered conference attendees
7:00 to 5:30	Exhibit Hall open Must have name badge to enter
8:00 to 8:45	General Session, Renaissance Ballroom All registered conference attendees
8:45 to 9:45	ASP Presentations, Renaissance Ballroom All registered conference attendees
9:45 to 10:00	Break, Exhibit Hall
10:00 to 11:00	GE Services/New Products Presentation, Renaissance Ballroom All registered conference attendees
11:00 to noon	Worldwide GT Business Update, Renaissance Ballroom Mark Axford, Axford Turbine Consultants LLC **All registered conference attendees**

AFTERNOON

Noon to 2:30	Lunch/Exhibits **Must have name badge to enter**
1:30 to 2:30	Women in power, Mohave
2:30 to 4:30	Breakout Meetings: LM2500, LM5000, LM6000, LMS100 **Users only**
4:30 to 5:30	**Breakout Meetings: LM2500, LM5000, LM6000, LMS100** **Users, ASPs, and GE only**

EVENING

6:30 to 9:00	Monday Night Reception, Convention Center Lobby **All conference attendees and registered spouses/guests. Must have name badge or wristband and be 21 years old for entry.**

Tuesday, March 26

MORNING

7:00 to 4:00	Registration
7:00 to 8:00	Breakfast **All registered conference attendees**
7:00 to 2:30	Exhibit Hall open **Must have name badge to enter**
8:00 to 9:30	Breakout Meetings: LM2500, LM5000, LM6000, LMS100 **Users, ASPs, and GE only**
9:30 to 10:00	Break, Exhibit Hall
10:00 to noon	Breakout Meetings: LM2500, LM5000, LM6000, LMS100 **Users, ASPs, and GE only**

AFTERNOON

Noon to 2:30	Lunch/Exhibits **Must have name badge to enter**
2:30 to 5:30	Special Technical Presentations **All registered conference attendees**
2:30 to 3:30	Aero Best Practices (CCJ), Madera/Pasadena Formaldehyde Regs and Air Testing (Montrose), Catalina Advanced Inspection Ahead of Major Outages (HRST), Sierra/Ventura
3:30 to 4:30	RM&D for Peaking Facilities (ProEnergy), Catalina GE LM DLE 101 (Engie), Madera/Pasadena How NO_x and CO/VOC Control Has Changed Since 2000 (Environex), Sierra/Ventura
4:30 to 5:30	Eliminate Generator Obsolescence and Unscheduled Outages (Brush), Catalina More Sustainable Aero Turbine Operation through Lubricant Chemistry Management (EPT Clean Oil), Madera/Pasadena Advanced Exhaust Insulation and Winterization Solutions (Arnold Group), Sierra Ventura

Wednesday, March 27

MORNING

7:00 to 8:00	Breakfast
8:00 to 11:45	Open Forums: LM2500, LM5000, LM6000, LMS100 **All registered conference attendees**
11:45 to noon	Wrap-up/Adjourn, Renaissance Ballroom **All registered conference attendees**

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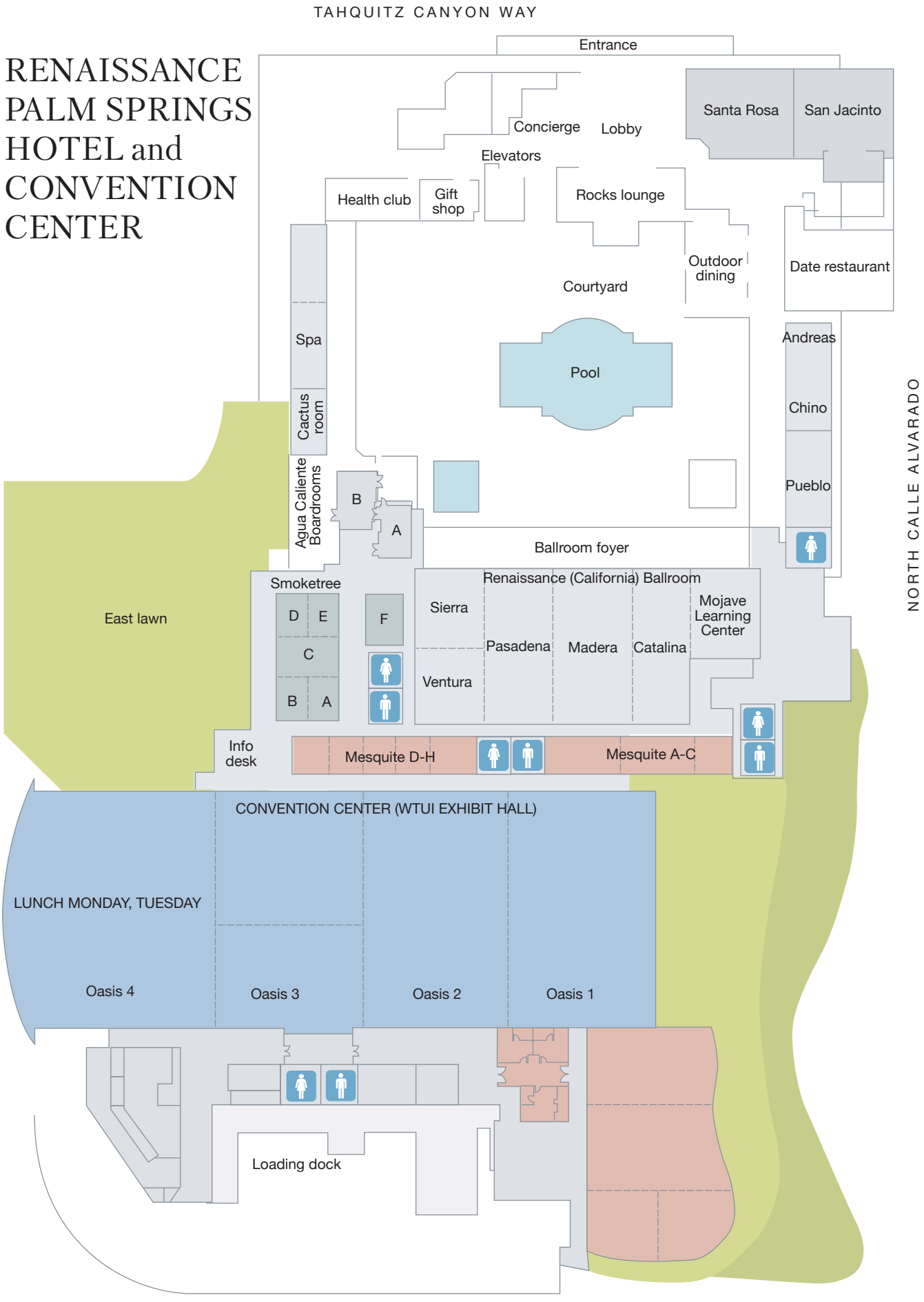

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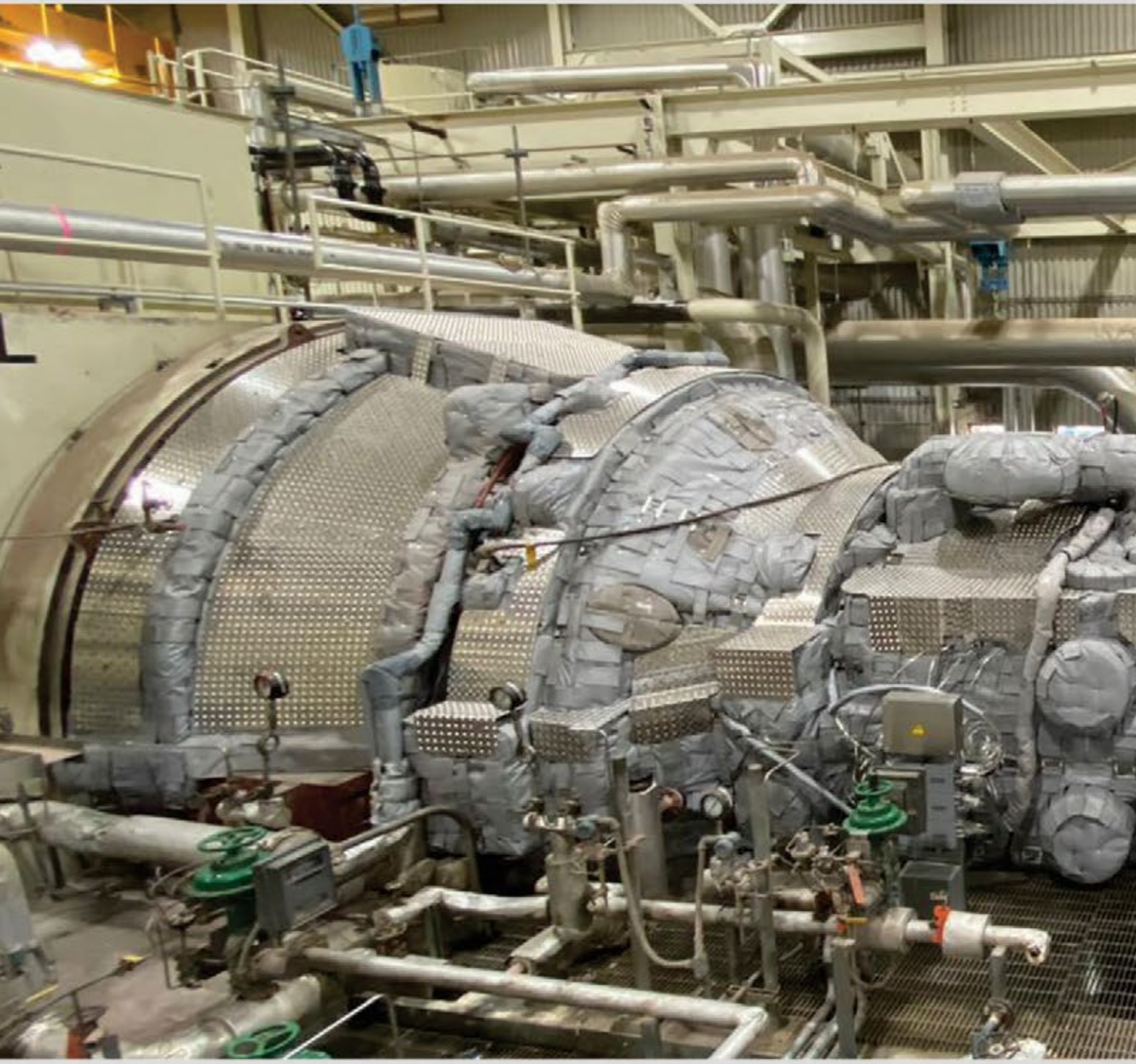

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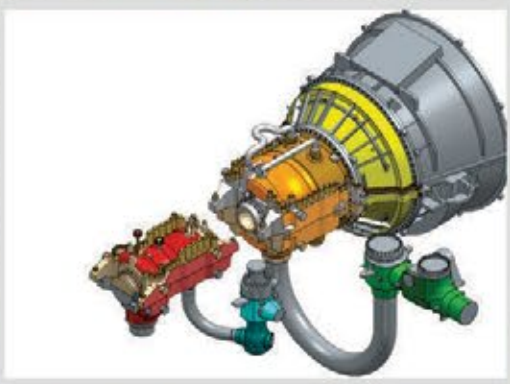

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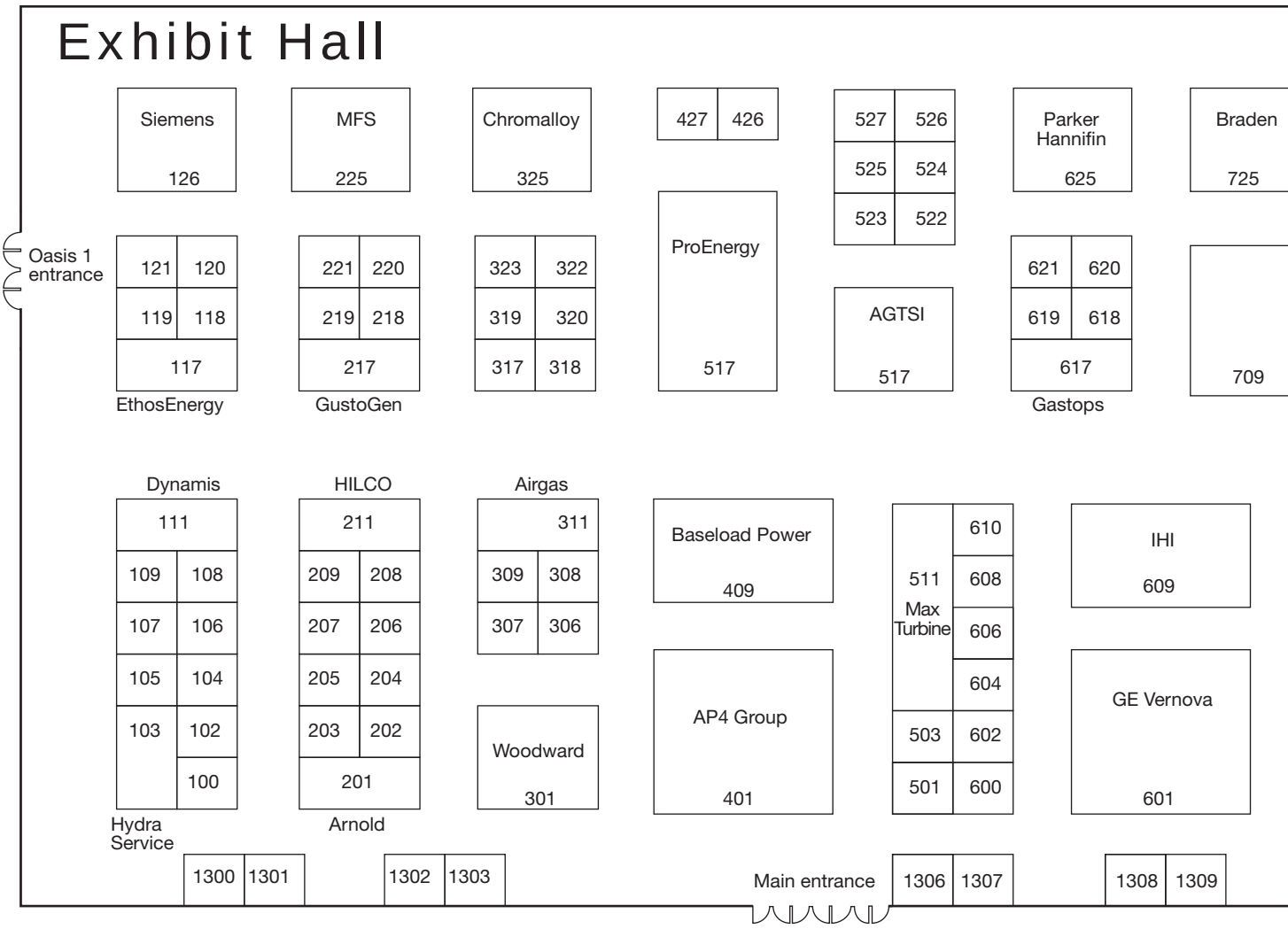
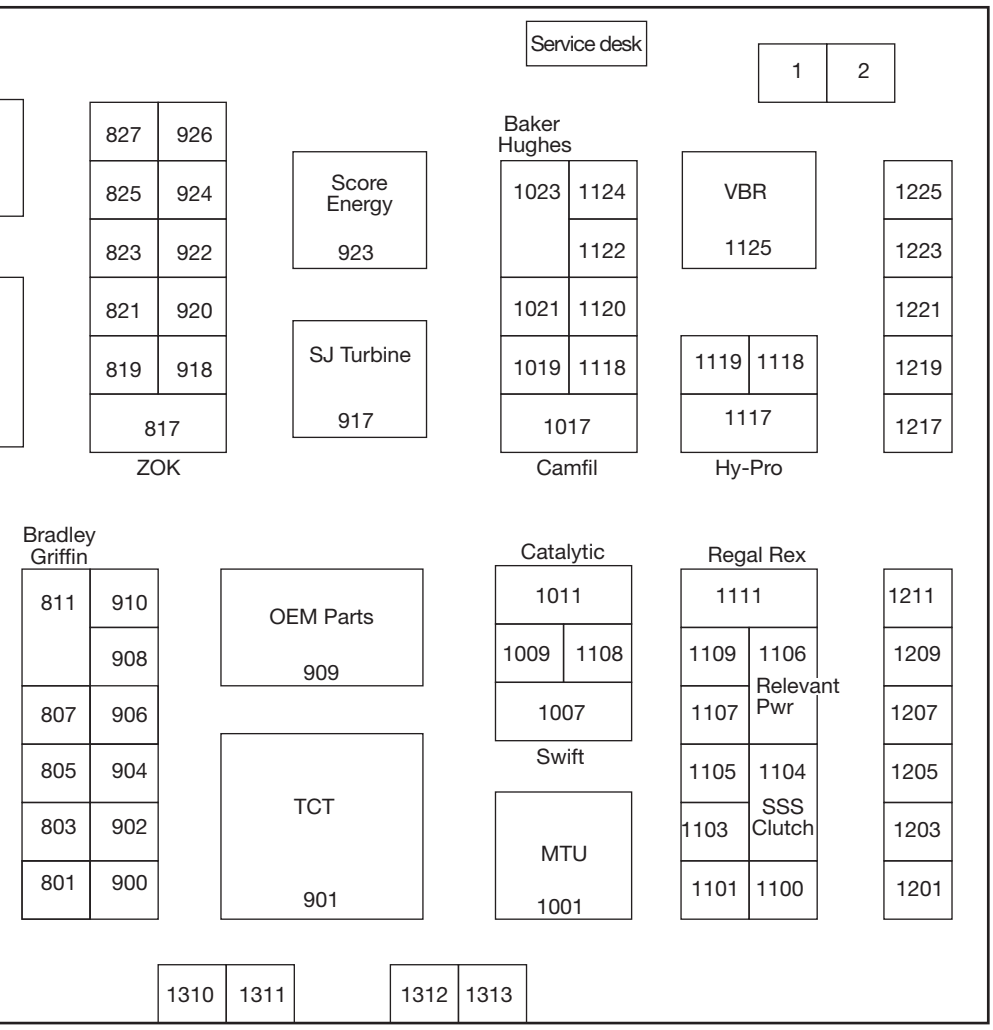


Alphabetical order by exhibitor as of Feb 17



Company	Booth
Montrose Environmental Group	619
MPW Industrial Services	618
MTU Maintenance Berlin-Brandenburg	1001
Munters	1103
National Electric Coil	1209
National Mechanical Services	904
Nederman Pneumafil	1105
NYCO America	1107
OEM Parts Network	909
Orr Protection	606
Pacific Standard Environmental	1118
Parker Hannifin	625
PAS MRO	621
Peerless CECO Environmental	309
Petrotech	1009
Prince & Izant	119
ProEnergy	417
Regal Rexnord	1111
Relevant Industrial/Switch Filtration	1109
Relevant Power Solutions	1106
Rochem Technical Services USA	524
Rust Automation & Controls	323
Schock Manufacturing	1021
Score Energy Limited	923
SCR Solutions	1122
SEIRIS USA	1124
Siemens Energy	125
SISO Engineering	805

Company	Booth
Sisu Energy & Environmental	906
SJ Turbine	917
Sky Mart	1119
SSS Clutch Company	1104
Strategic Power Systems	100
Sulzer Turbo Services Houston	910
SVI Bremco	1100
Swift Filters	1007
Synergy Catalyst	1101
T2E3	205
Teledyne	1219
TOPS Field Services	427
Toshiba America Energy Systems	527
TransCanada Turbines	901
TTS Power	902
Turbine Technics	2
UECompression	322
Umicore Catalyst USA	501
Unison	602
Universal Analyzers	1217
US Cleanblast	1211
VBR Turbine Partners	1125
Vector Systems	1207
Veolia WTS Services USA	308
ViewTech Borescopes	1205
Waygate Technologies	1203
Woodward	301
Xinergias	1201
Zokman Products/Reed Services	817

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Peerless CECO Environmental
SISU Energy & Environmental
SVI Bremco
TTS Power
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Exhibitors in booth number order as of Feb 17

Booth	Company
2	Turbine Technics
100	Strategic Power Systems
102	Environex
103	Hydra Service
104	Drake Controls West
105	Industrial Air Flow Dynamics
106	Duct Balloon
107	Integrated Power Services
108	Donaldson
109	Liburdi Turbine Services
111	Dynamis Power Solutions
117	EthosEnergy
118	Frenzelit
119	Prince & Izant
120	Ground Power Parts
121	M&C Tech Group North America
125	Siemens Energy
201	Arnold Group
202	CleanAir Engineering
203	Kaam Group
204	Continental Controls
205	T2E3
206	Emerson
207	Iris Power (Qualitrol)
208	Cemtek KVB-Enertec
209	HPI Energy Services
211	HILCO Filtration
217	GustoGen
218	AMETEK Power Instruments
219	BASF
220	Enerpac
221	Hill Brothers Chemical
225	MFS (Mechanical Field Support)
301	Woodward
306	AGT Services
307	Caldwell Energy
308	Veolia WTS Services USA
309	Peerless CECO Environmental
311	Airgas Specialty Products
317	Air Hygiene International
318	Global Energy Services Alliance
319	Core Tech Industrial
320	Fossil Energy Research
322	UECompression
323	Rust Automation & Controls
325	Chromalloy
401	AP4 Group
409	Baseload Power Generation Parts & Services
417	ProEnergy
426	Mee Industries
427	TOPS Field Services
501	Umicore Catalyst USA
503	Direct Turbine Controls
511	Maximum Turbine Support
517	Aeroderivative Gas Turbine Support
522	Alta Solutions
523	Cormetech
524	Rochem Technical Services USA
525	Entrust Solutions Group
526	Mjorud
527	Toshiba America Energy Systems
600	EnergyLink International
601	GE Vernova
602	Unison
604	Industrom Power
606	Orr Protection
608	AAF International
609	IHI
610	eLogger
617	Gastops
618	MPW Industrial Services
619	Montrose Environmental Group
620	Interlock Energy
621	PAS MRO
625	Parker Hannifin
725	Braden Group
801	Groome Industrial Service Group
803	Heiberger Solutions
805	SISO Engineering
807	Brownell Aeroderivative Consulting
811	Bradley Griffin
817	Zokman Products/Reed Services
819	Beijing DeNOx Environment & Technology
821	Doble Engineering

Booth	Company
823	Exponent
825	Met Weld International/CRDX
900	GTSMRO
901	TransCanada Turbines
902	TTS Power
904	National Mechanical Services
906	SISU Energy & Environmental
908	Detector Electronics
909	OEM Parts Network
910	Sulzer Turbo Services Houston
917	SJ Turbine
918	ChangeOVR
920	Chentronics
922	Evident Scientific
923	Score Energy Limited
924	Minimax Fire Solutions International
926	Marioff NA
1001	MTU Maintenance Berlin-Brandenburg
1007	Swift Filters
1009	Petrotech
1011	Catalytic Combustion
1017	Camfil Power Systems
1019	Advanced Turbine Support
1021	Schock Manufacturing
1023	Baker Hughes
1100	SVI Bremco
1101	Synergy Catalyst
1103	Munters
1104	SSS Clutch Company
1105	Nederman Pneumafil
1106	Relevant Power Solutions
1107	NYCO America
1108	Durr Universal
1109	Relevant Industrial/Switch Filtration
1111	Regal Rexnord
1117	Hy-Pro Filtration
1118	Electric Machinery
1118	Pacific Standard Environmental
1119	Sky Mart
1120	Advanced Filtration Concepts
1122	SCR Solutions
1124	SEIRIS USA
1125	VBR Turbine Partners
1201	Xinergias
1203	Waygate Technologies
1205	ViewTech Borescopes
1207	Vector Systems
1209	National Electric Coil
1211	US Cleanblast
1217	Universal Analyzers
1219	Teledyne
1301	HRST
1306	Lone Star Controls

International Association for the Properties of Water and Steam

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

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

Acronyms to remember

AGB—Accessory gearbox (also called the transfer gearbox)
AVR—Automatic voltage regulator
CCM—Condition maintenance manual
CCR—Customized customer repair
CDP—Compressor discharge port
CFF—Compressor front frame
COD—Commercial operating date
CPLM—Critical-parts life management
CRF—Compressor rear frame
CWC—Customer web center (GE)
DEL—Deleted part
DLE—Dry, low emissions combustor
DOD—Domestic object damage
EM—Engine manual
FFA—Front frame assembly
FOD—Foreign object damage
FPI—Fluorescent penetrant inspection
FSNL—Full speed, no load
GG—Gas generator (consists of the compressor and hot sections only)
GT—Gas turbine (consists of the gas generator pieces with the power turbine attached)
GTA—Gas-turbine assembly
HCF—High-cycle fatigue
HGP—Hot gas path
HPC—High-pressure compressor
HPCR—High-pressure compressor rotor
HPCS—High-pressure compressor stator
HPT—High-pressure turbine
HPTN—High-pressure turbine nozzle
HPTR—High-pressure turbine rotor
IGB—Inlet gearbox
IGV—Inlet guide vane
IPT—Intermediate-pressure turbine (LMS100)
IRM—Industrial repair manual
LCF—Low-cycle fatigue
LM—Land and marine
LO—Lube oil
LPC—Low-pressure compressor (not on LM2500; just LM5000 and LM6000)
LPCR—Low-pressure compressor rotor
LPCS—Low-pressure compressor stator
LPT—Low-pressure turbine
LPTR—Low-pressure turbine rotor
LPTS—Low-pressure turbine stator
MCD—Magnetic chip detector
MOH—Major overhaul
NGV—Nozzle guide vane
OEM—Original equipment manufacturer
PN—Part number
PT—Power turbine (turns a generator, pump, compressor, propeller, etc)
PtAl—Platinum aluminide
RCA—Root cause analysis
RDS—Radial drive shaft
RFQ—Request for quote
RPL—Replaced part
SAC—Single annular combustor
SB—Service bulletin
SL—Service letter
STIG—Steam-injected gas turbine
SUP—Superseded part
TA—Technical advisor
TAN—Total acid number (lube oil)
TAT—Turnaround time
TBC—Thermal barrier coating
TGB—Transfer gearbox (also called the accessory gearbox)
TMF—Turbine mid frame and thermal mechanical fatigue
TRF—Turbine rear frame
VBV—Variable bleed valve (not on LM2500; just LM5000 and LM6000)
VBVD—Variable bypass valve doors
VIGV—Variable inlet guide vanes
VSV—Variable stator vane
VSVA—Variable stator-vane actuator

(*Continued from p 8)*

The first morning

The pace of the meeting quickens after breakfast Monday in the Renaissance Ballroom foyer and adjoining terrace as all registered attendees gather in the ballroom for opening remarks by WTUI President Ed Jackson, plant manager of Missouri River Energy Services' Exira Generating Station in Brayton, Iowa.

Jackson, who was elected WTUI's leader in 2022, is only the sixth president in the organization's more than three decades of service to the industry. His predecessors: John Hudson, 2020-2022; Chuck Casey, 2013-2020; Jon Kimble, 2008-2013; Jim Hinrichs, 1992-2008; and John Tunks, 1990-1992.

Following the introduction of officers, directors, breakout session chairs, and support staff, plus the treasurer's financial report, badge rules (p 25), and other business matters, the three ASPs authorized by GE to work on LM engines—IHI, MTU, and TCT—will update attendees on their activities and plans.

Highlights of the first morning's presentations after break ends at 10:00 are the following:

- GE Services' offerings and the OEM's new products review.
- Brough/Axford industry and market report. Tony Brough, president, Dora Partners & Company, will update the group on the state of the global gas-turbine market using engine-specific and geographic stats considered by many the industry's most reliable. Mark Axford, president, Axford Turbine Consultants, who has presented to this group on the state of the energy industry for nearly two decades and a crowd favorite (sidebar, p 23), will use his crystal ball to help attendees prepare for the future.


Brough


Axford

Engine-specific sessions

Breakout meetings for the LM2500, LM5000, LM6000, and LMS100 gas turbines, the core of WTUI's technical program, begin Monday afternoon at 2:30 and run until 4:30 for users only. ASPs and GE gain admission to the sessions at 4:30. The technical program ends at 5:30.

The breakout sessions continue Tuesday morning for users, ASPs, and GE from 8:00 to lunch at noon, with a break at 9:30. Wednesday, the breakout sessions go from 8:00 to 11:45 for users, ASPs, and GE. Adding, that's more than nine hours of intense information transfer from engine experts to the user community. You can't get "training" of such high caliber anywhere else in the world.

The LM2500 program is guided by Garry Grimwade, who has O&M responsibilities for four LM6000s, four GE10s, and a LM2500-powered combined cycle at Riverside (Calif) Public Utilities. Before his involvement with land-based aero engines, he spent a decade working with "big iron," including a 700-MW merchant facility and two GE "H" frames. Grimwade, who hails from the UK, served in the US Navy as an aviation machinist's mate before investing five years at the Pacific Gas Turbine Center overhauling aero engines.

The LM5000 session is chaired by Perry Leslie, who watches over

the Yuba City Cogeneration Plant for Wellhead Services. His responsibilities there include I&C, mechanical maintenance, and operations. Leslie has served that facility since 2004 while also managing the now-shuttered Binghamton Cogeneration Plant for a brief period. Before Yuba City, he spent six years as a field service technician for GE in the Bakersfield area working on LM1600, LM2500, LM5000, and LM6000 engines. He began his career with a six-year stint in the US Navy as a GT systems technician (electrical).

The LM6000 program is led by Breakout Session Chair Dave Fink of Onward Energy. Fink, an I&C technician and operator at Southwest Generation's Fountain Valley (Colo) facility, also is responsible for maintenance at that six-unit LM6000 peaking plant. His power-generation career includes six years as an electrician's mate in the US Navy and a decade as I&C technician at Calpine's Gilroy facility (1 × 1 7EA-powered combined cycle and three LM6000 peakers). Fink also spent eight years with F W Marsh LLC, supporting GE in the commissioning and field service of LM engines.

The LMS100 session is guided by Jason King, a plant manager for Onward Energy. The only attendees invited to LMS100 sessions are GE employees and users. No ASPs are licensed by GE at this time to work on the LMS100.

Special technical presentations

Tuesday afternoons at Western Turbine meetings are reserved for nine Special Technical Presentations, approved by WTUI leadership, to extend the meeting's content beyond the four GE aero engines on the program. The hour-long presentations (with Q&A) are arranged in three parallel sessions beginning at 2:30, 3:30, and 4:30.

2:30-3:30

Best practices, *Scott Schwieger, Combined Cycle Journal.* Best practices submitted to CCJ by aero users as part of the annual awards program sponsored by the periodical and WTUI, will be reviewed, with open discussion to follow. Attendees are invited to share their best practices from their seats. *Madera/Pasadena*

Formaldehyde regulations and air testing, *Blake Ericson, Montrose Environmental Group.* New regulations require that many LM2500 and LM6000 gas turbines be tested for formaldehyde emissions. One of the challenges faced by some owner/operators is that traditional testing methods cannot accurately determine formaldehyde emissions below several hundred ppb, let alone the 91-ppb threshold specified.

The presenter will identify new optimized techniques for measuring formaldehyde emissions at much lower concentrations than are possible using standard methods. Some are said to provide continuous and real-time data useful in combustion tuning, compliance, engineering, and demonstration of combustion or post-combustion controls. *Catalina*

Coordinating advanced HRSG inspection techniques relative to major turbine overhauls, *Jack Odlum, HRST Inc.* Aging HRSGs experience problems that require greater effort to find and assess compared to those associated with newer HRSGs. Pressure-part component degradation mechanisms like creep, fatigue, and pitting require advanced inspection tools to detect problems early and allow adequate time for planning of repairs to coincide with already-scheduled major turbine outages.

Leadership Team 2024

Western Turbine's leadership team consists of the officers, directors, conference chairpersons, and support personnel who plan and execute the world's largest and most comprehensive technical meeting on GE aeroderivative engines for electric power production, gas compression, and ship propulsion. Day-to-day operations are managed by an experienced support staff.

The individuals in this army of volunteers dedicate hundreds of hours of personal time annually to keep you informed on engine technology, operation, and maintenance.

The material presented by owner/operators, the OEM and its authorized service providers, and independent third-party providers of products and services is important and conducive to your success. Participation in WTUI meetings will help you manage your plant in a manner that maximizes revenue, efficiency, and availability/reliability, and minimizes pollutant emissions—all while maintaining the highest degree of safety.

Officers

President, Ed Jackson, *Missouri River Energy Services*
Treasurer, Wayne Feragen, *Noresco*
Historian, Mike Raaker, *Raaker Services LLC*

Board of directors

Dave Fink, *Onward Energy*
Dennis Johnson, *Sentinel Energy Center*
Luis Sanchez, *TransAlta Corp*
Garry Grimwade, *Riverside Public Utilities*
Andrew Robertson, *Wellhead Services Inc*
Gilbert Shupe, *SRP*
Al Vanhart, *Parkway Generation LLC*

Conference chairpersons

LM2500, Garry Grimwade, *Riverside Public Utilities*
LM5000, Perry Leslie, *Wellhead Services Inc*
LM6000, Dave Fink, *Onward Energy*
LMS100, Jason King, *Onward Energy*
New users, Andrew Gundershaug, *Calpine Corp*

Support staff

Conference executive director: Wayne Kawamoto, *Kawamoto Power Consulting*
Conference coordinator: Charlene Raaker, *Raaker Services LLC*


Feragen


Fink


Grimwade


Gundershaug


Jackson


Johnson


Kawamoto


King


Leslie


C Raaker


M Raaker


Robertson


Sanchez


Shupe


Vanhart

Presentation will highlight several advanced inspection techniques, their strengths and applications, and the locations and timetable to target their use ahead of major turbine outages. Examples and photos of these techniques, significant findings, and the impacts they have on future outage planning will be discussed. *Sierra/Ventura*

3:30-4:30

DLE 101, *Marc Forget, Engie Electrabel.* GE LM DLE technology differentiates itself from SAC (single annular combustor) by using lean premix combustion. Aim of the presentation is to educate DLE users and demystify DLE technology and controls. Users should expect to come away with a better understanding of operational issues they may encounter and be better prepared to efficiently troubleshoot problems.

Speaker will begin by outlining the differences in construction and setup between the two combustion systems—including combustors, premixers, and DLE fuel-system layout and controls.

The need for DLE unique instrumentation—such as gas-quality and combustion-stability measurements, GP sensors for fuel-flow calculation, and accurate fuel regulating valves—will be discussed, as well as the impact of these instruments and components on gas-turbine operability.

Following an overview of the basic principles of DLE combustion controls, attendees will be introduced to key system parameters—such as the different calculated flame temperatures, combustor staging, window operation, and fuel-flow regulation and distribution—as well as the impact of ABAL logic. *Madera/Pasadena*

RM&D for peaking facilities, *Chris Evans, ProEnergy.* The demand for dispatchable power generation continues to increase. Witness the record starts, stops, and overall usage of aeroderivative gas turbines nearly each quarter for the past three years. A result is an increase in equipment wear and tear. This is important: The power market's reliance on aeros means WTUI members cannot afford unplanned outages caused by being blind to actual equip-

Monday, 11:00, Ballroom:
Axford presents his annual report on the global GT business

Mark Axford is one of few non-user attendees who has participated in virtually every WTUI meeting since the organization's incorporation in fall 1991. His connection with land-based aero engines began in 1978 with Stewart & Stevenson Services, which received its first US LM2500 genset order from the Hawaiian Independent Refinery in 1982. Interestingly, HIR's project leader at that time was Wayne Kawamoto, today WTUI's conference executive director.

Axford left S&S, later GE Energy, as VP sales and marketing, establishing Houston-based consultancy Axford Turbine Consultants LLC in 2001. The aero expert is well respected internationally for his work in assisting buyers and sellers of turbomachinery with purchase and sales transactions.

He maintains contact with the aero community even on personal time. The photo is of a visit to the Hamakua Energy Center on the northeast shore of Hawaii (Big Island) during his, and wife Trixie's, Christmas vacation. Axford sold this 60-MW 2 × 1 LM2500-powered combined cycle during the 1990s to Enserch Development Co as a Purpa Qualifying Facility. It is now owned by a subsidiary of Hawaiian Electric Industries Inc and permitted to burn diesel fuel, naphtha, and biodiesel.

Axford has been the featured speaker at WTUI annual meetings for nearly two decades. His predictions of future gas-turbine business trends and sales, pretty much have been spot-on. The editors believe the Renaissance Ballroom will be "packed" for this presentation; come early to get a choice seat.

Mark Axford at Hamakua Energy Center in December 2023

ment condition between inspections. That would force them operate reactively to alarms or failures.

Remote monitoring and diagnostics (RM&D)—proven outside of peaking applications—enables users to take a proactive approach, predict when problems are developing, and give operators the opportunity to mitigate those problems until a planned outage is possible. True predictive analytics have proved elusive to peaking facilities because of their very nature—including change operating profiles, run times, and varied stops and starts.

The speaker will discuss the application of intelligent technology—such as predictive analysis, machine learning, and advanced pattern recognition—to discern the asset's operating profile, subtle performance variations, and actual condition. The data result in accurate site-specific trend analysis, a failure-severity analysis, an estimated time to failure, and real-time performance deviations. *Catalina*

How NO_x and CO/VOC control has changed in the post-2020 world, *Joseph Otto, Environex.* Emissions control technology has advanced considerably over the past several years to meet the ever-evolving challenges of the power industry. The need for operational flexibility and the advent of low-carbon fuels has created even more challenges for catalytic emissions-control systems already being pushed to their limits. Catalyst technology researchers and suppliers have stepped up with new formulations and designs to meet the industry's latest demands.

Goal of the presentation is to bring aero users up to speed on the new tools available to help them meet current and expected emissions-control challenges—including the following:

- High-temperature dual-function catalysts developed especially for use in simple-cycle peaking plants. Experience and data provided will help users decide if high-temperature dual-function catalysts are viable for their plants.
- Hydrogen fuel blending. Integrating hydrogen into the fuel mix may help to reduce carbon emissions, but CO_2 is not the only emissions consideration involved with using hydrogen. Be aware that the higher firing temperatures associated with burning hydrogen increase GT NO_x emissions which, in turn, increase the NO_x conversion requirements for SCR systems.

  Speaker will discuss the impact hydrogen blending has on SCR/CO systems and the factors to consider when evaluating what changes may be needed to ensure reliable emissions performance with H_2 use.
- Other catalyst technology developments—including low-DP designs along with their intended and unintended consequences, new catalyst formulations and designs, changes to the supplier landscape, etc. *Sierra/Ventura*

4:30-5:30

More sustainable aero turbine operation through lubricant-chemistry management, *Peter Dufresne, EPT Clean Oil.* While aeroderivative GTs are efficient, jet lube monitoring and maintenance practices lag behind those established for analogous industrial GT oils. Most jet oil programs neglect the application's primary cause of failure: Inadequate management of the GT's lifeblood—its oil. Because maintenance and sustainability go

hand-in-hand, methods for better jet-oil management can reduce further the impact on aero engines.

Presentation will outline best practices for lubricant chemistry management that allow aero engines to produce power even more efficiently and sustainably than they already are. *Madera / Pasadena*

Mitigate unscheduled generator outages with an excitation controller upgrade, *John Holbrook, Baker Hughes.* As your generator's excitation controller ages, the need for maintenance increases, as does the chance of components becoming obsolete or unusable. Regular maintenance and repairs are important to ensure longevity and optimal operation. Another option is to replace your analog controller with a modern digital-based version. The speaker will discuss the advantages of the Brush Prismic A3100 excitation controller as the best upgrade option. *Catalina*

Advanced thermal exhaust insulation and winterization solutions for all LM2500 and LM6000 models, *Pierre Ansmann, Arnold Group.* Presentation begins by pointing to the problems Arnold's insulation systems avoid with the company's highly engineered 3D-shaped blankets that fit perfectly to the shape of exhaust system components—including the following:

- Interlocking steps between blankets, and use of stainless-steel oil and super-tight wire mesh to virtually eliminate vibration damage.
- Blanket damage requiring repair/replacement every outage.
- Surface hot spots conducive to insulation damage.
- Overheated noise enclosure.
- Loose fibers and dust that can cause health and safety issues.

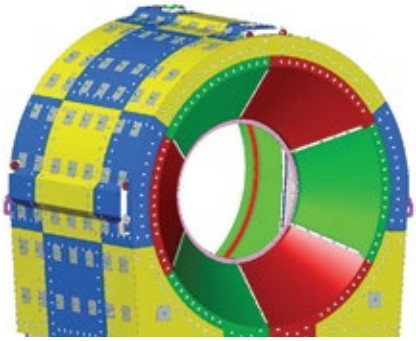
Sierra / Ventura

Acknowledgement

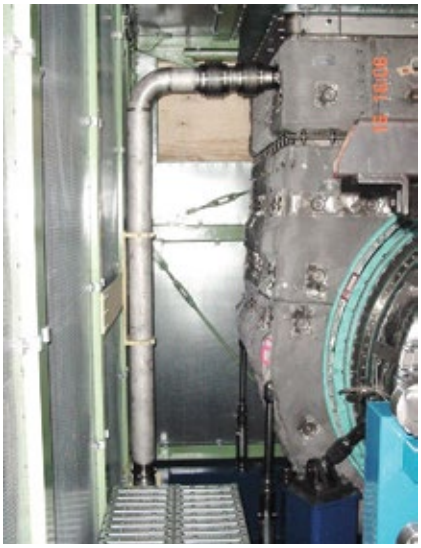
The heart and soul of WTUI, Jim Hinrichs, the organization's second and longest-serving president, told the editors years ago, is the dedicated user who understands that helping a colleague is an investment in his or her own company and expertise. "What's Joe's problem today, could be mine tomorrow," he said.

In the opinion of the editors and others, it is unlikely the aero engines served by WTUI would have achieved commercial success as quickly as they did without dedicated owner/operators contributing to the solutions implemented by the OEM and others to improve their operability and maintainability.

The Honor Roll, left, salutes the



Arnold Group insulation systems for LM2500 and LM6000 engines are designed for a perfect fit to the gas turbine, thereby maximizing the lifetime of the thermal shield



WTUI officers and members of the board of directors, who have contributed mightily to the success of this organization since its founding in 1990, and to the industry at large. If you see the nametag of anyone on the list in your travels, please thank them for their productive and unselfish contributions to the successes enjoyed by the greater LM community.

Strategic Power Systems, led by CEO Salvatore A DellaVilla Jr, is due special recognition for its work in tracking and reporting accurate and unbiased availability and reliability data since WTUI's founding. SPS's Operational Reliability Analysis Program (ORAP®) provides users the data and metrics they need to extract top performance from their aero engines.

WTUI 32 (2023)

The basic structure of WTUI's 32nd Annual Conference and Expo at the San Diego Convention Center was similar to that of earlier in-person meetings, as well as of the 33rd event in Palm Springs. It began with a golf tournament on Sunday, March 12, 2023, registration, Andrew Gundershaug's conference familiarization session, and the exhibitor-sponsored welcome reception.

Highlights of the Monday morning program were the following:

- WTUI Historian Mike Raaker's backgrounder on the organization from before incorporation to the present.
- Introduction of officers, board of directors, session organizers, and staff.
- President Ed Jackson's review of recent WTUI business.
- Treasurer's report, including the announcement of contracts in place for meetings at the Long Beach Convention Center and Hyatt and Renaissance hotels in 2025 (March 30-April 2) and 2026 (April 5-8).
- Presentations by Authorized Service Providers IHI, MTU, and TCT to update users on the capabilities of their service centers, key personnel, etc.
- The highly regarded worldwide gas-turbine business update by Texas-based Mark Axford (Axford Turbine Consultants LLC) and Illinois-based Tony Brough (Dora Partners & Company LLC), an annual feature of WTUI meetings.
- GE Gas Power Services' update—a short review of GE Vernova's businesses covering the company's installed base, service centers, and aftermarket inventory of parts, modules, and engines. Package enhancements, training courses, digital enablers, and hydrogen capabilities also were mentioned.

Breakout sessions for the LM2500, LM5000, LM6000, and LMS100 engines followed lunch and a visit to the exhibit hall. Those technical meetings, open only to users, ASPs, and GE, ran the remainder of the afternoon.

The Monday Night Reception offered attendees another opportunity to visit with vendors and to mingle with user colleagues.

Breakout sessions filled most of Tuesday and Wednesday mornings. Special Technical Presentations were conducted Tuesday afternoon. WTUI 2023 closed at noon Wednesday following GE's hour-long session on new products.

The LM2500 sessions, totaling nine hours of meeting time, were organized and conducted by Garry Grimwade of Riverside Public Utilities. They included engine-specific presentations by GE, TCT, MTU, IHI, and Strategic Power Systems Inc (SPS), plus robust open discussion. CCJ's coverage here is based in large part on notes assembled by SPS's Bob Steel, who participated in all sessions.

GE was accorded the first spot in the LM2500 lineup, with several of its engineers presenting. Product Leader Nam Tram began the company's participation with a safety moment and fleet overview (2800 active units, including LM2500, LM2500+, and LM2500+G4 machines; more than 125 million operating hours).

For immediate access to CCJ's summary of their presentations, scan the QR code nearby.

Badge Rules

Blue
User members who are registered conference attendees

Yellow
Authorized Service Providers (TCT, MTU, IHI) + GE

Red
Exhibitors

Black
One-day pass, Monday only (excludes dinner)
Must have membership

Purple
One-day pass, Tuesday only
Must have membership

Green
Press, publication companies, approved guests, SPS note-takers
Requests submitted by special interest groups/individuals which have been approved in advance by the board of directors

Gray
Board of directors, officers, and staff
Elected members of the board of directors, appointed officers, and conference staff

Late news

Tyson Chambers, maintenance supervisor, Lincoln Electric System, was elected to WTUI's Board of Directors after the Leadership Team 2024 sidebar on p 22 was finalized.

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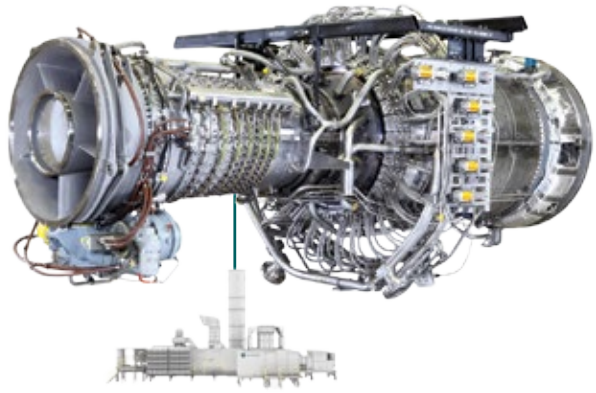


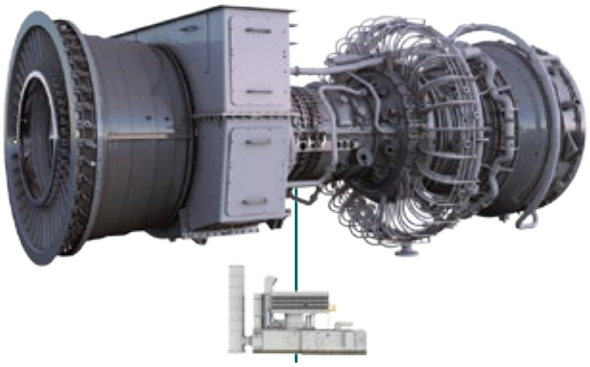
LM2500XPRESS*

The world's most modular power plant

LM6000*

The Sprinter

Quick start and compact power, all in one.



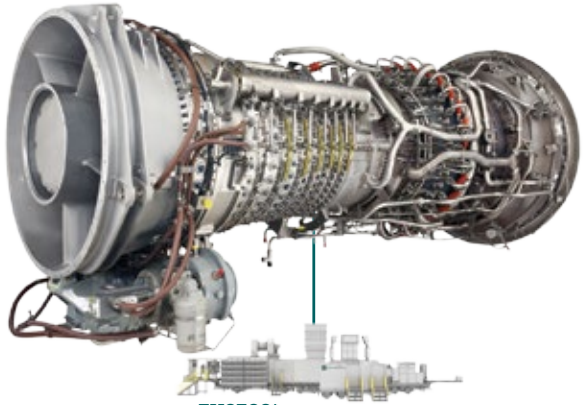
LM6000VELOX*

50 million operating hours (OH)

TM2500*

The Seasoned

Mobile power plant with shortest install time come rain or shine.



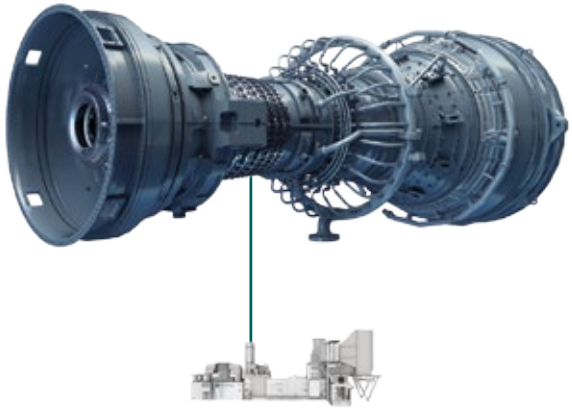
TM2500*

Power plant on wheels

LMS100*

The Adapter

Part load or full load, it can lift them all.



LMS100*

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HSE for LM2500 Base/+/G4 Testing for LM2500/LM1600

Avenza, Italy

MOH for LM2500 Base/+/G4
HSR for LM6000
Testing for LM2500

J-Port, Hou, USA

MOH for LM6000, LM2500 Base/+/G4 & LMS100
Testing for LM2500/LM6000

Port Klang, Malaysia

HSR for LM2500 Base/+/G4

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Advanced Filtration Concepts
Airgas Specialty Products
AP4 Group
Caldwell Energy
Cemtek KVB-Enertec
Dynamis Power Solutions
GasTOPS
NAES
OEM Parts Network
Reed Services Inc
SSS Clutch Company
StandardAero Component Services
Turbine Technics
Woodward
Zokman Products (ZOK/RSI)

SILVER
Braden Filtration
Bradley Griffin
EKO Green Industrial
Gusto General
Industrom Power
Pacific Standard Environmental
Rochem Technical Services (USA)
SISO Engineering
SISU Energy & Environmental
TMS Generation
Universal Analyzers

Tyler Dowty, product service engineer, followed with a review of completed engine programs—including bearing improvements to mitigate hard-particle contamination and resulting wear, ruggedized components for the HPC, VSV actuator bracket wear, and TMF liner wear. If you're not familiar with the acronyms, see the sidebar on p 20.

Active engine programs include efforts to address trailing-edge oxidation of HPT first-stage blades, an updated fuel-manifold hinged bracket, and mitigation of ejector-screen distress.

Best practices then were reviewed by the speaker for air filtration systems, fuel-manifold hinged brackets, among others.

Next, Lead Package Engineer Pedro Montiel (1) offered a solution to address high temperature in the turbine enclosure, (2) clarify that upgrades including resettable counters only require a software update, not a full controls upgrade, and (3) confirmation that Technical Procedure 2155 covering installation of the hydraulic-start-pump electric motor would be uploaded to the GE customer portal.

Wayne Romeo, FieldCore service manager, reviewed GE's aero field-service capabilities and recent experiences. He noted that the O&M Manual and IPB were accessible from the GT Portal. This is important because it's more efficient for the service team to help in troubleshooting problems if users are familiar with these documents.

Suggestions based on recent experience:

- When water washing, be sure to cover controls/electronics.
- When performing a clutch inspection, check the Y strainer for debris—an indication of impending failure. A related tip: Keep up on Hilliard recommendations for clutch inspection and overhaul. They can prevent an expensive failure.

Mike Carlson, fleet manager, then reviewed service and product bulletins without follow-on discussion.

Theo Sanchez, aero service product leader, handled remote monitoring and diagnostics and other digital topics. RM&D monthly reports were acknowledged as effective for improving collaboration at the site level. Some users said the biggest challenge to making the reports available to all who should be involved in the discussion was getting IT security to agree.

Mike Pipes, well known by many aero users for his years of close association with WTUI, handled CM&Us (conversions, modifications, and updates). Some discussion points:

- Four-hour lockout avoidance. This mod keeps the engine turning while the trip is investigated. It uses the torque required to turn the engine to determine if the unit can be restarted before the four-hour lockout. However, if the slow roll is interrupted, lockout is required.
- Fast start requires a purge on shutdown. However, the time that the purge remains valid for performing a fast start is site specific and impacts downstream equipment.
- The FLEX500 upgrade is available only for control of SAC engines. It is not compatible with DLE.
- LM2500 (base and plus) Xtend™ hot sections: Be aware that an interval extension is for the HPT only; it does not include the combustor. For users concerned that extending hot sections to 50k hours may involve a loss in performance, GE says there's only negligible loss when operating with the Xtend hardware.

TransCanada Turbines' presentation by Robert Smans reviewed the ASP's shop and field findings concerning the following: CFF, damage to the CRF engine mount, HPC rotor and stator, wear to the HPC VSV lever-arm, CRF, wear to the hinge bracket on dual-fuel manifolds, combustor, second-stage HPT nozzle support, clogging of cooling holes in the combustor and HPTR first- and second-stage blades, TRF, No. 7 ball-bearing event, and missing fairing rivets in the TRF.

Brief discussions also touched on oil analysis, preventive-maintenance challenges, and tarpaulins for engine shipping containers.

The following details were provided by TCT on its findings Tuesday morning:

- The forward and aft clevises for the left-hand engine mount were damaged during removal because a pin seized. A weld repair was made successfully. Lesson learned: Take care during engine removal to prevent damage.
- HPC VSV lever-arm wear was found to be within limits after 25k hours of operation. Careful inspection was stressed.
- Hinge bracket wear on a dual-fuel manifold was first addressed by redesigning the bracket, but that did not solve the wear issue. And the original brackets were no longer available. A 4000-hr temporary fix using PTFE was proposed and is described in the presentation. GE is working on a design to remove the hinge.
- Cooling-hole clogging is believed to have been caused by calcium introduced from NO_x-water contamination. Solution is simple: Maintain NO_x water to spec.
- Most of the five or six ball-bearing events that occurred last year were on +G4 engines with bearings that did not have nitride hardening. Solution is obvious.
- Fairing rivet heads found missing on the TRF of a +DLE engine in Europe were replaced in the field using the IRM repair procedure. Suggestion: Check with your ASP before doing any such work. Sometimes repairs can be made without pulling the engine.
- When analyzing lube oil, have the particle count performed to National Aerospace Standard 1638, not ISO. Since GE uses NAS 1638, a direct comparison is possible.
- A question was raised regarding the use of shock blocks on shipping containers. It was said that GE recommends acceptable limits for the G number; however, no defined procedure was provided on what to do if the G loading is exceeded.

MTU's presentation was shared

among Uwe Wassel from field service, Oliver Eckert from shop engineering, and Tobias Kalfhaus from inspection engineering. They examined several recent problems tackled by shop and field-service personnel that any LM2500 owner/operator could face. For each, the three experts described the observed condition and provided relevant support information and recommendations to resolve the issue.

First topic: CRF/TMF/TRF oil-supply-tube repair and TRF oil leakage. To illustrate the level of detail available in the presentation at your disposal, consider the following:

Diagrams show where oil-supply-tube deformation (CRF) and wear (TMF) occur and TRF oil leaks are likely to happen. Wrong handling during disassembly is one reason for the damages identified and several recommendations are made to avoid said problems. Steps are given and well photographed to guide both in-shop and onsite repairs. Repairs not approved by GE, which does not mean you shouldn't consider them, are identified.

A user presentation of a B-sump oil-supply-tube failure traced to the wear sleeve and how that was corrected onsite is recommended reading. It saved months of downtime that would have been required for a shop visit.

Other issues identified include these:

- Oil mist coming from vapor-separator vent was observed on three units with vapor separators of similar design. Cause of the oil mist: Empty drain box. Operators on rounds should check the drain-box daily.
- Main gas-strainer plugage alerted by a sudden increase in T48 spread that prevented a unit restart. Recommendation: Check the Y-strainer each time maintenance is performed upstream in the circuit and at least every 8000 hours.
- Hot-gas-induced vibration reading. A recoup air leak was blowing directly on the accelerometer causing the noisy vibration signal. The gremlin was gasket damage. Stress proper torquing when gaskets are installed.
- Water-wash auto drain valves installed incorrectly.
- Inspection findings that point to issues you might want to put on your checklist included these: Heavy internal and external corrosion of the HPC; high starter return temperature, weep-hole partial blockage by air-duct vespel strip material, DLE diffuser pin missing (refer to Service Bulletin 170), contaminants found in the fuel-gas path resulting from liquid-fuel operation, blasting grit found in DLE premixer strainer, and excessive machine grease on fuel-gas connection.

Other highlights of the LM2500 sessions were:

- A presentation by Woodward Controls covering the lifecycle of the company's products along with examples of site upgrades.
- Case history of a No. 5-bearing supply oil leak inside the TMF strut. Highlights included these: (1) An eight-hour delay in separating the engine from the power turbine was attributed to damage to the heat shields around the PT and TMF honeycomb. Recommendation: Pull the engine and PT together. (2) Main mount bearings for the engine were found worn during reinstallation, extending the outage. Recommendation: Check mounts when removing the engine.
- Kidney-loop oil conditioning was said to provide oil of better quality than that supplied by OEM, with the best systems capable of removing coke from the bearings. A test at a machine running on landfill gas reportedly increased its oil life six-fold.

ORAP stats for the LM2500 would be of greater significance if more owner/operators participated in the program. Get the details on how you can benefit from ORAP at www.

spsinc.com.

The leading contributors to forced-outage incidents in 2022 were instrumentation, emissions, fuel-gas controls and valves, compressors, and generator control and protection.

LM5000

The LM5000 sessions were organized and conducted by Perry Leslie of Wellhead Services. Only 28 of the 102 units produced by GE for service were still operating at the end of 2022. With virtually no aftermarket to speak of, Air New Zealand Gas Turbines closed its LM5000 shop as 2022 drew to a close, leaving MTU the only ASP serving the fleet. GE and a few specialty maintenance and overhaul shops still vie for what business there is.

Sessions dedicated to this engine were characterized by relatively short presentations from interested parties and robust open discussion among users dedicated to keeping their units in service. Topics of greatest interest included power-turbine bearing failures and variable-geometry check.

A positive takeaway from the meeting was an announcement by MFS, a gas-turbine solutions company from The Netherlands, led by Alex Peelen, that it is equipped to handle the maintenance and overhaul of LM5000s. The company launched in 2001, has experience with LM1600, LM2500, LM5000, and LM6000 engines, as well as some frames.

With vibration always a topic of interest to these attendees, Chairman Leslie invited Robert Mihata of Alta Solutions to discuss vibration basics with a focus on the LM5000. It was well-received.

Another guest speaker was Steve Johnson, owner/founder of S J Turbine, who was involved with LM5000s as a user before WTUI incorporated, later serving on the board of directors for several years.

He reviewed the challenges owner/operators faced with this engine in the early years, especially with regard to steam injection (STIG).

Sulzer reconfirmed its support of LM5000 users and addressed the power-turbine bearing-failure issue.

Robin Sipe of S&S Turbine Services Ltd discussed his company's support for the legacy turbine and its ability to make the impossible, possible. He illustrated this with a case history of a unit that most would write off as scrap and making it serviceable.

LM6000

The LM6000 sessions were organized and conducted by Dave Fink of Southwest Generation. This is a large fleet, totaling about 1000 units worldwide. Major presentations by GE, TCT, MTU, IHI, and SPS addressed issues related to models of this engine from A through PF+. The presentation summaries below are terse and meant to identify content that may be of interest to you. As noted at the beginning of this special section, details are available to WTUI members at https://wtui.com/forums. For access, email Webmaster Wayne Feragen at wferagen@wtui.com.

CCJ's coverage here is based in large part on notes assembled by SPS's Tom Christiansen, who participated in all of the sessions focused on this model.

GE was accorded the first spot in the LM6000 lineup as it was for the LM2500 breakout. Product Leader Nasser Chraibi began with a safety moment and an overview of the LM6000 fleet. A highlight of his opening statement: GE is working on the development of dual-fuel capability for the PF+ model.

John Heaton followed with summaries of various engine programs. Topics included the following:

- HPC: S1-blade mid-span shroud issue, S3-5 blades, S14 blade distress, VSV inner-shroud bushing wear.

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- LPT: PCC flex joints.
- Variable-geometry pump: Maintenance and storage.

Jurgen DeCeuster discussed topics of importance associated with GE package programs, including these:

- VBV transition-duct cracking.
- Load test certification of gas-turbine lifting equipment.
- Exhaust-diffuser and clamshell cracks.
- Life of jacking-oil hoses for the Brush DAX generator.

The users-only session on Tuesday morning was particularly valuable to owner/operators. Discussions focused on the following:

- Plans for aging plants. Sites reported problems with instrumentation, cabling, fire protection, and controls. A user suggested replacing cabling and sensing lines after about 15 years of service, and to transition from pressure switches to transducers.
- Nearly two dozen attendees said they had units in the shop waiting for parts. One noted that PF combustors are difficult to find and colleagues should plan for wait times of up to about a year. Another said that even lead times for SIP style S3-5 blades can be three to four months.
- LEL sensors for fire protection systems can be another source of problems.
- The impact of load reversals received significant interest. One user said his plant averaged 450 starts annually with load following down to 25 MW. At 1500 starts, S3-5 blades must be replaced, he said, as well as bushing, shrouds, and possibly the spool. He mentioned this as an example of how work scope can increase when replacing the S3-5 blades.

A follow-on comment by another attendee was that his plant expected work-scope creep and suggested colleagues ask the ASP what they should expect during the shop visit based on previous experience.

Service Bulletin 310 was recommended reading.

- Entrained water in the lube-oil system was another topic of considerable interest with solutions that included periodic replacement of filters, kidney loop, coalescing filters, plumbing changes, etc. It's certainly worth reading if this is a concern at your plant.
- Varnish was yet another discussion point during the session.
- One user's solution to solenoid-valve issues: Replace critical valves annually.
- Combustor issues came next with emissions exceedances, swirler wear, fuel-nozzle bore wear, impact of water injection rates, etc, factored into the discussion.
- Thoughts on how to keep operators engaged in their responsibilities followed.
- HPT S2 nozzle distress. The full-wrap TDC component has more than double the operating hours as the old design and is still operating.
- Maintenance planning: Risk tolerance and budgets are the two biggest factors in spare-parts planning which the attendee said should be done in-house. If you let the ASP or OEM manage your parts it's unlikely going to work in your favor.

MTU was the first ASP to present in the session. Ralph Reichert was at the podium first, followed by Marco Mori. Here's what Reichert had to say:

- Domestic object damage by T48 thermocouples. Recommendation: Replace your T48 t/cs after each hot section instead of the overhaul interval.
- Replace all S3-5 HPC blades at every hot section or 1500 starts. Blades can be replaced through the

top case as suggested in SB 310R2.

- Case history: An HPC S5 blade liberation was followed immediately by a stall. About half of all the downstream blades were scrapped and the stator vanes from S3 forward were damaged.

Service bulletins earmarked for review focused on the following:

- IND 0347, 0349, and 0343, covering the enhanced VBV bell crank, improved HPCS S1 and S2 inner-vane shrouds, and Sprint® nozzle improvement are documents to consider reviewing.
- IND 0340 applies to PC engines only and concerns the new HPT S2 nozzle assembly.
- IND 0342/0348 cover 4B/5R bearings with nitride hardening for long life. They have had no reported issues.
- IND 0323 discusses an improved O-ring material not conducive to hard deposits, as a means for reducing leakage in lube-oil systems.

Mori began with an in-depth look at an incident where a unit failed to start because of fuel-system contamination. The symptoms were that all GP2 sensor readings were below the expected light-off value of 22 to 23 psia. Contamination was in the form of a fine-rust dust from an external carbon-steel pipe installed by the user between the filter element and package. Note that GE requires stainless steel downstream of this final filter.

Next case history was of an LM6000 PF that was producing 33.4 MW when it should have been generating about 41 MW. Troubleshooting activities revealed the flapper and shaft of an eighth-stage valve were not rigidly connected at all loads. MTU recommends users track ambient temperature and pressure versus output to indicate when the engine is not performing as it should.

IHI. Findings reported by IHI Power Systems' Hiroshi Aoki came next. Failure of No. 5R bearing and oil shield on the CRF were detected when a user saw high C-sump temperature and common drop in MCD (magnetic chip detector) resistance. Similar events had been reported previously for the 4B bearing. As others familiar with this issue had recommended previously, IHI also suggested nitride hardening of the 5R bearing as a solution.

At another plant, magnetic metal shavings were found in the screen of the AGB's scavenge line. Disassembly of the transfer/accessory gearbox revealed significant damage had occurred to bearing components since last maintenance—an interval of 8200 hours that included 1300 cycles. Recommendations: Restore lube oil to the quality recommended by the OEM and monitor the chip detector going forward.

The MCD alerted on the failure of No. 4 ball bearing in the CRF at yet another plant. Once again, nitride hardening was the recommendation.

An S3-5 bolt was found missing from the VSV housing during maintenance. Records indicated that it was part of a shipment of bolts sent to the OEM in late 2017 that did not have the required self-locking feature. While non-conforming hardware had been purged from GE's supply, there was no reliable way to ID suspect parts in the field.

Users were pointed to SL6000-IND-21-001 for guidance, along with instructions on how to check for the bolt-locking feature and adequate run-on torque provided in Work Packages 4012 and 2412.

Recently, excessive corrosion was found on the VIGV forward inner cases of four units during major overhauls. Such damage (corrosion pits too deep) is considered unrepairable. One way to avoid the problem is by drying the engine after water washing.

Unrepairable fretting was found on the pressure side of LPT S5 disc dovetail serrations in multiple engines, at least one of which was in baseload service. Attendees were reminded that




a full inspection is recommended during major overhauls.

TCT's Robert Smans was the last of the ASP representatives to present. Here's what he covered:

- LPC corrosion, which often is traced to humidity in the package. Recommendation: Fully dry the unit following a water wash; a high-speed crank is insufficient. Plus, when the unit is idle, turn on the package heater and cover the inlet.
- LPC S0 disc separation, which might occur in some models if certain conditions exist. Learn more in Service Bulletin 356/357.
- VSV actuation-ring fretting from the Burgen cable ferrule end of BSI plugs. Suggestion: Orient the ferrule on the plug such that it is not in the lower-half safety-cable holes to prevent contact with the VSV actuation rings.
- VSV lever-arm damage (for example, bent/cracked/distorted arms and tangs) from the IGVs through S5 VSV.
- HPT S2 outer-band erosion and cracking, which if found early, could prevent a liberation event. Presentation offers guidance on finding and monitoring cracks, which typically occur from 250 to 20k hours and from 200 to 2000 starts.
- Gear tooth wear on variable-geometry pumps attributed to cavitation. Particultes released can cause clogging of filters and oil contamination, affecting VSV, VIGV, HCU, and VBV actuation. If an overhaul is required, use original OEM gears, not reverse-engineered parts.

Smans suggested magnetic chip detection system instrumentation for early problem identification in lube-oil systems. He favors weekly verification that the fluid contains no particles but said a monthly interval should be adhered to. Use NAS 1638 for comparison purposes, as TCT recommended earlier in the LM2500 section. Field Guide GEK117488 can help identify the source of chips.

If your MCD alarms, shut down the engine and refer to Work Package 4017. If the particulates are bearing material, replace the bearing and make sure to flush the system afterwards. If not bearing material, put the engine on watch, check detectors daily if possible, and keep a sharp eye for vibration problems.

Smans continued: Tarpaulins protect shipping containers in transit and storage. Remember, shipping containers can rust. Handle containers carefully with lifts and transport supervised by qualified and experienced personnel.

ORAP. Data from more than 25% of the units in the LM6000 fleet are shared among owners/operators in the ORAP community, making the statistics meaningful for decision-making. If you are not familiar with ORAP, it's worth your while to read through the short presentation made at WTUI 32 to better understand the value of participation in this program.

Information now available on the WTUI website is for calendar year 2022. If you're attending the 2024 meeting you can get the 2023 data live during the LM6000 breakout session.

The following were the top 10 contributors to forced-outage incidents at LM6000-powered simple-cycle plants (includes gas turbine, controls and accessories, driven equipment, and balance-of-plant equipment supporting the GE and generator) in 2022: combustion system, controllers and software, vibration, fuel-gas metering and staging valves, variable bypass valve system, fuel-gas control and shutoff valve, fire/gas detectors, hydraulic starter, water injection valves, and variable stator vane assembly.

Interestingly, the top four contributors to forced outages in 2022 also were among the first four in 2021. The only two on the 2022 list not among the top 10 in 2021 were water injection valves and fire/gas detectors. They replaced speed sensors and lube-oil pressure.

If you arrange for access to the ORAP data, you'll get a breakdown of the contributors to the forced-outage incidents and gain valuable insights. Example: The 106 combustion-system incidents in 2022 totaled 877 hours at 20 plants while the 72 vibration incidents had far greater impact, causing 6084 outage hours at 19 plants.

LMS100

The LMS100 sessions were organized and conducted by Steve Worthington, who manages Arizona Public Service Co's Ocotillo Power Plant. This was Worthington's last year at the podium, having completed his term as session chair. Jason King of Onward Energy was announced as the incoming chair for 2024 and beyond.

The 81 units in this fleet are supported by GE; no ASPs are involved. The GE representatives were Tim Schneck, product owner; Nate Yux, senior product service engineer; and Ivan Felix, LMS100 platform manager. SPS CEO Sal DellaVilla was the official notetaker for the LMS100 program.

Schneck opened the session Monday afternoon with a safety moment and then introduced the aero FieldCore team, led by Wayne Romeo, to discuss maintenance considerations and recommendations. Here are the highlights:

- Owner/operators should endorse an effective preventive maintenance (PM) program—including oil conditioning and analysis—to maximize engine reliability and availability. Cleanliness (external) from oil misting/leaks and dirt buildup was cited as beneficial for maintaining the condition of VSVs actuator/lever arms, and other hardware.
- Water washing of the engine on a scheduled or performance-driven basis is an important maintenance action, Romeo said. HEPA filters provide additional benefit for improving compressor and engine cleanliness.
- It's highly important to keep GEK work packages, IPBs, and other related site documentation current and available to plant personnel, who can then share it with contractors as necessary.
- Support struts of the adjustable-leg design are preferred to facilitate engine alignment with less wear on bolts.
- The old-style FOD screen continues to be an issue and should be checked for rust, which could signal a break in the screen. This is very important because a compromised screen could provide a pathway for debris to damage the supercore. Users discussed screen improvements made at their plants to maintain screen integrity.

Open discussion revealed the following:

- FieldCore acknowledged that its personnel do not have deep off-engine (intercooler, VBV, expansion joints, etc) knowledge and experience to share with owner/operators at this time. Users expressed a desire that FieldCore expand this capability.
- The need for field support by experienced local technicians and engineers equipped with the proper tools remains an issue. Working closely with your GE and FieldCore representatives is critical to solving problems quickly and correctly.
- FieldCore said it had invested $500 million in tooling for both US and Latin America. However, recruiting the maintenance talent necessary to do the work remains challenging. Users expressed concern that outage execution typically is taking longer they believe it should. Some reasons, they think: Slow response to PAC case issues; insufficient search tools to query data; field-service reports, as well as parts, are slow in coming.

An ORAP analysis of the leading contributors to downtime in 2022 also

is posted to the website. Lube-oil issues were the top concern in 2022 with 28 incidents cited at 11 plants accounting for nearly 600 hours of outage time. In 2021 controls and software contributed to 58 forced-outage incidents.

Special technical presentations

Highlights of the nine hour-long special technical presentations made Tuesday afternoon (March 14) are summarized below. Slide decks are posted at https://wtui.com/forums. Recall that access to this site requires an email request to Webmaster Wayne Feragen at wferagen@wtui.com.

Best practices, *Scott Schwieger, Combined Cycle Journal.* Best practices submitted to CCJ by 13 generating plants during the Covid years, as part of the annual awards program sponsored by the periodical and WTUI, are reviewed. Focus of the best practices profiled is on the continuing efforts at aero plants to make them safer. While you might not consider some ideas offered as "new," perusing the slides might refresh your recollection of improvements to consider in the future.

For example, several plants have swapped out portable ladders for permanent stairs with handrails, installed permanent platforms to eliminate risks associated with equipment inspection and maintenance (Fig 1), improved lighting to facilitate guesswork during rounds, etc.

1. Turbine package fans before (left) and after (right) installation of a platform to facilitate access and make the work location safer

Other best practices you might benefit from include the following:

- Turbine-oil sampling improvements to reduce inaccuracies and improve safety.
- Relocating grease fittings from high elevations to ground level.
- Moving valves requiring periodic oversight to locations more accessible to personnel.
- How file-sharing improved productivity at four peaking plants.
- Reduce O&M costs for gas chromatographs.
- Transitioning operator rounds from paper to electronic records.
- Fuel-compartment wind block eliminated unit trips.
- How focus on plant culture can drive positive change.
- Instruments for leak detection.

Monitor bearing health with confidence, *Simon Wilson, GasTOPS.* Bearing damage events and unreliable detection technologies are said to be the leading causes of unplanned machine outages and unexpected costs. Damage develops gradually and may be predicted accurately with the proper detection technology—such as GasTOPS's Oil Debris Monitoring technology, available since the mid-1990s.

It combines the company's online MetalSCAN product (Fig 2) with its offline advanced troubleshooting capabilities (oil, filter, and chip analysis) to provide an accurate picture of bearing health.

The problem with reactive monitoring technologies, according to the speaker, includes the following:

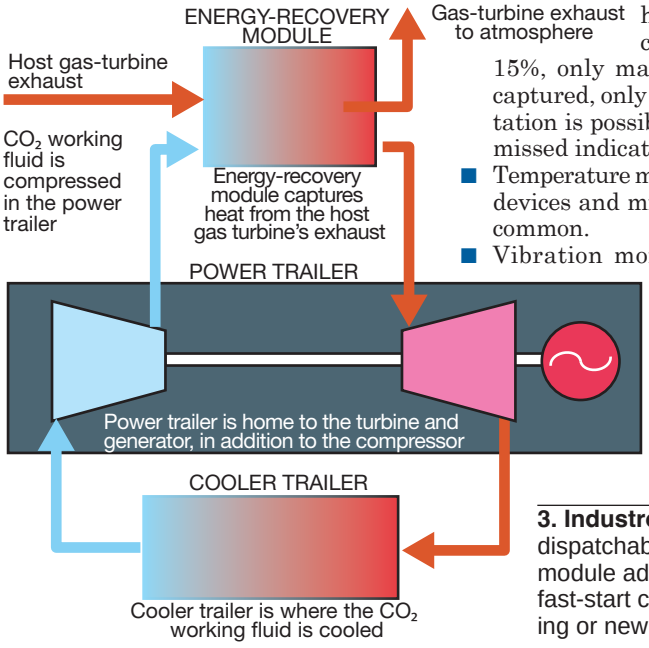
- Indication may be received only minutes, possibly seconds, before the event.
- Provides limited advance warning for maintenance planning.
- Severe and expensive secondary damage is possible.
- Limited or no root cause analysis.

Why Wilson says "reactive" doesn't help:

- Oil analysis—infrequent sampling period, lengthy feedback loop, inconclusive results, labor intensive, plus, missed indications are common.
- Chip detectors have a capture efficiency of only about 15%, only magnetic particles are captured, only qualitative interpretation is possible, false alarms and missed indications are common.
- Temperature monitors are shutdown devices and missed indications are common.
- Vibration monitoring is another shutdown device, one requiring expert interpretation.

MetalSCAN detects the initiation of damage and monitors its progression. Claims include 100%

2. MetalSCAN multi-sensor electronics enclosure installs outside the package. Sensor cables under the enclosure connect to sensors inside the package



3. Industrom Power's firm, dispatchable, clean-power module adds 10 MW (net) of fast-start capability to an existing or new LM6000

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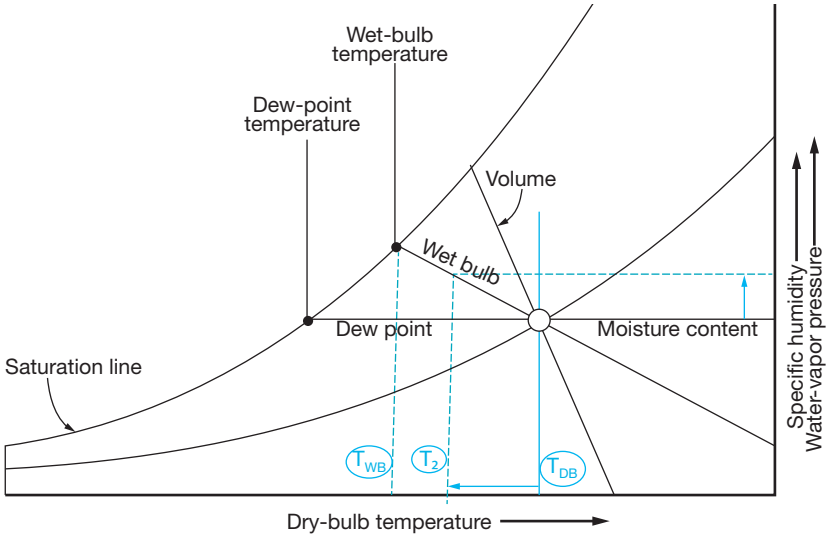

4. Fogging effectiveness is the dry-bulb temperature less T_2 divided by the dry-bulb temperature less the wet-bulb temperature

performance engineer compares fogging to other methods for increasing aero gas-turbine output—including evaporative cooling, chilling, wet compression, and air or liquid (NO_x water) injection. Result of the analysis: Wet fogging wins (Fig 4). A strategy for improving the performance of aero engines is discussed and includes current results and a path toward increased power and profitability in any climate.

Best practices for root-cause analysis in the context of a potential dispute, *Dr Ty Porter, PE, and four colleagues, Exponent.* Industrial failures often have the potential for a dispute between two or more parties related to liability for causation and, ultimately, responsibility to recover unexpected costs from the outage.

Unintentional improper handling of physical evidence and information can have a negative impact on the outcome of a potential dispute regardless of the technical reasons for the failure.

Focus of the presentation is best practices for plant personnel and other involved parties following an unexpected failure in the context of a potential dispute—including evidence handling and storage (Fig 5), provenance of email and other written communications, and information/data management. Case-study examples are included.

5. To limit component handling damage the best thing you can do is *nothing.* When you have a fracture surface (photo) use gloves and *never* try to put the damaged surface back together

6. Integrated Path Optical and extractive CEMS are compared in Cemtek's presentation. Former, abbreviated IP CEMS, are said to have several advantages over the latter for meeting EPA regulations

debris detection, flow-through sensor design, proven alarm limits, information is provided on particle size and type, remaining useful life can be predicted, and no maintenance is needed.

Firm, dispatchable clean power, *Paul Angel, Industrom Power.* Presenter has deep knowledge of LM products having spent more than 30 years with GE Aviation and GE Power before joining Industrom Power. He was an LMS100 product line leader for the OEM and earlier had design and product-line responsibilities on the LM2500 and LM6000.

Angel introduced attendees to a mobile clean-energy technology/system that recovers waste heat from new or existing gas-turbine assets to produce firm, dispatchable electric power (Fig 3). The fast-starting system does not require water. The carrot, in round numbers, is 20% more power and a heat-rate improvement of 17% for a typical LM6000.

His presentation began with an overview of the technology and how it works. Next, the components of a nominal 10-MW heat-recovery system for use with LM6000 engines was discussed—including performance improvements. An energy balance, startup times, and other operational benefits also are covered.

Increasing LM6000 turbine plant performance by 10% through wet fogging, *Constantin Dinu, ProEnergy.* Presentation by the company's senior

Utilizing integrated-path optical CEMS (IP-CEMS) to meet EPA regulations, *Gary Cacciatore, Cemtek*

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KVB-Enertec. Focus of the presentation is the technology, costs, maintenance, and calibration requirements associated with the use of IP-CEMS technology. It uses cross-stack Tunable Diode Laser Spectroscopy (TDLS) and Differential Optical Absorption Spectrometer (DOAS) to monitor gas emissions for CO_2, CO, NO, NO_x, NO_2, SO_2, HCl, and NH_3, in lieu of traditional extractive CEMS to meet EPA 40CFR60 regulations (Fig 6).

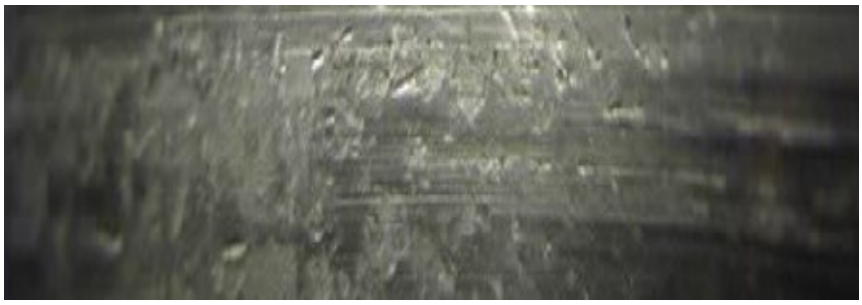
Speaker shares the information needed to evaluate use of this technology at your plant—including a cost comparison to extractive CEMS, spare parts, maintenance, calibration, etc. Case studies of recent installations are included, plus a review of a demonstration test performed to meet EPA 40CFR75 for a gas turbine operating on natural gas.

Shaft voltage and current monitoring, *Sunny Gaidhu, PE, Iris Power (Canada).* Shaft monitoring can provide early warning of rotor, stator, and bearing insulation problems, as well as grounding-brush condition, to support safe operation of large generators (Fig 7).

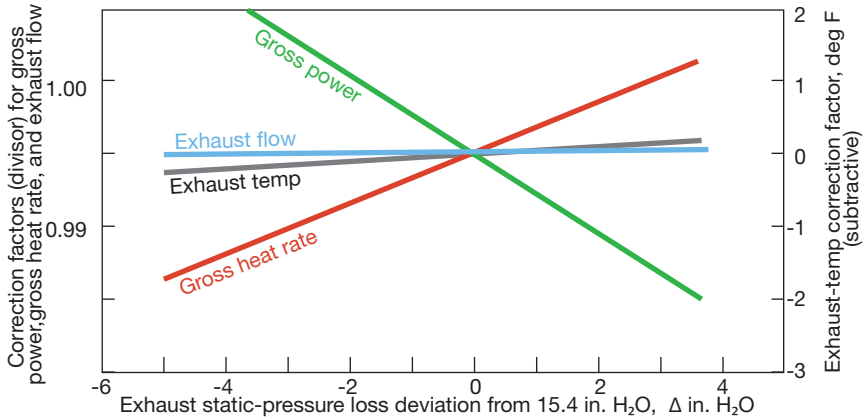
Shaft current and voltage signals are transmitted to instrumentation to facilitate continuous monitoring and processing of shaft grounding current and shaft voltage. This information can be used to do the following:

- Evaluate grounding-brush performance.
- Provide early warning of problems.
- Improve the quality of diagnostics if used in conjunction with other monitors—such as shorted rotor turns, vibration, etc.

A case study concludes the presentation.



7. Problems caused by shaft voltage include the creation of currents high enough to permanently damage turbine/generator shaft and bearings. Typical pitting is shown in the photo



8. Expected benefits of HRSG cleaning based on industry research. Chart summarizes results for a 201-MW gas turbine operating 8000 hr/yr with 4 in. H_2O of additional backpressure attributed to fouling. Groome's expectation is that it will recover 75% of the increased backpressure, thereby saving $192,000 in fuel annually, plus $150,000 from additional energy profits. Basis: energy price, $60 per MWh; natural gas cost, $5 per million Btu

Benefits of servicing and maintaining emissions-control systems and HRSG equipment, *Jeff Bause, Groome Industrial Services Group.* Company's KinetiClean process, EPRI-certified, is proven technology for cleaning HRSG heat-transfer surfaces more effectively than competitive methods to increase energy output, strengthen the bottom line, and reduce the risk of fines and regulatory action that can result from air-permit noncompliance (Fig 8).

Presentation describes the three-step process:

- Create a kinetic shockwave via a det-cord curtain.
- Remove any fouling remaining after the shock-wave step has been completed using the automated high-pressure/high-volume air distribution system.
- Remove debris that accumulated on the HRSG floor using the company's vacuum truck.

KineticClean's benefits include the following:

- Shock wave penetrates deep into tube bundles.
- Faster, full-coverage cleaning than alternative methods. Multiple tube faces are cleaned simultaneously.
- No manual tube movement is required.
- No scaffolding is required.

Presenter Bause illustrates the system's 25 years of success via case histories and photographs. A calculator is provided for owner/operators to plug in their data and see if KenetiClean is a good fit for them.

Gas turbine SCR in the changing world, *Dan Johnson, PE, Cormetech Inc.* Everything you might want to know about SCRs for powerplant application since their introduction in the 1980s—designs, catalysts, market dynamics, chemistry, materials of construction, history of industry participants, plus impacts of starts/minimum load/required emissions reduction/new fuels and blends/catalysts for CO oxidation and VOC elimination, etc. Schedule time for reviewing this presentation: It's 81 slides long.

9. Traditional SCR design (left) is characterized by a "wall" of catalyst which requires a large cross section to increase plant efficiency; however, adding catalyst decreases efficiency. Modern design at right with high-activity catalyst promotes higher efficiency in less space

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O&M advice free for the asking

Online forums sponsored by gas-turbine user groups are of increasing value to owner/operators, especially given today's smaller O&M staffs at simple-cycle, combined-cycle, and cogeneration plants and the loss of experienced personnel to retirement and better opportunities. Long gone are the days of on-the-job training when new employees would tag along with experienced crews to grow their knowledge over time.

Thus, today you may be at a loss on whom to call with an important question. If that's the case, try posting that question to the forum serving your engine model. Oftentimes you'll receive expert advice at no cost within a day or two. Most likely your issue is not unique. Also, in need of a part in a hurry? Ask colleagues online to loan you their spare until you can replace it.

Forums serving the larger user groups—such as Western Turbine's LM6000 Forum—typically provide the best results by virtue of their global reach.


Feragen

To illustrate the value proposition, CCJ editors selected a few questions posted to the LM6000 forum in 2023 along with a summary of the guidance offered. To join, go to www.wtui.com/forums. Questions? Contact Webmaster Wayne Feragen at wferagen@wtui.com.

1. Generator vent fans

Question: Has anyone retrofitted their "classic" belt-driven generator vent fan—TCF Azen or Hartzell—to direct drive? If so, whom did you use? Any lessons learned? Where did you source the fans?

Replies:

- We were a test-bed site for direct-drive fans on both the turbine and generator. Turbine fans were a constant problem and we eventually switched back to belt-driven units.

  Generator fans—all are TCF/Aerovent—haven't been as troublesome, but we do suffer intermittent high-temperature issues in summer.

  Whenever we test or inspect, everything checks out OK. We have tried a few minor mods to improve and balance air flow through the enclosure, but haven't seen a difference.

  Recommendation: If you are content with your belt-driven fans stick with them.
- If you're seeking a retrofit solution to direct drive, I'd recommend contacting Eldridge USA. Their expertise in providing turnkey solutions is noteworthy.
- Switched to a banded, three-rib V belt and haven't had anymore belt issues on the generator TCF/Aerovent fans that use a 3/BX73 belt.
- In the past, apparently there were belt-failure problems on all package fans. We implemented a maintenance program that verifies pulley alignment with a laser alignment tool and setting the proper tension using a belt tension tool. Misalignment and improper tension are the primary drivers of belt failure.

  Final step: Use soft starters in the MCC buckets to reduce slippage during starts.

  Result: Belt issues essentially have been eliminated at our plant. Today, belts typically are replaced only because of age-related cracking.

2. Problems with the VBV feedback signal

Question: We have some problems with the feedback signal on one of our variable-bleed-valve systems. It comes and goes, and may be good for several hours/days before it fails again. The OEM's troubleshooting guide says to measure resistances, check connections, etc. Everything seems fine. Does anyone experience a similar problem? A real solution is important to us, especially in winter.

Replies:

- Try replacing package and on-engine cables. If the plugs have been overtightened, damage may have been done to the cable sockets.
- Our site is constantly plagued with VBV and VSV (variable stator vane) feedback problems. Have you looked at any high-speed data logs to see what the signal is doing? Some of our issues have been logic errors that do not prevent nuisance trips when one actuator feedback fails. GE provided new logic (not installed yet) said to resolve several issues with feedback faults causing unwanted action. It doesn't solve root-cause issues, but it does keep the unit online and rejects the faulty signal.

  The responding user provided details on how his plant handles the issue described.

3. Hole in first-stage HPT blade

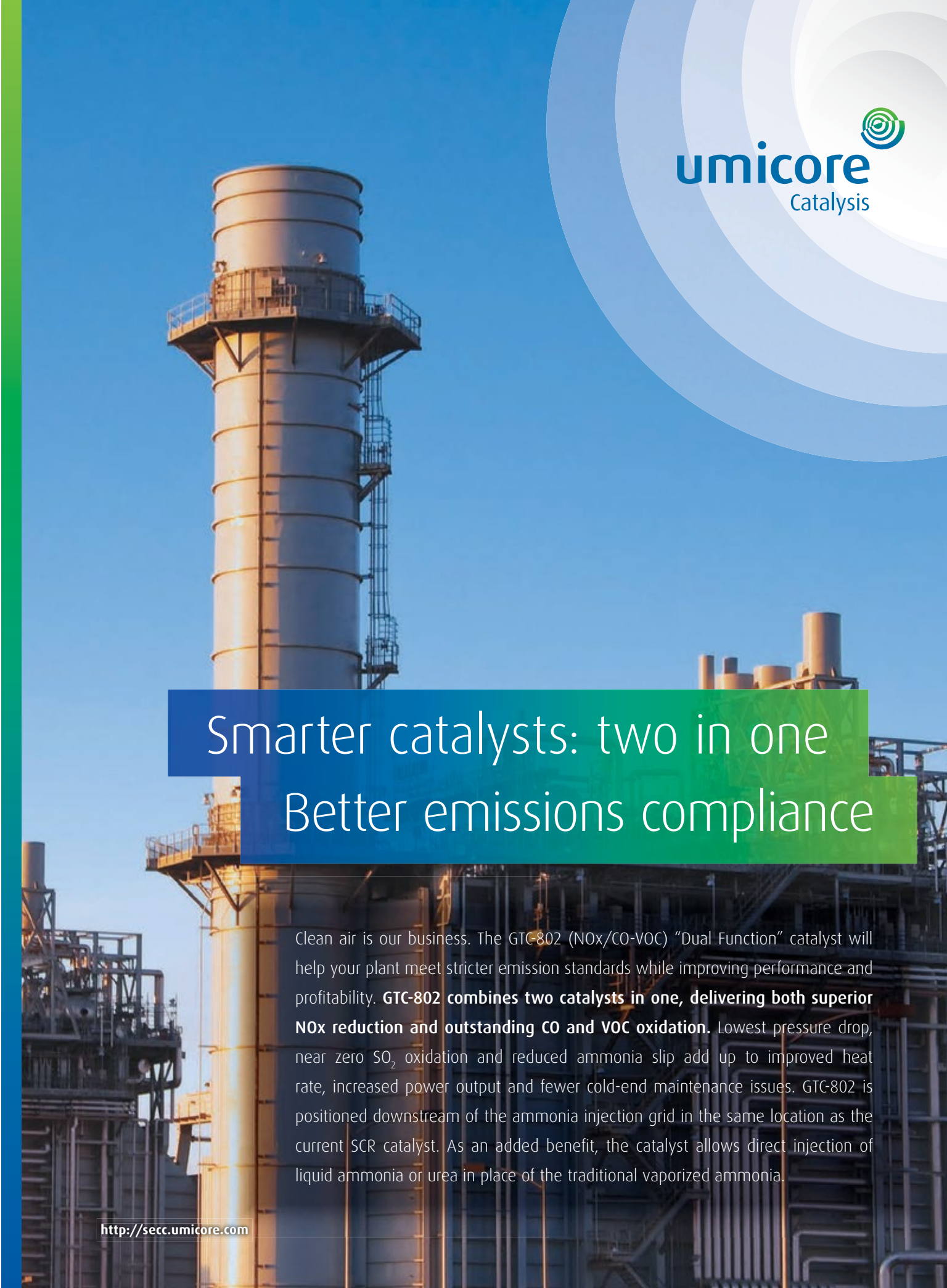
Question: During our annual borescope inspection, we discovered a through hole on the leading edge of a first-stage HPT blade. There is a slight amount of TBC loss on the combustor swirlers, but no visible damage or coating loss on the nozzles and later-stage PT blades. We are running five LM6000PCs, but this unit is the only one to have this type of damage. The unit underwent a hot section in 2022 and received a rotable, overhauled HPT rotor at that time with a mixture of new and overhauled first-stage blades. Have any other users had a similar experience or seen this type of damage?

Replies:

- Several years ago, we had similar damage on our HPT. Cause was identified as liberated material from a combustor secondary swirler (venturi).
- We've had similar failures over the last couple of years. One instance was attributed to an HPC blade event; the second to a nozzle failure, but the exact cause of that was not determined.
- We experienced similar damage in 2012, with DOD into the HPT first-stage blade. Origin was never determined except that it might have been caused by TBC coating released from the combustion chamber. Blade was replaced in the field.

4. HCU overhaul intervals, troubleshooting

Question: What do forum participants have to say about the overhaul of their hydraulic control units (HCUs)? Our site has had an HCU fail previously (VBV section). Today we are diagnosing an issue with the VSVs on another unit. Both feedbacks are in agreement, but position became erratic at about 83% stepping up in the positive direction. The issue was bad enough to



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affect load capability.

Today I performed electrical checks on all LVDTs (just for good measure) and torque motors. All passed. Cranked the unit and stroked the VSVs into several positions, but was unable to replicate. We're going to check the rod/head screens for any material caught, and possibly replace the HCU.

Replies:

- Our HCUs failed every time because contaminated oil was fed to the HCU and the internal components clogged-up. Oil contamination was traced to (1) topping off of the GT oil tank with generator oil, (2) the failing HCU filter allowing contaminants to pass through, (3) bypass over the HCU filter, etc. In every event we had to send out the HCU for overhaul. One event was attributed to installation of a short HCU in a long filter bowl.
- The questioner jumped back into the conversation thusly: Yesterday we ended up replacing the HCU. However, when we loaded the unit at about 48 MW the issue returned. We also received a power-supply fault for the chassis that contains the ACT_CNTRL cards (our PG units have redundant ACT_CNTRL cards, one driving A torque motor coil, the other the B/C coils; both cards are in separate chasses). Today, we will go down the servo cables in the package looking for shorts. If none are found, we will replace the power supply and load the unit again.
- A concerned user warned: Before you restart the unit, you may want to verify the quality of the synthetic oil to be sure mineral oil was not added inadvertently. Have a SOAP analysis done.

  Continuing, he said, the writer of the first reply shares unfortunate lessons learned. The consequences of continuing to operate with contaminated oil can be significant beyond damage to the HCU. Try to understand why the HCU failed, he recommended. If coking starts to develop in the sumps—especially B&C where the temperatures are highest—the risk of bearing failures is greater.

  He then quoted from the troubleshooting recommendations in Chapter 10 if the O&M manual, "If engine is operated for more than 200 hours with MIL-PRF-23699 oil containing more than 5% mineral oil, significant internal coking may occur."
- Another user entered the online chat: One thing to check is the mechanical system to make sure it is free to move across the whole range. The Woodward document had a service-life recommendation for the LM2500+ at six years as I recall. Can't remember if the LM6000 HCU was in the same document. I will check with the Woodward application team and report back.

  Just rechecked GE documentation and found the service life of the LM6000 HCU is six years or 50k hours.
- The original questioner reported back: Comments very helpful. We traced the issue to a faulty Woodward actuator control module. It was difficult to trace because we have redundant control of the torque motors (one module connected to torque motor A coil, the other connected to B and C). It seemed from the data log like the issue was common because both cards were stepping up their output. It wasn't until we ran a calibration on the B channel (B and C coils) that we were lucky enough to catch the erratic behavior from that module at that time. Replacement was the solution.
- Yet another user closed out the discussion by providing a pdf of Woodward's HCU manual and an information letter providing recommended maintenance intervals for Woodward auxiliary equipment. The only issues encountered at his plant have been contamination through oil and a grounded servo coil.

5. VBV actuator/LVDT

Question: We had a VBV actuator feedback fail. Looks like the soldered connections behind the actuator's Cannon connector were heavily corroded; one of the connections actually broke away at the soldered joint. Is anyone seeing this same failure mode? Might the manufacturer, Arkwin Industries in this case, have had a run of improperly soldered joints?

Replies:

- The soldering looks to be of poor quality (note that photos of the affected joints were provided via the online forum), but I have seen solder melt inside the package before because of heat if the part is in a hot spot.

  Perhaps the part had been refurbished and misrepresented as new. Suggest you reach out to Arkwin to confirm authenticity.

  Another thought: The O-ring could have been leaking if someone had tried to over-tighten the Cannon plug and twisted it.
- Questioner response: I agree that the soldering looks nasty. I have only seen Arkwin actuators on our machines, even our old PC model. We are planning to send this one out to AGTSI, having used their service previously for actuator overhaul.
- Another user, looking at a photo provided by the questioner, confirmed that the actuator is a valid GE Aviation procured part—the Federal Supply Code for Manufacturers is correct as is the part number.
- Questioner response: This actuator was OEM from GE on our power-generation units. We have never replaced a VBV actuator on these units until now.

  I did hear back from AGTSI and this is what I was told: Unfortunately, we do not offer repairs on these as the manufacturer does not offer this service. That said, however, there are third parties that offer this service but we are not sure if they are approved by the manufacturer. AGTSI does offer rotable exchange for new on these units, but it would be quite a bit more expensive than just having the connections soldered.
- During the back-and-forth online exchange, Score Energy was identified as a possible service firm for this work.
- Another user offered the following: From what I understand, Score Energy now is allowed to contract with US end users directly for off-engine parts. The company's Houston office has competitive offerings on rebuilding, exchange for new, and new outright purchases of LVDTs. However, the rebuild shop is in the UK and there is a long turnover time, so I opted for the new one with the used exchange.

6. Woodward device needed

Question: Having reliability issues with the auto sync on a unit in our fleet. Don't have a lot of detail, but the site team believes it's a malfunctioning DSM. The device is an SPM-D10 Synchronizing Unit (PN 5448-906). According to Woodward, this particular device has not been supported by them since April 2016. Does anyone have any spare devices they are willing to part with?

Replies:

- A user suggested going on the Woodward website and accessing the company's list of global business partners to identify service

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and spare-parts local suppliers that might be able to help.

- A second user strongly disagreed with the claim suggesting that the auto-sync issue is caused by the SPM synchronizer, as it rarely breaks, he said. The problem often arises when settings on the SPM are not correct, resulting in extended synchronization times unless adjustments are made using the keypad for the SPM.

  I urge you to trouble-shoot the circuitry thoroughly before making any financial commitments. If you pursue the purchase option, you might try Maximum Turbine Support or APM.
- A third user found the K100 relay was the issue in a similar situation. The contacts must get gummed-up and do not pass good voltage to the input card, he said. It happened on two different units, so plant replaced the relays on all four of its PD engines, which have MicroNet Plus control systems.

  This was for the remote auto sync and not the local TCP. Our site is set up with a remote supervisory control system that controls all the units and tells them to synchronize remotely (enable sync). If we went out to the site and put the TCP in "local" and then moved the hand/off/auto switch from "off" to "auto" it would synchronize just fine, but wouldn't sync if told to do so remotely. Not sure if this applies to your situation.
- As the previous user said, make sure the permissive signal (coming from the K28 relay in my unit) is active during auto sync. If it's taking a long time to auto sync, check the DSM settings and fine-tune as necessary.
- Yet another user noted that while the SPM-D10 Synchronizing Unit rarely breaks, he had to replace one recently because of a failed breaker-close output relay.
- The previous user agreed that the DSM was very robust and surmised that if the breaker-close output relay is damaged there could be a loose connection in the breaker closing circuit.

7. Likelihood of a major combustor problem

Question: After all the discussion about combustor problems at this year's WTUI conference and the general unavailability of spare parts for these components, we are evaluating the logic of ordering a spare hot-gas section. We have two PF2 engines and neither GE nor the ASPs have much in the way of spares.

What is the likelihood of a major problem in the hot-gas section of these units? Are any numbers available? Does someone have a spare hot-gas section? What is your strategy?

Replies:

- Very complex question, so the response is multi-faceted. Capital expenditures—such as purchasing a spare hot section—depend on many factors, including the following:
  - Mode of operation—peak, load-following, baseload.
  - Annual operating hours, which impacts the calendar time between hot sections.
  - Inlet filtration quality.
  - Size of installed fleet.
  - Operating experience.
  - Operator experience, fuel quality, number of trips, etc.

  My company will be operating multiple baseload units in several plants trying to run as close as possible to 8760 hours annually. Considering today's supply-chain challenges, we will own a spare hot section to rotate through the "fleet," maximizing the number of available hours to operate.

  If an owner operates relatively few hours in a seasonal pattern (for example, high demand in summer or winter), then it might be able to coordinate with the OEM to have the replacement got section available at the "right time" and not have to buy a spare.
- Having a spare hot section probably is overkill if you have only two units. However, if the units must have super-high uptime, then you need to weigh the cost of the hot section against the cost to the business when the unit is not operational. Something to consider: What happens if you buy a combustor and put it on the shelf and GE updates the design?
- I think routinely checking your T-48 spread and adjusting your fuel-nozzle pattern accordingly, along with routine borescope inspections of your dome cup area, inner/outer liners, and looking for early signs of spalling TBC, is a good proactive approach regarding hot-section life.

  I would also look at NO_x water mapping to be sure you are not over-watering your combustor. Over-watering and harmonics are the biggest causes of cracking around the cooling holes located behind the dome cup area that can cause downstream HPT first- and second-stage damage.

  How many fired hours will your two PF2 units be operating annually? If 8000 to 8500 hours, the best solution is to purchase a spare engine and rotate it into operation at each hot section and major. The spare engine is conducive to a short outage duration for swapping engines and maximizes unit operating hours. The hot section or major maintenance would be completed on the engine removed after the unit is back in service and before the next unit is due.

  Keep in mind that you don't want both units scheduling hot sections and majors at the same time—if the units are operating nearly the same annual hours. Reason: You would need hot-section parts for two units at the same time, compounding the issue. It would be best to get one unit into the first hot section (or swap the spare engine in) a year early to offset the hot section and major outage intervals for the two units.

  If the units will be operating less than 4000 hours annually and not so critical for availability, you might not need a spare engine.
- We are currently evaluating our needs for the new PF1 units we are installing, but more than likely will keep at least one spare engine on hand for our 10 units, with the possibility of upping that to two. We did consider purchasing a spare hot section as well, but the cost of the that section with the combustor included is near enough to the cost of having another complete spare engine that we're not sure it makes sense for us.
- Follow-on response from the user asking the original question: Looks like we're actually investing in a spare engine for several reasons—including minimizing downtime, advantages for major maintenance work, and assuring the district heating supply.

  However, the final decision hinges on what costs we should expect for preservation of the spare engine? Are there any maintenance or conservation activities that must be conducted regularly? Is it possible to estimate the costs involved?
- This response to the second round of questions: Get familiar with WP 3011 in the O&M manual. Plus, consider storing the gas turbine in its container inside a warehouse, or if has to be outside, place it under roof cover. When the container expands and contracts because of weather changes, and especially if it sits in the sun, the ability to keep the internal humidity under control is much more difficult. CCJ

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

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

Hiring and retaining a qualified workforce

Challenge. The industry continues to struggle with staffing and hiring issues. Multiple factors impacting staffing—including retirement of experienced personnel, highly competitive employment environments, and the decrease in the pool of interested and qualified traditional military candidates (navy and air force).

Solution. Sentinel Energy Center developed a comprehensive employee recruitment and qualification program for its team of Operations Technicians after experiencing significant turnover and under-qualified candidates to fill the gaps. Program begins with a paid internship period where the candidate is chosen based on reputable referrals. The candidate is processed through a local temp agency. There is no requirement of prior experience or set timeframe for the internship period. The candidate's natural safety awareness and maturity level are the first areas to be evaluated.

Next, candidates are given an extensive list of tasks to complete under supervision. These usually are related to site cleaning, painting, preservation, labeling, and signage. Based on the individual's performance, the tasks increase in complexity.

During major maintenance activities, candidates assist qualified O&M personnel in pre-job safety activities—including safe-work permit, hazard analysis, LOTO, confined space, hot work, observations, etc. They are also included in all employee and safety committee meetings.

There's constant feedback between

Sentinel Energy Center

Owned and operated by DGC Operations LLC

800 MW, gas-fired peaking facility equipped with eight LMS100 simple-cycle engines, located in North Palm Springs, Calif

Plant manager: Dennis Johnson

every department employee and plant management regarding the progress made by the interns. The opportunity to screen potential employees over a long period, allows site management to more thoroughly assess a candidate's character and work ethic. These individuals then are either offered a full-time opportunity or given an honest and professional exit interview, depending on the Sentinel committee's decision.

The interns hired are provided with a new-hire orientation packet that has them read, review, and show competency on all site safety procedures.

Then they are enrolled in a two-week program of full-time coursework conducted by a reputable external contractor specializing in industry training solutions. This program includes heat-transfer fundamentals, fluid flow, turbine theory, basic electricity, water chemistry, and various other topics related to plant equipment.

Successful employees then receive their qualification standard, which encompasses three levels that must be performed in sequence: Outside Operator, Control Room Operator, and Supervisory. The qualification cards are comprised of the following:

- Practical factors. Qualification signatures for learning specific tasks sorted by individual plant systems or pertaining to the administrative tasks that the position requires.
- Knowledge factors. Qualification signatures and exams for understanding system purposes, flow paths, and interconnections.

For the first few months of their Outside Operator qualification, the new employees parallel a fully manned weekday day-shift operations-technician's crew. They learn the shift routines and aid in site electrical and mechanical maintenance evolutions.

To complete this phase of the qualification program, the new employees must complete one full-shift rotation with a fully manned and qualified shift of operators rotating between nights and days, thereby exposing them to night-shift routines.

Upon successful completion of one set of shift rotations the employee is usually done with the Outside Operator qualification standard and ready for a final oral board administered by site management and EH&S personnel. Completion of this board qualifies the candidate as an Outside Operator who may assume any shift with any qualified Control Room Operator.

The employee then may begin work on the Control Room and Supervisory level qualifications. However, hands-on experience is required: Outside Operators must complete six months of on-shift time before being eligible to complete their Control Room Operator qualification and Control Room Operators must complete one year before being eligible to complete their Supervisory qualification. This ensures the operators have adequate time in these positions to experience many operational scenarios that may arise.

Results.

- Employees are vetted through a much more detailed process than the typical 30-min interview.
- Entry-level positions give candidates a chance at a challenging and fulfilling career that might not be accessible at other companies because of hiring requirements.
- New employees are exposed to the desired EHS, production, and site reliability culture from the start.
- The last several openings at Sentinel resulted in a near immediate filling of the position by a temporary candidate who had successfully completed the internship and evaluation process

Project participants:

Dennis Johnson, plant manager
Larry Wilson, maintenance manager
Jesse Ballou, operations manager

GoPro camera allows visual inspection of 'hidden' areas in turbine package

Lawrence County Generating Station

Owned by Hoosier Energy Rural Electric Co-op Inc (four units) and Wabash Valley Power Assn (two units)

Operated by NAES Corp

258 MW, six simple-cycle LM6000 natural-gas-fired peaking units, located in Lawrence County, Ind, and connected to Hoosier's 161-kV transmission line

Plant manager: Robert VanDenburgh

Challenge. Perform a more thorough visual inspection of the gas turbine/generator while the unit is in operation. There are several "hidden" areas in the turbine package not visible to the operator through the viewing windows. This can be a critical limitation when troubleshooting oil leaks.

Solution. The plant O&M team communicated with OEM field-service representatives about their approach to finding obscure package leaks. Investigators determined the solution for Lawrence was to purchase a GoPro camera/mounting arm. The camera can be positioned virtually anywhere in the turbine package, allowing the operator to clearly see "problem areas" from the control room. The camera improved the operator's ability to complete turbine visual inspections and also increased safety by eliminating the need to spend additional time in front of the package door/window.

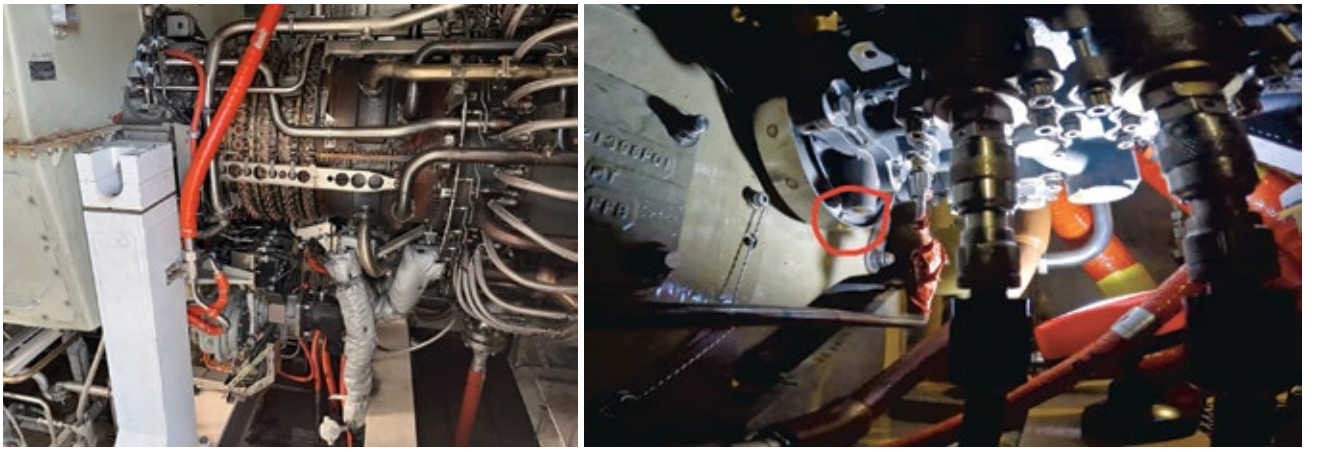
Results. The outside operator was performing running-plant logs when Unit 3 developed a small oil leak. It was obscured by the hydraulic starter and impossible to see the leak location from the package viewing window (photo, left). After shutdown, a GoPro camera was mounted in the package and positioned to clearly view the area in question (photo, right). During operation, the oil leak was found to be coming from the lube and scavenge oil pump. Engine repairs were completed at the first opportunity.

Project participants:

Matthew O'Hara, lead O&M technician

Jared Thomas, O&M/IC&E technician

Kevin Wildner, O&M technician



Package viewing window (left) does not allow for a thorough inspection of the engine. GoPro camera allows technicians to focus on "hidden" areas in the package (right)

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REO Cogeneration Plant

Owned and operated by Lansing Board of Water & Light

100 MW, 2 × 1 LM6000-powered combined cycle, located in Lansing, Mich

Plant manager: Tom Dickinson

'Ladder Last' program successful in preventing ladder falls

Challenge. The Lansing Board of Water & Light (BWL) studied ladder falls and found there were two reported falls annually across the company. Further investigation revealed Electric Production accounted for one reported fall annually for the last 10 years.

Solution. A permit program was developed to limit unnecessary ladder use and thus reduce the number of ladder-related injuries. The program mandates ladders be used only as a last resort and that ladder use on BWL properties are allowed only when it has been determined that it is unfeasible to use all other options to complete the task.

If it is determined that a ladder is the only means of performing the job at elevated height, a Ladder User Permit must be completed by the responsible supervisor or job leader prior to starting work.

Once the permit is filed, a ladder can be unlocked and tagged with the permit for the duration of the task. When the task is complete the ladder is returned to locked storage (Fig 1) and the permit retained onsite for one year.

Note that only Type 1A OSHA-approved ladders that have passed inspection may be used on any BWL jobsite. Also, workers must maintain three points of contact at all times when working from a ladder.

The following ladder alternatives were pursued:

- Four permanent work platforms were installed (Fig 2).
- Large work platforms were installed around each of the two gas turbines.
- Four rolling steps/Erect-a-Steps were purchased (Fig 3).
- One additional single-person Genie lift was purchased (Fig 4).
- Rails were installed on all existing stationary ladders.
- Scaffolding is used after exhausting other means of access.

1. Ladders not in use are secured in storage with a cable

3. Four RollAStop steps were purchased

Results. The ladder alternatives listed above are used routinely. Since the "Ladder Last" program was implemented in July 2021, Electric Production has had zero reported ladder-related injuries.

2. Permanent work platform allows safe access to blower

Project participant:
Joshua Zussman, technical safety trainer

4. Single-person Genie lift is a ladder alternative

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ARNOLD GROUP

Worthington

Battery-powered tools protect personnel against hazards posed by extension cords

Background. All onsite power tools/lights were corded and required extension cords for use in most places. Because the plant is not equipped with many receptacles, multiple extension cords often were needed. Running cords across the ground poses a trip hazard, even with caution tape and cones to alert about the hazard. Plus, use of an extension cord outside in the rain and/or snow significantly increases the risk of electrical shock.

Challenge. Eliminating the need for corded tools/lights reduces the number of extension cords required onsite, and the time and expense for their quarterly inspection. Staff was challenged to find a viable alternative to the corded tools/lights. The benefits: (1) reduce the number of trip and electrical hazards; (2) increase onsite storage space by eliminating bulky corded tools and their extension cords; (3) create a better working environment for maintenance.

Solution. The NAES safety committee researched and explored alternative solutions. The consensus was to order Milwaukee M18 cordless tools and lights (photo). All use the same battery so the swap to another tool is effortless.

All hand tools use the same battery and can be carried in one soft "toolbox"

Results. All onsite corded tools/lights were replaced with Milwaukee M18 tools—including drills, ¼-in. impact, ½-in. impact, heat gun, Sawzall®, band saw, vacuum cleaner, shop light, grease guns, and angle grinder. All these tools fit in a single bag, facilitating transport and reducing the space required for their storage. Note that each of the old tools had its own case.

The cordless solution improved safety by reducing the need for extension cords often associated with trip and electrical hazards. Plus, the new tools promote more efficient work progression because all use the same battery and there are no extension cords to take out and run to the work location. The new tools also are more reliable and reduce worker fatigue because they are lighter.

Project participants:

Matthew O'Hara, lead O&M technician

Jason Robertson, generation O&M/IC&E technician

William Hooker, generation O&M technician

Garett Ray, generation O&M technician

Worthington Generation Station

Owned by Hoosier Energy Rural Electric Co-op Inc

Operated by NAES Corp

174 MW, gas-fired peaking facility equipped with four LM6000 simple-cycle engines, located in Green County, Ind, and connected to Hoosier's 138-kV transmission line

Plant manager: Robert VanDenburgh

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Wildflower Indigo Energy Facility

Owned by an indirect affiliate of Diamond Generating LLC

Managed by DGC Management LLC

Operated and maintained by DGC Operations LLC

136 MW, gas-fired, 3 × 0 LM6000PC (Sprint)-powered facility, located in North Palm Springs, Calif

Plant manager: Mike Carpenter

Wildflower Larkspur Energy Facility

Owned by an indirect affiliate of Diamond Generating LLC

Managed by DGC Management LLC

Operated and maintained by DGC Operations LLC

90 MW, gas-fired, 2 × 0 LM6000-powered facility, located in San Diego, Calif

Plant manager: Mike Carpenter

IR camera doubles as safety tool

Challenge. Identify safer ways to complete critical tasks. Sometimes an item as simple as an inexpensive smartphone camera attachment can improve your safety program significantly.

Solution. One goal at Wildflower's plants was to make the filling of ammonia hydroxide tanks safer. Even though the tanks are equipped with remote level indicators, staff found that use of a FLIR compact IR camera is better suited for this purpose, allowing personnel to visually follow changes in tank level during filling operations and to confirm fluid flow.

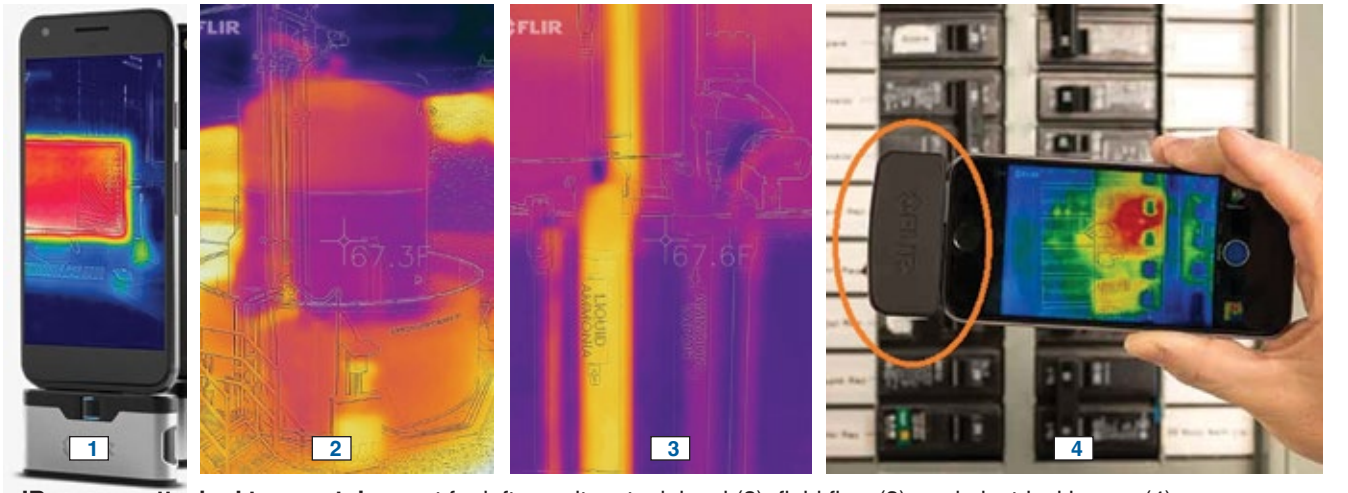
Fig 1 shows how an inexpensive IR camera attaches to the operator's phone and allows him or her to easily monitor tank level (Fig 2) and flow in piping (Fig 3) by way of infrared thermography and spot temperature. The IR camera also can be used plantwide for troubleshooting electrical issues and water leaks (Fig 4).

Results:

- A safer approach to tank filling operations and troubleshooting at minimal added cost.
- Increases safety by monitoring ammonia tank level and flow through piping in real time, instead of relying on a gage with no visual representation.
- Cost savings, by identifying hidden issues, such as bad fuses and lose wiring, or leaks.
- Use of an inexpensive camera instead of a bulkier and more expensive standalone version is more cost effective and practical.

Project participants:

Mike Carpenter, plant manager
Mike Noll, operations manager
All site personnel



IR camera attached to smartphone at far left, monitors tank level (2), fluid flow (3), and electrical issues (4)

Leading the Way in Emission Reduction: Braden Successfully Delivers Another Simple-Cycle Hot SCR Solution with New Drive Technology

In a significant milestone for the air quality and emissions management sector, Braden, a renowned industry leader, has successfully delivered another selective catalyst reduction (SCR) system with innovative 'DRIVE' technology in Sicily on an aeroderivative gas turbine.

Designed to address the pressing need for emissions reduction, this ground-breaking technology empowers plants to achieve Emissions Guarantee Design specifically for the minimum to maximum operating loads required by modern peaker and grid firming sites. By assisting plants in meeting new emission regulations, it contributes to building a greener and more sustainable world.

The newly delivered SCR unit incorporates an aqueous ammonia-based reagent system and is equipped with a tempering/purge-air fan system, enabling it to operate flawlessly in a 65-MW peaking plant. With meticulous attention to detail, the unit integrates a NO_x and CO multi-function catalyst within an acoustically optimized site, ensuring optimal performance while minimizing the noise impact on neighbors.

Braden's dedicated team of experts designed, fabricated, and commissioned this critical infrastructure system, ensuring full compliance with all European codes and regulations. As a result, the system is now fully operational, ready to support the Italian Grid.

This achievement marks a significant advancement in emission reduction technology and reaffirms Braden's commitment to delivering comprehensive solutions for air quality, noise control, emissions management, and energy storage. Through such innovative contributions, the company continues to pave the way toward a more sustainable and environmentally friendly world.

The Braden team responsible for the company's innovative SCR solution is, from left to right, Rand Drake, director of product solutions; Mike Seddon, controls engineer; and Matthieu Grandclaude, engineering manager

Mariposa Energy Project

Owned by an indirect affiliate of Diamond Generating LLC

Managed by DGC Management LLC

Operated and maintained by DGC Operations LLC

200 MW, gas-fired, 4 × 0 LM6000PC (Sprint)-powered facility, located in Alameda County, Calif

Plant manager: Mike White

Focusing rounds on specific issues contributes to improved plant performance

Challenge. One of the major challenges Mariposa had during summer operations with a single operator on duty was being able to investigate heat-related events while the plant was dispatched. Management relied on calling out vendors to troubleshoot and resolve the issues. This was problematic because there was never any communication or retention of the issues to understand and fix; we leaned heavily on outside sources which put us at risk of them not being available.

Solution. Last year, Mariposa implemented summer rounds focusing on specific areas of interest—namely chillers and HVAC. This allowed staff to follow all findings in Maximo under one tracking work order and weight the areas that needed improvement. The main areas of interest ended up being chiller condenser fan VFDs (tripped breakers/overloads) and enclosure HVAC units (which always should have been monitored).

Results. Plant personnel worked with the VFD OEM to better understand the current settings and see if any additional improvements or settings were possible and should be implemented to mitigate current issues.

Daily inspections were able to identify a problem before the plant was dispatched, allowing staff to correct the issue prior to startup. Mariposa had about two callouts last year which was a major shift from the previous years. It also allowed the entire team to understand the issues as they progressed so we would have direction when the chillers failed to perform.

Project participants:
Mike White, plant manager
Fred Yarcho, operations manager
All site personnel

HRSG FORUM

2024 Conference and Exhibition

Marriott St. Louis Grand • June 10 - 13

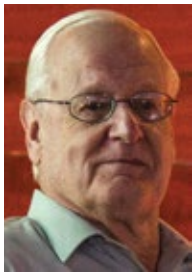
2023 Conference Report, p 64

Steven C Stultz, Consulting Editor

The upcoming HRSG Forum 2024 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. Discussions and the robust sharing of ideas are moderated by Bob Anderson, Competitive Power Resources, and Barry Dooley, Structural Integrity Associates (UK). They are guided by a steering committee of industry veterans: Eugene Eagle, Duke Energy; Albert Olszewski, Constellation Energy; Yogesh Patel, TECO Energy; and Scott Wambeke, Xcel Energy.

Bob Anderson



Barry Dooley

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Register today for the only Power Users conference focused on heat-recovery steam generators, high-energy piping, and cycle chemistry. Visit either https://hrsgforum.com/ or https://www.powerusers.org/ for full details and registration information.

HRSG Forum requires no membership or credentials other than an interest in learning more about HRSGs, maintaining and operating them better, improving their design and performance, and sharing your own expertise and experiences with others.

What you'll learn in St. Louis

This year's event in St. Louis begins on June 10 with an SCR/CO emissions control workshop focusing on system design, chemistry, operation and maintenance, and distinctions between catalyst and non-catalyst factors that impact performance.

That afternoon, participants reconvene for a deep-dive workshop on boiler-feed-pump fundamentals, installations, O&M, performance issues, and troubleshooting.

June 11 and 12 are the general sessions packed with presentations by users, service providers, and consultants, highlighting specific operating experiences and case histories.

Then on Thursday, the Electric Power Research Institute (EPRI) will lead attendees through the latest research designed to improve combined-cycle operations, focusing on high-temperature components, high-energy piping, plus low-temperature components (a topic raised at last year's meeting). A key takeaway will be EPRI's respected and authoritative state-of-the-industry review and close look at today's ever-changing challenges.

Last year's highlights

The 2023 event in Atlanta, the organization's first physical meeting since the Covid interruption, established the current four-day in-person format, encouraging all attendees to participate in the following:

- Cycle Chemistry Workshop—Film-forming substances (CCJ No. 76, p 31).
- Materials Workshop—Welding and metallurgy (CCJ No. 76, p 37).
- General Session presentations by Users (begins on p 64, this issue).
- General Session presentations by service providers (begins on p 70, this issue).
- EPRI Technology Transfer Workshop (CCJ No. 76, p 73).

As stated last year by Bob Anderson, HRSG Forum chairman, "What makes the HRSG Forum format work is the active participation of attendees—users, manufacturers, service providers, and consultants. This arrangement is important to provide timely and accurate answers to questions, and to hear what users have to say about their needs. Exhibitors (47 in 2023) are encouraged to attend the technical sessions."

Sponsors in 2023 were Viking Vessel Services, Tuff Tube Transition, EPRI, Zepco, Arnold Group, Dekomte, GE, Nooter/Eriksen, Precision Iceblast, Questtec Solutions, SVI/Bremco, Thompson Industrial Services, Accurity Industrial Contractors, Advanced Valve Solutions, Badger, Cust-O-Fab, Eagle Burgmann, Groome Industrial, Degauss, Millennium Power Services, Power & Industrial Services, Structural Integrity, TEAM Valve Solutions, and Vogt Power International.

HRSG Forum is associated with the European HRSG Forum and the Australasian Boiler and HRSG Forum, enhancing its international content and relevance.

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User presentations

HP evaporator replacement

Yogesh Patel, Tampa Electric/TECO, and Vignesh Bala, Vogt Power, gave a detailed, experience-based presentation on the replacement of HP evaporators for the two combined cycles at the 1800-MW Bayside Power Station, Unit 1 (3 × 1) and Unit 2 (4 × 1), commercial since 2003 and 2004, respectfully. The units are equipped with GE 7FA gas turbines and Alstom HRSGs.

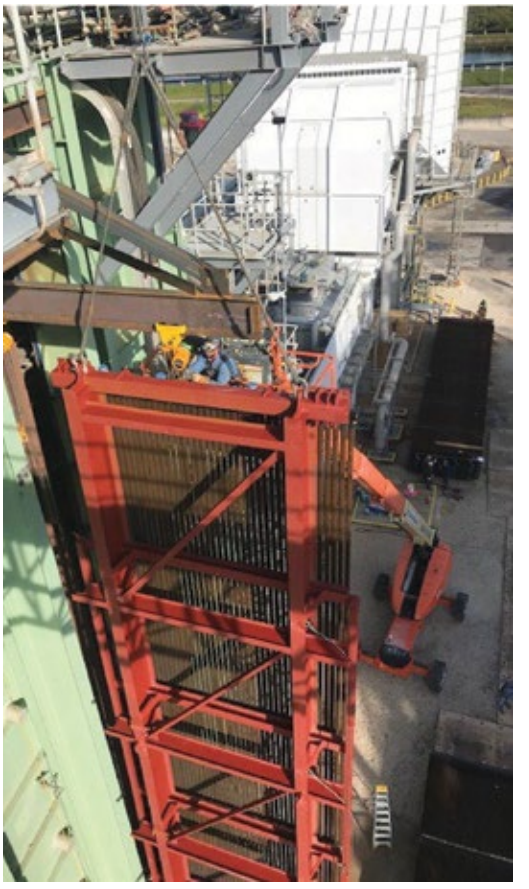
In December 2016, the station incurred several HP-evaporator tube failures in two of its seven HRSGs. All experienced under-deposit corrosion. Failure analysis indicated significant amounts of deposit weight density (DWD) within the tubes. The first sample showed the loading at 154 g/ft^2.

1. Heavy deposit loading in HP evaporator tube

In 2018, borescope inspections at Unit 2 showed a concentration of debris within the front headers and within the tube bundles approximately 18 to 20 in. above the bottom header. Tube leak-location experience was then analyzed. Tubes were removed (Fig 1) showing heavy deposit loading and wall-thickness issues.

Replacement decisions were made. Bala discussed planning, detailed design, fabrication, delivery, and construction. TECO selected Grade T11 tubes with carbon-steel fins and elected to fabricate in the US (Boiler Tube Company of America/BTA) for schedule and ease of inspections.

Preliminary construction planning considered both side and top access. Top entry was not effective because of the drums, so TECO selected the individual-lift side-entry option. The power producer also selected in-shop hydro with autho-



2. Side-entry installation of HP evaporator harp

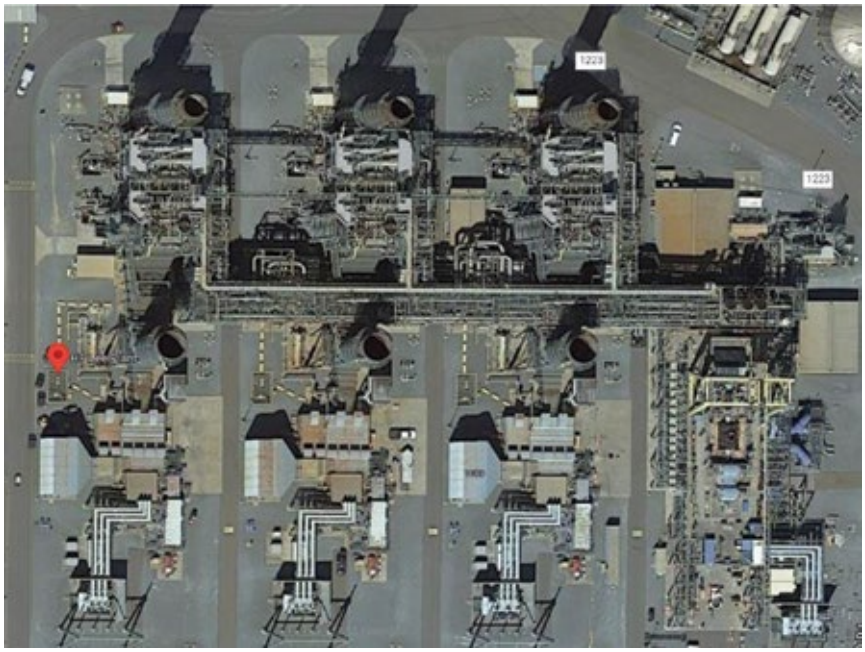
rized inspection to ensure the integrity of welds and conduct any repairs before delivery.

"Demolition was one of the most challenging parts of the construction phase," explained Bala. Harps were severed and removed.

"Coordination within the last 100 ft is critical; new harps must be delivered in the proper sequence!"

Installation included 48 individual harp lifts using one handling frame and one up-righting frame. A monorail system was used to slide the harps into the HRSG (Fig 2). Welding and NDE followed.

Post-presentation questions and discussions focused on the benefits of removing HP evaporator tube samples and having them analyzed for internal deposit loading, the impacts of poor long-term water chemistry, and the need to monitor for total iron.



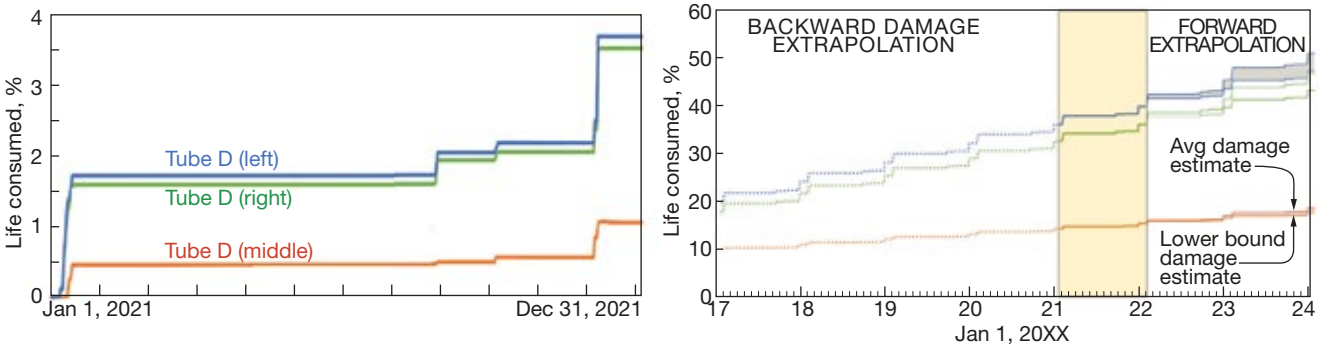
3. Duke Energy's H F Lee 3 × 1 combined cycle tracks damage to HEP and HRSG components in real time

HRSG damage monitoring

Duke Energy and Structural Integrity Associates (SI) jointly discussed online monitoring—more specifically a unique *HRSG damage monitoring system*. Presenters Eugene Eagle (Duke) and Kane Riggenbach (SI) looked at real-time assessment of system performance and component integrity for both HRSGs and high-energy piping.

Their example: Duke's 920-MW H F Lee Energy Complex, a 3 × 1 combined cycle (commercial 2012) anticipating future cycling requirements (Fig 3).

The Siemens F-class gas turbine/Vogt triple-pressure HRSG units at Lee have accumulated nearly 70,000 hours and have had damage issues related to RH and HP attemperation. "Many SH/RH drain, operational, CT exhaust, and attemperator control logic changes have been implemented," explained Eagle. Current operation is baseload, with low-load turndown to



4. Damage accumulation during monitoring (left) and extrapolations based on actuals (using previous inspections as benchmarks) at the right

5. Spool piece installed in HP to cold RH bypass

40 MW per gas turbine.

They began with an interesting HRSG overview, adding that each unit has surface-mounted, thermocouples of an advanced design that were installed at commissioning. It showed components typically susceptible to creep, fatigue, creep-fatigue interaction, corrosion fatigue, oxidation, and exfoliation. The focus (16 areas per unit) includes interstage and bypass attemperators, intermediate headers and tubing downstream of attemperators, branch connections, final-stage outlet headers, and drums.

Structural Integrity provided and monitors the PlantTrack™ system installed after 70,000 service hours.

Program goals are early detection when rate of damage is rising, and prioritizing locations and systems with a long-term goal of extending inspection intervals. Data can also be used to assess accuracy of fitness-for-service assumptions and adjust recommendations.

Specific life-management benefits include detection of operational or process changes (failed nozzles, leaking valves, etc) and evaluations of control logic changes (valve opening, spray amounts, etc). Comparison of operating modes (and impacts on component life) are made between units and plants, for low-load operations, operating with and without steam sparging, and for changes in startup times.

Riggenbach explained damage trending saying that "when monitoring, a time series of damage will be created," then adding that "a historical rate of damage consumption can be extrapolated." Previous inspections can be used as benchmarks. With this, future projections of damage consumption can be made (Fig 4).

Various examples of data presented on the PlantTrack Dashboard also were provided.

Duke's plan is to develop trends and translate the data for sister units.

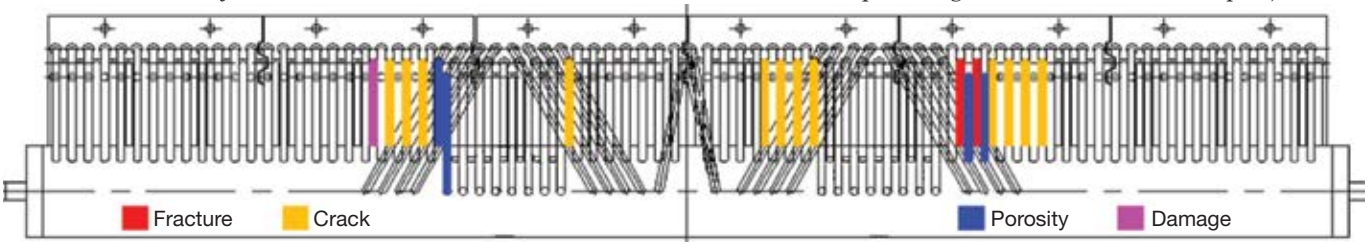
The presentation generated many questions, comments, and discussions. Placement of thermocouples (total of 128) was further explained. Other comments focused on thermocouple attachment (EPRI method used), the security hurdles of sending live data away from the site, the possibility of using the data for faster startups, and using the data to estimate remaining life of piping.

Attemperator repairs

Al Olszewski, Constellation Energy, reviewed fleet-wide *Attemperator inspections and repairs*. This non-plant-specific presentation covered selected issues with various attemperators, including:

- High-pressure (HP) to cold-reheat bypass. Fig 5 shows internal indications at downstream girth-weld (P91 material). Girth weld was machined out and repaired with spool piece.
- Intermediate pressure interstage (vertical). Significant quench-cracking of liner was revealed. Inspection is ongoing; a spare now is available onsite.
- Hot reheat interstage (vertical). The liner liberated after 68k hours and was repaired with liner pins.
- HP interstage. A P91 nozzle liberated at weld after 35k hours. Thermal-mechanical fatigue was cited as the cause. Opening was rounded to reduce stress.
- Hot-reheat bypass to condenser. Repeat cracking of upstream and downstream girth welds after 45k hours. Now monitoring for thermal fatigue.

Many similar case histories and repair solutions were discussed after the presentation, stressing the need for frequent and complete testing (including addition of thermocouples). The



6. Tube failure points identified by field engineer during inspection: fracture, two locations; crack, 12 locations; porosity, four locations; damage, one location

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7. Dedicated kits for each valve help reduce costs and labor

8. St. Charles Energy Center gathers HEP and HRSG temperature data via a wireless sensor network to help target inspections and plan outage scopes

benefits of proper clearances and use of OEM parts in critical applications also were mentioned.

HRSG tube failures

The Qurayyah Combined Cycle Power Plant in Saudi Arabia comprises multiple blocks, each 3 × 1 with GE 7FA.04 gas turbines and GE D11 steam turbines. The unfired triple-pressure HRSGs are Doosan and CMI vertical-gas-path units.

Ghazi Al-Shammari discussed HRSG tube failures and consequences. He walked through the plant's background, then focused on the tube failures in one unit that became apparent in 2016 (high water consumption, noise, and steam emitted from the main stack).

All tubes and headers were visually inspected. Tube defects were found at 19 locations near the hot-reheat header. Thermal-fatigue cracking also was apparent close to the tube-to-header welds (Fig 6).

The speaker walked through the various damage mechanisms found and then the root-cause graphic depiction of thermal stresses.

Recommendations made based on plant experience were these:

- After each HRSG shutdown, ensure all TCVs/bypass MOVs and inlet isolation MOVs are closed.
- Follow normal startup procedures and physically verify all valve positions, both open and closed.
- Watch for any abnormal valve behavior—including noise, vibration, or temperature change.
- All manual drain isolation valves should be open at all times.
- All drain MOVs should be on auto at all times.
- Operators should physically monitor drain-valve levels and differential temperatures at all times.

Qurayyah has reduced (1) annual forced outages attributed to tube leaks from five to one, (2) water consumption, and (3) tube metal temperatures.

Discussions and suggestions followed on numerous issues—including the following:

- Manual bypass around the attemperator block and control valve (should be removed).
- Spray-valve operation and maintenance.
- Inability to drain RH and SH tubes (in this design).
- Proper and improper use of dampers.
- Tube failure-analysis options—including removal, accuracy of data programs, and root-cause/damage mechanism distinctions.

Valve maintenance program

Barnard Frezza, Athens Generating, operated by NAES, discussed the *Valve maintenance program* at the 1080-MW plant with three 1 × 1 combined cycles equipped with Siemens 501G gas turbines, Nooter/Eriksen HRSGs, and Siemens HE steam turbines.

Athens did not have a valve monitoring program when commissioned in 2004. Work orders were put in by staff if a valve had visible failure, noise, or leaks. The plant learned over time that this reactive approach led to unplanned maintenance, costly repairs, and outages.

Athens has been working with Millennium Power Services since 2017 to track and prioritize valve maintenance, and bring their program up to industry standards through a proactive approach. One benefit is "improved heat rate through reductions in water and steam losses," said Frezza.

Millenium keeps records and maintenance interval data, and plans for future inspections based on plant budget and needs. Each valve has an associated report.

Athens uses Millenium's TrimKit™ program to reduce costs and labor, and to provide all new parts for specific valves. Refurbished parts can be returned to the kits (Fig 7).

Millennium now offers Athens a 10-yr plan, revised as necessary.

Wireless HEP program

CPV's St. Charles Energy Center in Maryland (Fig 8) has implemented a wireless high-energy-piping (HEP) program, which was described by Jacob Boyd. Background: The 745-MW plant, commissioned seven years ago with two GE Fast-Start 7FA.05 gas turbines, one GE D-11A steam turbine, and two CMI HRSGs, typically cycles from 140 to 170 times annually.

Near the end of 2019, one HRSG suffered a through-wall leak at a girth weld on a hot reheat (HRH) steam-to-condenser bypass line. The failed weld was removed and sent to Structural Integrity (SI), finding that thermal fatigue was the most likely cause.

"Plant personnel worked with SI to install thermocouples around the area to assess the magnitude of thermal transients during load changes and normal operations," explained Boyd. Significant temperature variations around the pipe circumference (up to 700 deg F) were noted during load-change events. SI data were sent to the OEM who redesigned the HRH bypass attemperator spray-nozzle assembly. Plant staff modified the attemperator logic.

The plant had only been operational for two years, and "plant staff was concerned there may be other unknown high-energy piping issues that could fail prior to regularly scheduled inspection," said Boyd. "Working with Structural Integrity, a solution was proposed to install a wireless sensor network and thermocouples to remotely read data in near real-time and incorporate the readings into St. Charles' PlantTrack online database."

SI performed a risk-ranking prioritization known as Vindex™ (Vulnerability Index) that considers factors such as creep life, Grade 91 risk factors, consequence of failures, etc, and assesses each weld or location of interest according to damage potential. The plant then installed thermocouples at 10 different locations throughout the HEP system, plus nine online pipe-hanger monitors.

Data were used for the spring 2023 outage. Online monitoring of the HRH bypass had shown five high events and 155 medium events. Field results in 2023 then identified multiple ID and

OD indications. A spool piece was needed and installed.

Said Boyd, "the system is a highly valuable tool to target inspections and plan outage scopes. We now have improved plant safety and reliability, while reducing O&M costs and the potential for lost generation."

Chemistry and corrosion, user survey results

Barry Dooley, Structural Integrity (UK), presented the latest international statistics on cycle chemistry and FAC, summarizing results from 270 combined-cycle and fossil plants. He began with the following observation: "It looks like hydrogen damage/under-deposit corrosion is increasing around the world. This is a big issue!" He would soon return to this topic, discussing repeat cycle-chemistry situations (RCCS).

Dooley first reviewed chemistry-influenced tube failure damage and failure mechanisms, corrosion-product transport attributed to inadequate feedwater low-pressure circuit chemistries, and steam turbine deposits/damage/failures.

For the latter, leading current steam-turbine damage mechanisms are:

- Corrosion fatigue of blades and discs in the phase transition zone (PTZ) of the LP turbine.
- Stress corrosion cracking of discs in the PTZ.
- Pitting (initiator of damage).
- Liquid droplet erosion.
- Flow-accelerated corrosion.
- Deposition.

He reviewed the repeat cycle-chemistry situations found in the assessments, then focused on hydrogen damage and internal HP evaporator deposits as an example.

Dooley noted that the International Association for the Properties of Water and Steam (IAPWS) would soon publish a procedure to quantify corrosion-product transport during startup. He called this an "exciting development" and summarized the procedure:

- Flush feedwater sample point as soon as pressure is available.
- Measure and register oxide levels in feedwater by proxy methods during startup.
- Take samples for filtered iron intermittently to establish a correlation to proxy results.
- Note times for milestones: first fire, bypass, turbine rollup, synchronization, etc.
- Plot iron levels versus time after first fire and mark milestones.
- Integrate (iron level, feedwater flow) from first fire to steady state level; iron transported to boiler during startup.

He then turned to both single- and two-phase FAC, which he said are "still occurring worldwide and not being identified properly" as they do not share the same mechanisms.

Looking for single-phase FAC evidence in HRSGs he offered a few interesting notes, including "things to look for":

- Level of oxygen at condensate-pump discharge and boiler feed pump.
- Color of LP and IP drums for "ruggedness of redness." Red appearance will be "patchy" with grey magnetite showing through when oxidizing power is "low."
- Levels of iron ("Rule of 2 and 5"): Less than 2 ppm total iron in condensate/feedwater, less than 5 ppm in evaporators/drums.

His concluding reminder: resources for all areas of water and steam are freely available for review and download at www.iapws.org.

Open discussion

A sampling of questions and discussion topics submitted to the HRSG Forum

as part of the registration process included these:

- What are the best practices for welding carbon-steel tubes to headers (including inspections)?
- Poll: How many users are taking HP evaporator deposit-density tube samples?
- Tube sample methods and locations were discussed, initiating discussions on chemical cleaning and under-deposit corrosion.
- HRSG tube-plugging impact on hydraulic flow characteristics led to discussions on (1) tube temperature changes, and restorability of abandoned tubes, (2) inventory of spare tubes retained onsite, including filler metals; and (3) experiences with tube repair versus plugging. Interesting comment from Bob Anderson during this exchange: If you plug, you don't know the failure mechanism and root cause to reduce chance of repeat failures.
- Best practices for boiler feedwater pumps and control valves for controlling HP-drum levels led to discussions on attemperators and valves.
- Drum-level trips related to instrumentation and controls.
- Repair experience with attemperator nozzle bore hole cracking.
- Duct-burner replacement: Determining the need, timing, and material options.

Vendor presentations

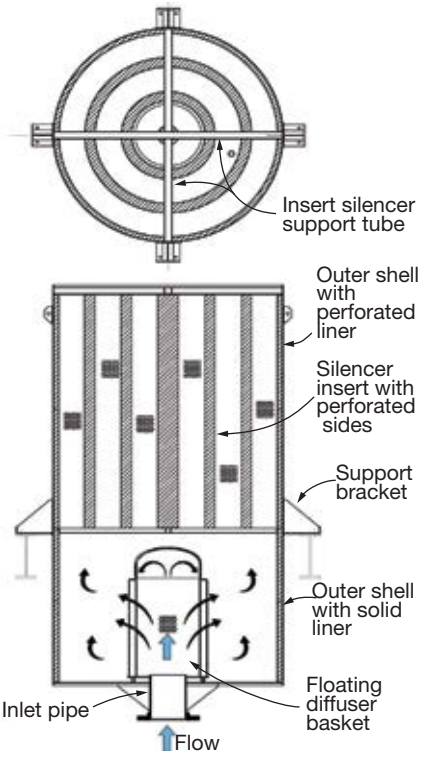
Vent silencer design, inspection

Samir Baydoun and Tucker York, SVI Bremco, presented *HRSG vent-silencer safety inspections and design,* focusing on the safe and quiet discharge of high-pressure steam. Most silencers are installed at high elevations downstream of steam-drum relief valves, HP/RH safety valves, and startup ventilation. They can also be installed on blowdown tanks and deaerators. Their primary purpose is to meet site-permitted noise limits.

Main vent-silencer components are: diffuser assembly with inlet pipe, silencer shell with or without liner, and silencer inserts (Fig 9).

Presenters covered common failure and safety concerns, usually caused by deterioration of the silencer perforated liner or diffuser basket and loss of acoustical insulation (Fig 10). The result is loss of aerodynamics and acoustical performance, but a major safety issue occurs when parts of the liner separate and eject out of the silencer.

Visual inspection methods are presented in an eight-point summary



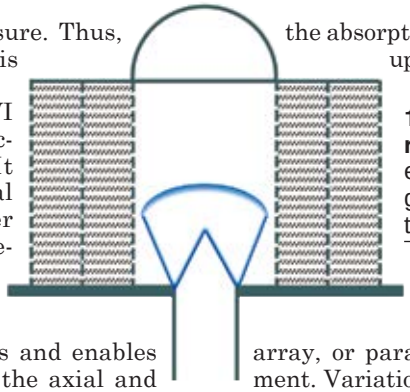
9. Vent silencer layout and operation

10. Failures and safety concerns often are associated with deterioration and loss of material in diffuser-basket perforated plate

covering corrosion, missing bolts, cracking, weld damage, and improper draining. Go-Pro cameras can be used to check baffle sheets, frames, and supports. Cameras can also check various welds and diffuser-cap conditions.

Root causes of damage could be inherent in design or in selection of materials, welding processes, corrosion, and water collected at the bottom of the silencer (clogged drains). Thermal fatigue can also occur because of temperature, number of cycles, and other operating conditions—including backpressure. Thus, routine inspection is critical.

Details of an SVI Dynamics vent silencer are provided. It uses an inlet radial diffuser with either a one-, two-, or three-wall arrangement (Fig 11). The floating diffuser replaces common metal bells and enables thermal growth in the axial and transverse directions. The lower plenum section is an expansion chamber for radial dispersion of flow, and promotes uniform flow transition to the absorptive upper stage. The upper stage is designed in either concentric-baffle configuration, tubular array, bar array, or parallel-baffle arrangement. Variations are in thickness, spacing and active length to further dissipate acoustic energy (Fig 12). The diffuser basket is critical to redistribute the energy radially.



11. Floating inlet radial diffuser enables thermal growth in the axial and transverse directions

The silencer works by acoustically shifting from broadband to middle-to-high-range frequencies.

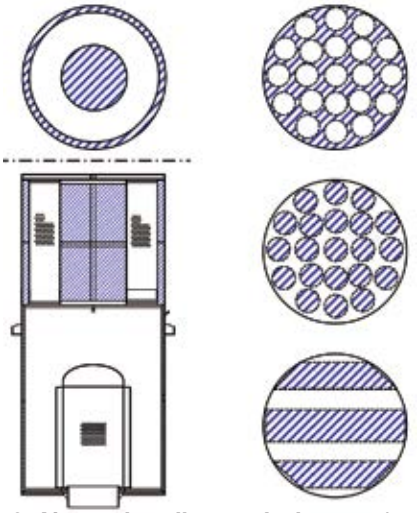
Discussions included design details and welding to ASME specifications, and the benefits of detailed exams of failed materials.

Comparing methods of boiler-tube repair

Tuff Tube Transition	Conventional
No butt weld	Butt weld
Fillet weld	Open root/complete joint penetration
No purging	Purging required for alloys such as T91
No RT	RT required in most repair cases
Self-aligning fit-up	Open root/root gap fit-up
No bevel required	Bevel required for most butt welds
No radiation barrier	Radiation onsite
Reduces downtime	Increases downtime
Easier weld	More difficult weld
Reduces contractor costs	Increases contractor costs

Tube repair innovation

Tuff Tube Transition (TTT) offered *Innovative HRSG tubfe repairs*, specifically a sleeve-type connection that eliminates open-root butt



12. Absorptive silencer designs assist in the dissipation of acoustic energy

welds, does not require back purge, and eliminates the need for NDT/RT. This provides a "faster and more reliable joint alignment," said Marshall Hicks of Viking Vessel Services/TTT.

As an overview offered by Hicks:

- The thicker material of the sleeve-type TTT increases the connection stiffness and decreases stresses (virtually eliminates fatigue cracking in tube-to-header joints).
- The reduction of stresses corresponds to a decrease in the weld connection stresses.
- The 30% reduction in thermal stresses claimed is said to increase connection life and reduce the number of failures, plus increase service life by 50% to 75%.

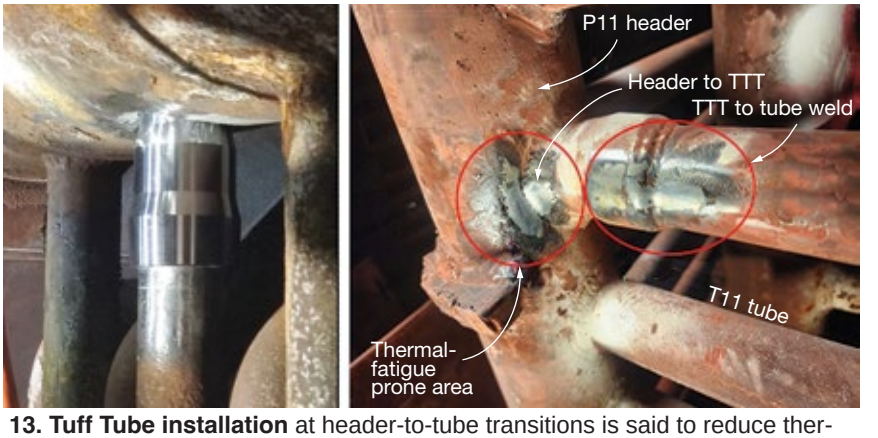
The Tuff Tube Transition, developed by Viking, was first used at Calpine Freestone Energy Center in Fairfield, Tex. TTT was applied on sections with P11 header and T11 tubes in an HRSG that had been in service for 20 years (Fig 13). These purgeless sleeves are made of T22 (2.25 Cr-1 Mo).

After two years of service and 102 cycles, PMI Specialists Inc, a metallurgical services firm, was asked to evaluate the condition of the welds. Finite-element-analysis results were discussed.

Table compares TTT and conventional methods of tube repair.

Tuff Tube Transition is US made and warranted, and offers full packages for HP, IP, and LP sections. When asked if TTT applied to both steam-touched and water-touched service, the answer was "both."

The discussion period dove further into experience. There are currently no reported issues with TTT installed in



13. Tuff Tube installation at header-to-tube transitions is said to reduce thermal stresses by about one-third

nine HRSGs. Questions included any resulting flow restrictions, but to date there have been no negative effects. Further results and discussions are anticipated at HRSG Forum 2024.

Detecting spray-water leakage

Denis Funk, Flexim, discussed *Ultrasonic detection of spray-water leakage* to find leaks and prevent attemperator steam pipe and superheater/reheater tube damage.

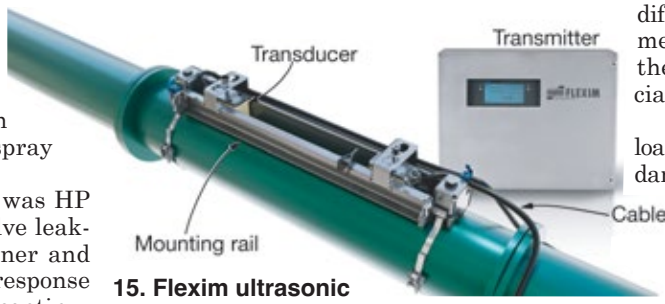
This was a case study from 2020, when a major CCGT operator had issues with HP and RH steam tube damage. Several cracks also had been discovered in attemperator spray liners.

The suspected root cause was HP attemperator spray block valve leak-by, with quenching of the liner and tubes during low load. First response was to diagnose leaking by continuously monitoring conditions using existing instrumentation, with these problems:

- Differential flow meters are limited in turndown and low-flow resolution.
- Comparison of upstream and downstream t/cs did not show sufficient accuracy for low-flowing leak-by.
- Acoustic monitors were not providing flow values, just noise signatures.

The operator then consulted with EPRI and Bob Anderson, Competitive Power Resources.

14. Fluxux 6 portable transducers on 3-in.-OD pipe



15. Flexim ultrasonic measurement technology

Testing involved Fluxus 6 series portable equipment with transducers for extended temperature range at three different locations on the HP and RH spray lines. These are non-invasive ultrasonic flow meters (Fig 14).

Measurements were taken during valve opening and when fully closed (for leakage detection). Testing showed that the ultrasonic meter and the calculated flow (heat-balance equations) matched very closely. However, the differential-pressure-based flow meter was not able to capture the flow rate precisely, especially during low loads.

Funk noted that "During low loads, leakage can cause the most damage because the spray is not completely evaporating."

Two ultrasonic transducers (Fig 15) are mounted with a defined distance onto the pipe. By sending sound signals alternating with and against the flow, a transit time difference can be measured. This corresponds to the flow velocity, and calculation of volume flow and mass flow.

The equipment features no moving parts, no pipe penetrations, high repeatability, and is factory calibrated.

Applications include natural gas, boiler feedwater, blowdowns, compressed air, cooling water, hydrogen cooling, and steam.

An interesting question followed: Can this distinguish between water and steam? The answer was "yes," using diagnostics.

After various utilities reported successful use of this equipment during discussions, Bob Anderson carried support a bit further, saying: "Once you know the fluid, pipe OD, wall thickness, materials, etc. and enter this into the meter, it automatically gives you the transducer spacing and calibrates the system. The meter communicates with the transducer to acquire the specific calibration curves. Fluid temperature is also an important variable, but temperature elements in the transducer automatically provide this as well."

Silent sentinels

Kurt Bedar, NDE/PRD Consulting, offered a *Pressure/safety relief valve maintenance program*. "Pressure relief valves," he began, "are one of the most ignored parts of the plant. They are the silent sentinels for safety."

"Relief valves are often handled and stored like pipe fittings, but need to be treated as delicate instruments," he said (Fig 16).

Bedar stressed, "Perhaps no one valve plays a more critical role in preventing industrial accidents than the pressure relief valve." Sometimes referred to as a safety or safety relief valve, it helps mitigate industrial accidents caused by the over-pressurization of boilers and pressure vessels."

The three main parts of the valve are nozzle, disc, and spring. "Pressurized steam enters through the nozzle and is then threaded to the boiler. The disc is the lid to the nozzle, which opens or closes depending on the pressure coming from the boiler. The spring is the pressure controller," he explained.

Common problems are a lack of testing and improper original specification. The former leads to reduced relieving capacity, leaking and shimmering, and improper repairs attributed to workmanship or failure to identify and correct problems. Also, said Bedar, "Replacement parts should be OEM only, and technicians must be certified."

His conclusion: "It is essential that each PRV owner, in cooperation with an approved PRV service provider, establish an effective quality-control system to ensure that valves tested and repaired have been returned to conditions equivalent to the standards for new valves. By combining the use of competent repair personnel with an effective quality control system and conducting repairs in accordance with the provisions of the National Board VR Stamp certification program, a pressure relief valve tested or repaired will perform as expected when needed."

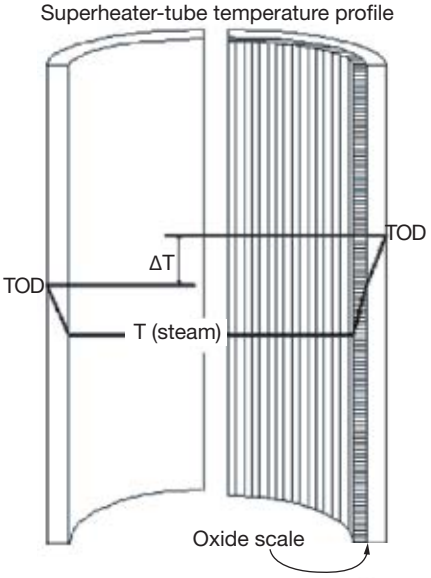
Aging HRSGs

Mark Stockman, United Dynamics Advanced Technologies Corp (UDC), discussed *NDE techniques for an aging HRSG fleet*.

Stockman began with some generalized, conservative observations:

1. Retirement age for HRSGs was often assumed (when installed) at 25 years for a baseload unit.
2. Baseload was defined as four cold starts, 52 warm starts (weekend shutdowns) and several eight-hour-shutdown hot starts per year.
3. The big buildout was in the early 2000s. Those units are getting close to end of life.

16. Oxide scale buildup effect on tube metal temperature (oxide-scale theory)



17. Pressure relief valves are delicate components

But some coal plants built in the 1950s are still operating, exceeding 50 years. So do we need to get more life out of the HRSGs? "If so," he suggested, "we have to focus on the life extension of installed units. This means thorough condition assessments."

He offered some building blocks for life assessment and life extension:

- Review PI data and focus on overstressed components.
- Know that many problems are not visible from a standard inspection.
- Dig deeper using NDE techniques to determine where the next failure might occur.

Example: Use PI data to trend HP superheater outlet temperatures downstream of the duct burner, the temperature before attemperation. Look for temperature excursions. This is a target for NDE to determine the extent of damage. It also helps with root-cause analysis.

He offered other examples, then focused on HP, SH, and RH overheating, looking at tube-internal oxide scale and detection by NDE.

He described an oxide-scale theory in which 1 mil of scale equates to a tube OD temperature increase of 2 deg F. (Dooley later commented that this might be 4 deg F.) See Fig 17.

For oxide-scale thickness of 0.01 to 0.03 in., this means a temperature increase of from 20 to 60 deg F.

Explaining further: "The primary failure mechanism in steam-carrying SH/RHs at temperatures above 900F is stress rupture. Primary contributors are temperature, stress, and time. Stress and temperature increase with time," Stockman explained.

He then looked at tube-to-header welds for OD-propagated cracking, using magnetic particle testing on superheaters, reheaters, and HP economizers. Other areas shown were P91 drain and steam-drum nozzles.

Phased array, he said, is used primarily for ID-initiated cracking (tube-to-header welds, etc), for economizers, and drains in particular. He then reviewed ultrasonic thickness testing on elbows, economizers, and balance-of-plant areas.

Turning to drones Stockman looked at pipe supports and other areas not accessible from platforms, scaffolding or grade.

He then turned to metallographic replication to analyze piping components without removing samples. Videoscope inspections were next, looking at evaporator tubes, attemperator downstream piping and drums. Stockman ended with under-insulation corrosion, which he called "too often neglected." CCJ

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Don't forget the stack in your annual inspections

There are several reasons stacks don't get much attention from operators on their rounds—among them:

- They're static and there's nothing much to see externally except perhaps peeling paint.
- Forgetting the switchyard, they're likely a longer walk from the control room base than any other plant component.
- Internal access is not possible with the plant in operation.

This means you don't know much about the true condition of your stack unless you make it a priority to conduct an internal and up-close external inspection annually. Regular inspections can identify problems before they cause an outage, a loss in performance, potential safety issue, etc.

SVI Dynamics' Scott Shreeg identified several common failure points for a steel stack to be aware of when conducting your annual inspection (photos). They are:

- General corrosion.
- Stress or fatigue cracks caused by repetitive or excessive movement. These usually develop at openings or discontinuities in the metal.
- Buckling of the stack shell caused by corrosion thinning of the shell material.
- Cracking of the stack shell and its support structure from fatigue attributed to thermal cycling.

Annual inspection checklist

When perusing the list below keep in mind that the inspection and maintenance programs for unlined stacks (single wall) and stacks with a floating liner differ in some respects.

- Check bolts and nuts for degradation—including anchor bolts, those restraining platforms and ladders, etc.
- Examine the following for general condition, plus any evidence of corrosion and cracks in base metal and welds:
  - Baseplate.
  - Anchor chairs.
  - Breech opening reinforcement.
  - Shell plate.
  - Circumference stiffeners.
  - Shop and field joints (welded and bolted).
  - Lateral supports.
  - Access doors.
  - Dynamic stability devices.
  - Exterior conditions of test ports.
  - Exterior lagging.
  - Expansion joints.
  - Grounding lugs and cables.
  - Guy wires (visual check for degradation and broken wire strands), cable clamps, and anchors.
  - Platforms and ladders: gratings, handrails, and platform supports.
  - Outer shell-plate coating.
  - Concrete foundation. If cracks are large, a follow-up concrete NDE may be necessary.
- Thermal imaging is recommended when the inspection must be performed with the unit in service. It is particularly helpful for detecting areas where excessive heat transfer exists because of liner or lagging insulation loss.

When your stack needs go beyond simple inspection

SVI Dynamics has more than 25 years of experience in steel stack design, fabrication, construction, and inspection. This means the company can be a valuable partner for your plant, given its ability to determine the root cause of stack issues uncovered during an inspection and to suggest solutions using today's most advanced engineering analysis software.

The company's inspections are conducted to the widely accepted ASCE stack inspection code, with enhancements based on SVI's experience. Inspections are supervised and reviewed by a registered professional engineer with details provided to the plant.

Inspection reports include the details of stack measurements taken, a summary of root-cause investigations conducted in response to defects found (if any), engineering calculations as needed to support decisions regarding stack structural integrity, and recommendations for follow-up inspection, repairs, and replacements.

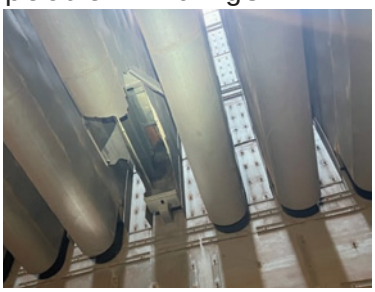
Triennial steel-stack inspection

- Visual inspection of shell plate for the full height of the stack.
- Random ultrasonic (UT) shell-plate thickness measurements every 10 ft from the bottom of the stack to the top.
- Follow-up with penetrant or UT inspections of questionable welds.
- Full-height interior visual inspection, including expansion joints.
- Drainage condition.
- Condition of silencers and their supports.
- Condition of turning vanes, flow dampers, and stack rain cap.
- Visual inspection for internal floating liner sheets, studs, insulation, batten channels.

Typical inspection findings

Stack corrosion

Liner stud failure



Exhaust silencer failure

Failed silencer supports

Liner failure

Stack silencer damage

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PROENERGY CONFERENCE 23

Modified aircraft engine anchors dispatchable power-gen package

Making ProEnergy 23 (promoted as the "Premier LM-Focused Event"), organized by ProEnergy Services (PES), Sedalia, Mo, an annual conference underscores PES' intention of becoming the dominant player in the market for dispatchable electric power from aeroderivative gas turbines. To date, this has meant onsite and depot-based repair and services (Sidebar 1), power project development, installation, long-term O&M, remote M&D, and facility ownership.

Adding to that portfolio, PES now offers its own standardized engine package for sale, the PE6000 (Sidebar 2) designed around used CF6-80C2 aircraft engines (the airplane equivalent of an LM6000) with a low-pressure module added.

The three-day confab, directed by PES Chief Commercial Officer Carlos Picon, Nov 7-9, 2023, covered a lot of ground, which can be divided into three broad areas: (1) prognosticating on the evolving landscape for a low-carbon electricity sector, (2) the continuing need and growing importance of dispatchable power to support renewable resources, and (3) the role of aeroderivative gas turbines (GTs) as critical dispatchable resources. The PE6000 is intended to serve as a low-cost dispatchable aero GT option.

Numerous technical presentations and panels supported these broad areas by addressing unit, engine, and balance of plant (BOP) component performance, improvements, and O&M strategies.

To help attendees navigate the coming blizzard of technical information, ProEnergy hosted an engine familiarization workshop on Tuesday, the first day of the meeting. Moderator Daniel Bavery walked participants through the LM6000, from the air inlet to the exhaust section, explaining how the engine works and the functions of its principal parts. Nearly a hundred slides (most equipment photos and drawings) brought participants up to speed on nomenclature and important points to remember.

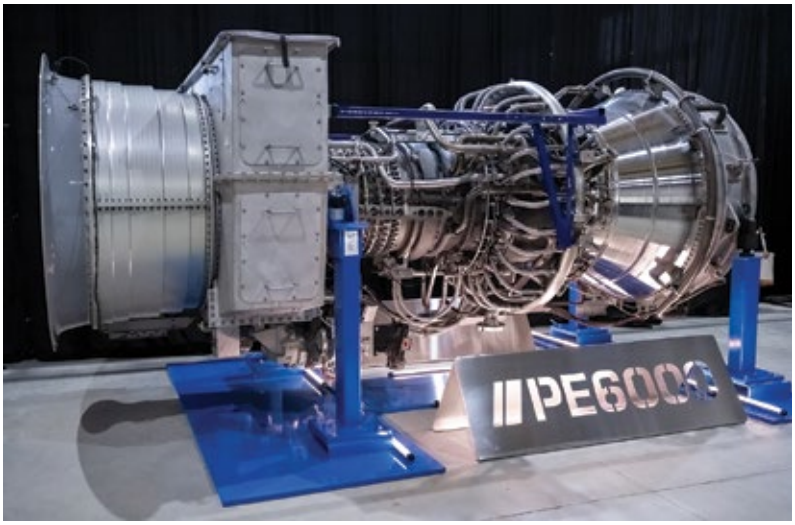
The new engine

The PE6000 represents an enormous investment in people, machining capability, and partnering with outside groups, noted PES SVP Rob Andrews (Fig 1). At the time of the conference, first two units, models 101 and 102, had recorded more than 500 starts and 10,000 operating hours; unit 103 had 20 hours and 10 starts; and unit 104, on display at the meeting (Fig 2), was ready for field trials. Testing on hydrogen also had begun. Up to eight additional units are destined for one or more WattBridge sites in Texas.

Jens Peter-Schmidt (Fig 3) of RWE (one of Germany's largest energy companies), reported that the utility is building a "peaker strategy" around low-cost, standardized, simple-cycle GTs of approximately 46 MW each. RWE pilot-tested one of the PE6000 mobile feasibility units (Figs 4 and 5) at a plant in Germany after it had accumulated about 1000 hours at sites in the US and Mexico. RWE's goal is to reduce capital costs from 400 to 600 euros/kW to around 300.

Schmidt did note that because of some corona transfer issues, the unit was commissioned later than planned and was more costly. But commissioning was complete by the end of 2022, in time to receive a net-zero subsidy from the European Union. He concluded by reporting that the "upcycled" unit achieved the same performance as conventional units.

1. Rob Andrews, SVP, ProEnergy Services (PES)



2. PE6000 destined for field testing after the conference

3. Jens-Peter Schmidt, project manager, RWE

Wednesday program

The first speaker, Bobby Noble (Fig 6), EPRI's program manager for gas-turbine R&D, launched the event in high gear with a review of the emerging landscape for power generation lumbering toward a net-zero world for carbon. His Market Keynote ("Changing global landscape as the energy transition unfolds") outlined global decarbonization pathways and emphasized (1) the need for supporting infrastructure, such as transmission lines and centralized hydrogen storage and delivery facilities; and (2) continuing RD&D so the industry has optionality to reduce risks in meeting goals.

The critical role for aero GTs, though under new operating regimes, was best illustrated by the transition from the "Duck Curve" (from the grid system operator's point of view) to the "Canyon Curve" (Fig 7). In fact, Noble said that aero GTs were poised to be the "key asset" to make renewables work. He warned against technology setbacks: "We can't have the Hindenburg for gas turbines and hydrogen."

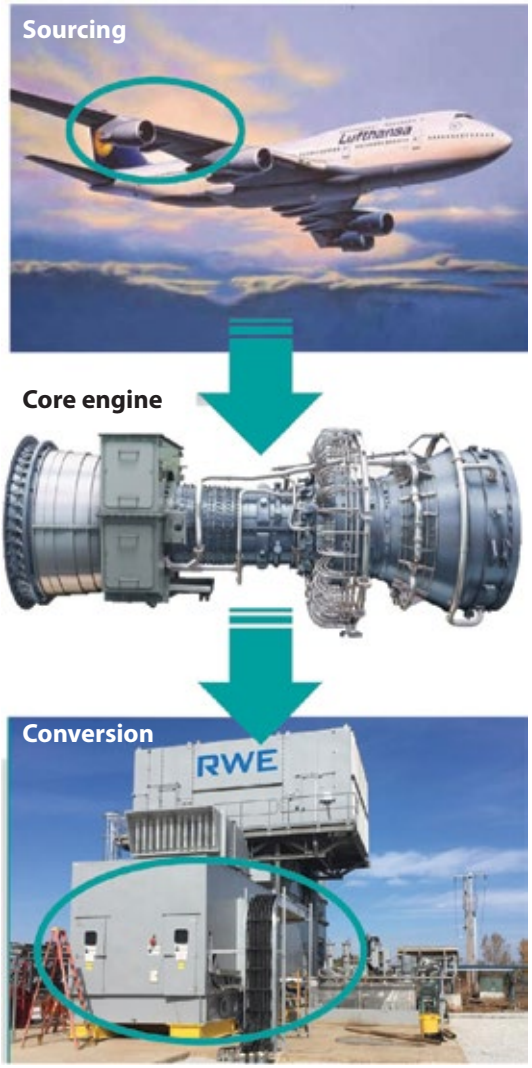
Calpine's SVP asset performance management and outage services, Tom Long (Fig 8), followed Noble with an Operational Keynote, "Building and operating an energy transition portfolio."

While most attendees were familiar with the behemoth independent power company (26,000 MW of generation), most likely were unaware that it (1) has a portfolio of 200 gas and steam turbines across 28 states, (2) is the world's largest geothermal owner/operator, and owns a 700-MW battery storage facility plus 800 MW of solar generation.

Long noted Calpine's long-standing commitment to decarbonization, which began 40 years ago with its first geothermal megawatt. He emphasized the company's continued journey towards decarbonization and the importance of being entrepreneurial and nimble in a competitive market.

He mentioned the advancement of combined-cycle carbon-capture projects, highlighting their significance in the company's efforts towards decarbonization. Calpine recently was awarded CCS projects by DOE for its Baytown Energy Center near Houston and Stutter Energy Center in Yuba City, Calif. Both are multi-unit gas-turbine-powered combined cycles.

Long acknowledged the challenges associated with carbon-capture projects—including reliability and integration into existing facilities. He stressed the importance of maintaining reliability and firm power generation while transitioning to carbon-free energy resources.



4. Pairing a used aircraft version (CF6-80) of the LM6000 with a low-pressure module is the basis of the PE6000. Fig 5 provides details

Good, bad trend curves

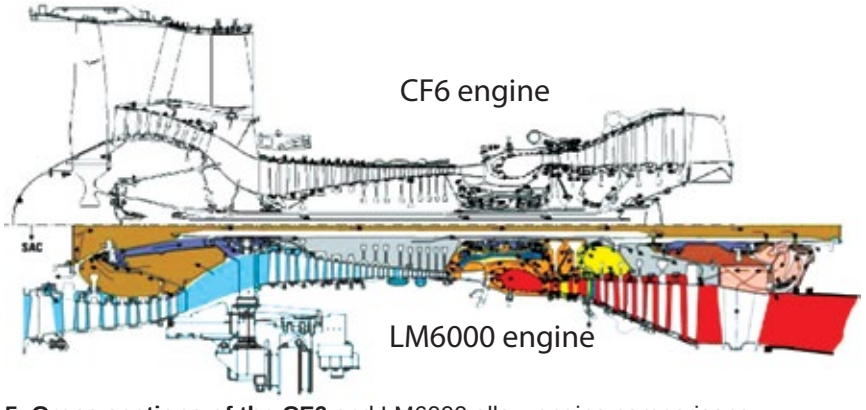
In at least some places, regulators are getting the message about dispatchable resources. One panelist reported that the state of Texas passed Proposition 7 (Sidebar 3) to pay for the Texas Energy Fund, a source for low-interest loans to incentivize dispatchable generation.

The German government is supporting a goal of having 23 GW of "hydrogen ready" dispatchable generation by 2035 (Sidebar 4). A panelist argued for better education of, and communication to, policymakers and citizens on the need for dispatchable power.

Still, there are challenges. One is that many states give priority to permitting renewable projects in the approval queue, many of which simply will not go forward. Meanwhile, dispatchable-gen projects, which are less risky but critical to supporting those renewable projects, get less attention.

From the O&M perspective, Tom Christiansen (Fig 9), SVP, Strategic Power Systems, reported that simple-cycle plant availability and reliability have been on the decline since the early 2000s with a huge drop over the COVID pandemic years.

Fuel-gas valve makers take note: These were the number two contribu-



5. Cross sections of the CF6 and LM6000 allow engine comparisons

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

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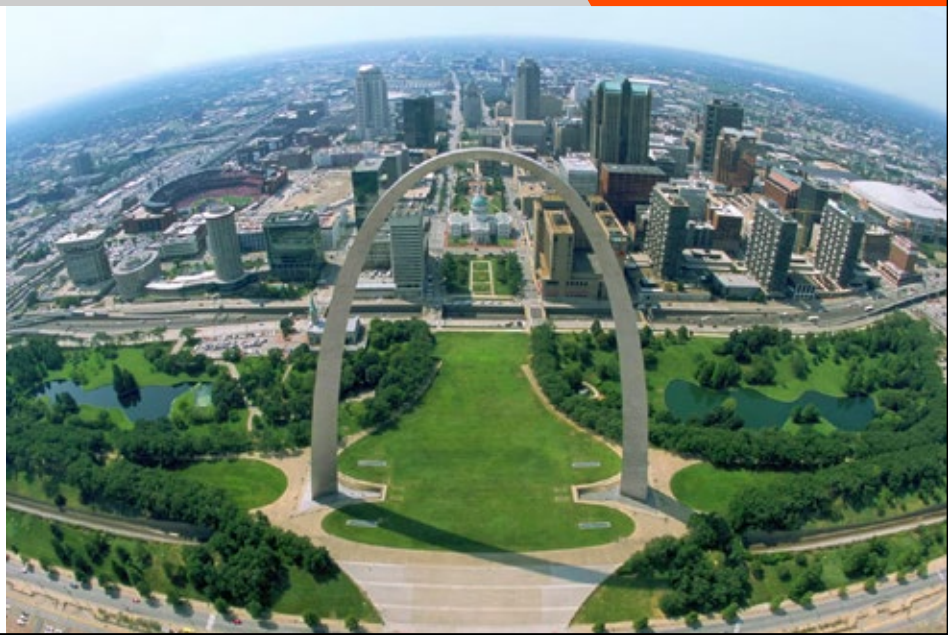


tor to forced outages over the last five years and, by extension, unreliability and unavailability. Control-system components and combustion-system hardware were two other top broad categories affecting performance.

The LM6000 fleet, in particular, has been "trending towards unplanned work and outages," noted PES' VP aero products, Bob Bosse (Fig 10). Major overhauls were down 84% year on year, while "hospital visits" were up 80% over the last two years. Unplanned work generally was up 67% over the last two years. Many owners need to consider whether their maintenance strategy reflects a peaking or baseload mentality as operating profiles shift.

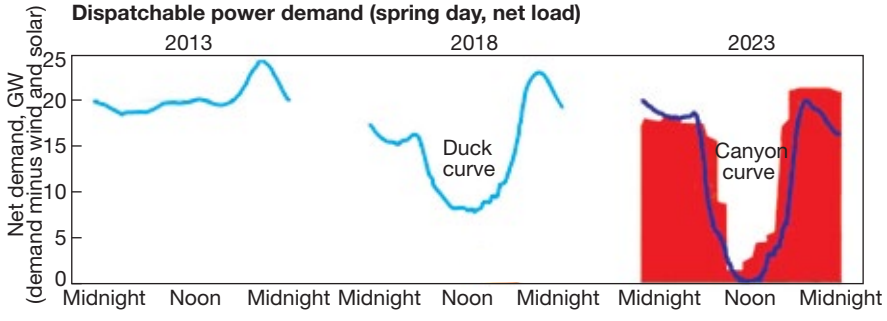
Heard 'round the meeting

Pearls of wisdom and/or knowledge uttered among the panel presentations and audience exchanges included the following:

- Without hydrogen, nothing flies in Europe.
- The US Supreme Court has ruled that EPA does not have the authority to make sweeping determinations, such as considering CO_2 a pollutant. Rather, they have to be legislated by Congress.
- There have been massive curtailments [of renewables] in New England and West Texas.
- Methane leak detection and certifying natural gas does not exceed a leak threshold is one way to make natural gas more "sustainable."
- Ancillary services are the key to making renewables happen, especially the value of spin and no-spin reserves.
- Back in the day, the OEM said the LM6000 had no cycling limits.

PES' Andrews echoed this sentiment in his R&D update for LM6000 hardware on Wednesday afternoon: If you are putting more water through the turbine for capacity boosts during lucrative market situations, you need to allocate funds to accommodate corresponding risks such as bearing failures from water entry into the lube-oil system, and more frequent hot-section inspections to track blade and vane cracking. This was just one example.

A panelist reminded everyone that GE-4012 insists that you do an external inspection every time the unit comes off line. If you don't have records for this, good luck negotiating with the OEM when you have a serious engine problem.



7. As lower-carbon fuels and renewables drive the transition from the Duck Curve to the Canyon Curve, the value of dispatchable resources anchored by the PE6000 will increase

8. Tom Long, SVP asset performance management and outage services, Calpine

9. Tom Christiansen, SVP, Strategic Power Systems

Thursday program

Thursday was a busy day, running from breakfast at 7 a.m. through dinner, which ended with dessert at about 8:30. Sandwiched between those bookends were an O&M panel (details in Sidebar 5), several technical presentations, a virtual plant tour, and the formal unveiling of the PE6000.

The technical presentations were arranged in three concurrent tracks, each divided into three one-hour sessions. The lineup below offers a glimpse at content that many in the industry could benefit from, possibly encouraging your participation in the 2024 conference:

Adapting in the energy transition

- Fleet and plant trends open forum
- Decarbonization with hydrogen and alternative fuels (double session)

Operating for peak performance

- SCR life-of-system care: maintenance, upgrades, and direct injection
- Power augmentation update and best practices
- Supply-chain summit: minimizing operational interruptions

Modernizing with high technology

- Optimizing the life of Brush generators
- Reducing costs with remote operations centers: two perspectives
- Predicting failures and minimizing downtime with remote monitoring and diagnostics

The editors selected a couple of presentations to illustrate the level of detail provided attendees:

M&D and predictive analytics. Drilling down to one utility's LM6000 (and LMS100) fleet, Plant Manager Steve Worthington (Fig 11), Arizona Public Service Co, offered an exceptional review of the 10 LM6000s and five LMS100 units he is responsible for. Since the utility entered the Western Energy Imbalance Market (EIM) in October 2016, starts on the LM6000s have increased by around 40%.

Worthington analyzed issues leading to a failed start and lost megawatts over 147 events. Top five issues were failures of the vibration monitoring system (31,700 MWh lost, 31.4 MW-days), turbine-package instrumentation failures (17,600 MWh, 17.5 MW-days), ammonia-system failures (13,800 MWh, 13.7 MW-days), gas regulating station failures (8300 MWh, 8.2 lost MW-days), and power-block gas-delivery system failures (3800 MWh, 3.8 MW-days).

In addition to maintenance, equipment replacements, etc, Worthington credited the implementation of plant health committees and input from PES' M&D Services as the number two and

three solutions for managing these events.

A separate presentation by Worthington and PES' Donovan Duncan (Fig 12), manager of O&M plant services, addressed M&D and predictive analytics. Two issues with HP compressors were detected 30 days ahead of time by monitoring and correlating key performance variables. As part of its LM6000 M&D services, PES has developed six predictive models addressing generator cooling, turbine mechanical, generator mechanical, compressor, turbine scavenge, and combustion.

Critical subsystems. Adjusting maintenance strategies to reflect your operating profile doesn't just apply to the engine, but critical subsystems as well. Jeff Wirt, Energy Link International, covered life-of-system care for SCR units—including upgrades, catalyst testing and replacement, ammonia injection grid (AIG) lance inspection and cleaning, and others. A few non-obvious upgrades to consider are an aqueous ammonia screen to protect the AIG nozzles from plugging and other ills, replacement of pneumatic valves with 24-Vdc electric ones, and double block and drain valves on the ammonia piping.

Wirt displayed a handy guide for annual and quarterly SCR maintenance activities (Figs 13 and 14).

He also described a direct ammonia injection SCR scheme the company has been working on in collaboration with PES, which avoids the often-troublesome AIG. Testing shows that their version of direct injection, the generic process typically used only on fired boilers needing 70% to 80% NO_x reduction, can achieve sufficient ammonia-GT exhaust mixing to meet emissions performance goals.

A virtual tour and interactive best practices session was substituted for the planned live plant tour because of a severe rain storm. Landon Tessmer, PES VP commercial operations, conducted the virtual tour of WattBridge's H O Clark facility (details in CCJ No. 76, p 95), which is operated by ProEnergy. Tessmer's detailed presentation was supported by a drone flyover video.

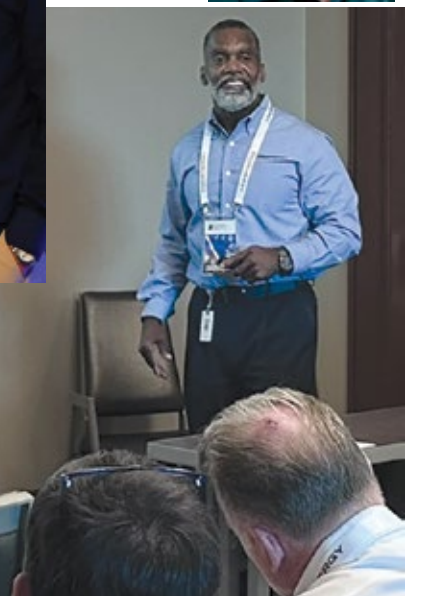
The weather gods gave ProEnergy a reprieve in the late afternoon, allowing attendees to visit the company's new Level II aero service center in Houston, where the PE6000 was unveiled. This facility is the base from which PES supports the more than 50 LM turbines it has under contract in Texas. It also serves as a staging ground/flow-through support center for the company's Level IV aero facility in Missouri.

The unveiling was preceded by a formal keynote presentation by Ellen Smith, senior managing director, FTI Consulting, a 40-yr veteran of the electric-power industry. She encouraged participants to make operational excellence an overarching priority through their actions. More specifically:

- Safe operations always. . .leave no doubt.
- Insist on consistent and constantly improving performance. Remove excuses—such as cold weather, hot

10. Bob Bosse, VP aero products, stands to the right of Kevin Burttschell, VP gas turbine manufacturing. Both PES executives participated in the Trends panel with Christiansen (Fig 9)

11. Steve Worthington, plant manager, Arizona Public Service Co



12. Donovan Duncan, manager of plant services, PES

15. Ellen Smith senior managing director, FTI Consulting

13. Recommended annual SCR maintenance

- Test aqueous ammonia quality.
- Inspect catalyst system internals.
  - Distribution grid
  - CO catalyst
  - Ammonia injection grid
  - SCR catalyst
  - Exhaust stack
- Test catalyst coupons for performance.

14. Recommended quarterly SCR maintenance

- Inspect AVS control panel for loose terminations, grounding, alarm history, etc.
- Inspect hot-air blower and motor assembly for vibration and proper lubrication.
- Inspect hot-flue-gas control valve to verify full closure and proper operation of limit switches.
- Remove and inspect injection nozzles and filter screen.
- Verify proper operation of hot-air flow meter.
- Inspect ammonia filters; replace as necessary.
- Check ammonia flow meter for proper operation and correct parameters.
- Verify proper operation of ammonia control and shutdown valves.
- Check instrument-air pressure switch for proper operation.
- Verify all transmitters are operating correctly.

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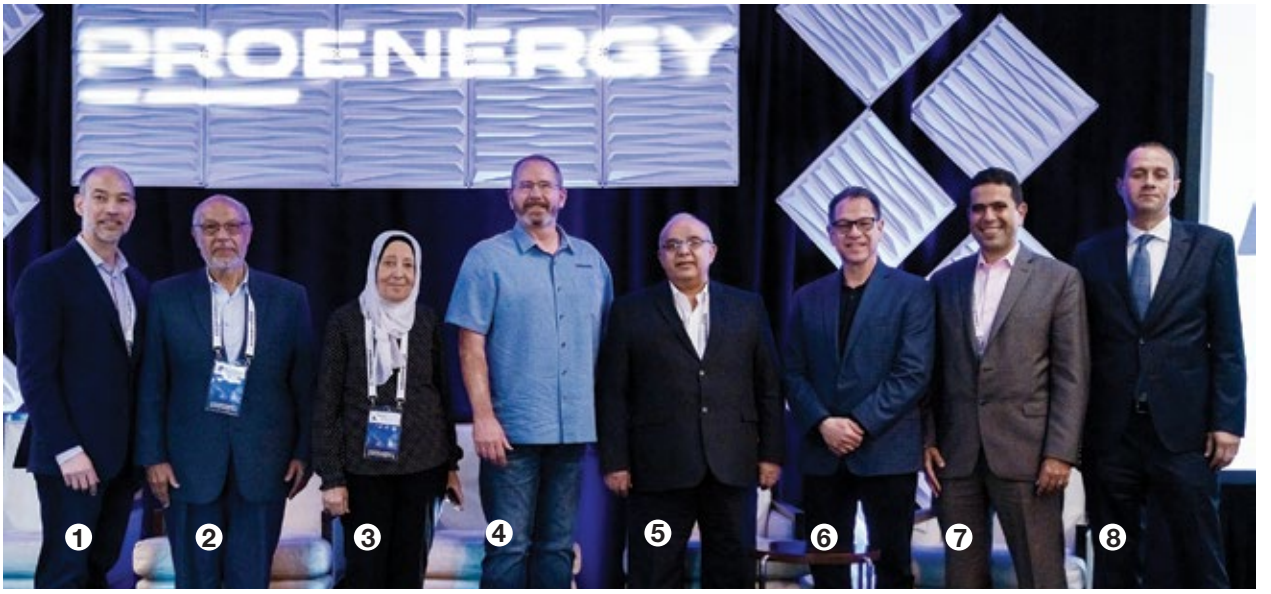
weather, old equipment, etc.
- Purposefully learn from others at similar plants, user group meetings, etc.
- Invest in people and have a plan for technical and leadership training and education.
- Be (overly) protective of your reputation and compliance processes.
- Make sure budgets align with operational goals—be specific.
- Focus on culture, make operational excellence a team event.

Rob Rowland, ProEnergy's SVP operations concluded the program before the reception an dinner with appropriate remarks on the significance of the PE6000. CCJ

1. ProEnergy, Egyptian power producer partner on aero maintenance



ProEnergy recently expanded its global reach in aero-engine maintenance services, signing a total-care service agreement (TCSA) with a subsidiary of the Egyptian Electricity Holding Co (EEHC) for eight of its LM6000 generating units. The state-owned company operates more than 55,000 MW of generation capacity and manages electricity delivery to more than 38-million consumers.

East Delta Electricity Production Co (EDEPC) is the EEHC subsidiary responsible for operation and maintenance of the two plants covered under the contract—288-MW Sharm El Sheikh expansion (five LM6000 PCs and one LM6000 PF) and 84-MW Port Said (two LM6000 PCs). The contract includes management of all maintenance events for the gas-turbine packages—including, but not limited to, hot sections, combustors, and major overhauls. Photos of the plants are below.

An important aspect of the arrangement is EEHC's commitment to decarbonization of electric generation, which aligns with ProEnergy's goals. In 2022, one unit at Sharm El Sheikh successfully operated on a hydrogen/natural-gas blend during COP27, the 27th Conference of the Parties of the United Nations Framework Convention on Climate Change.

An Egyptian delegation participated in PROENERGY 23, sharing its LM engine experiences, including operation on the hydrogen/natural-gas blend. Those in the photo are: (1) Carlos Picon, ProEnergy; (2) Mohamed Abu Senna, chairman, EDEPC; (3) Nadia Katry, executive director for commercial and financial affairs, EEHC; (4) Jeff Canon, ProEnergy; (5) Mohamed El Tablawy, executive director for planning, research, and power projects, EEHC; (6) Sergio Picon, ProEnergy; (7) Mohamed Mohsen, commercial director, Tanmeia; and (8) Mohamed Shawky, Tanmeia. Note that Tanmeia is an Egyptian company engaged in power, energy, transportation, and associated O&M.

Sharm El Sheikh

Port Said

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2. Repurposed 747 engine core underpins PE6000 turbine

ProEnergy, Sedalia, Mo, unveiled its 48-MW PE6000 aeroderivative turbine at the company's annual technical conference in November 2023. The engine is designed for dispatchable power applications to quickly close the gap between power supply and demand that often occurs during severe weather solar ramp-off, and days with low or limited production from renewables.

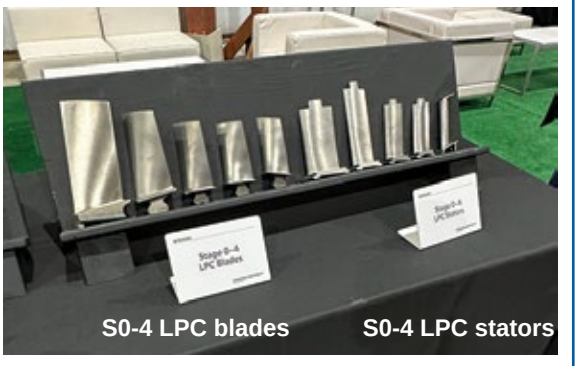
Each PE6000 begins with a ProEnergy-overhauled engine core from GE's CF6-80C2, which is found in aircraft including the Boeing 747. The concept of matching a flight-engine core with aeroderivative parts was born and executed through a collaboration between RWE, a major European utility, and ProEnergy. That first engine using market-available aero components pioneered a seven-year, $115-million investment in the PE6000 program to include R&D, manufacturing, and infrastructure.

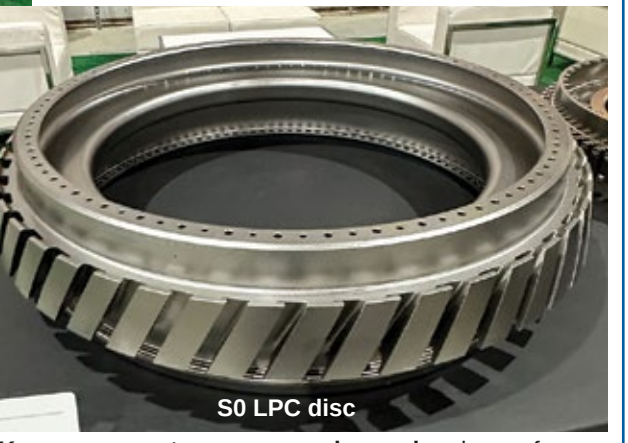
"Our in-house engine and repair expertise was a critical enabler of the PE6000 program," Rob Andrews, PE's SVP of operations, told conference attendees. "We developed other key areas of expertise in system and component design, materials engineering, and manufacturing excellence to progress our R&D program both internally and in collaboration with key partners and suppliers."

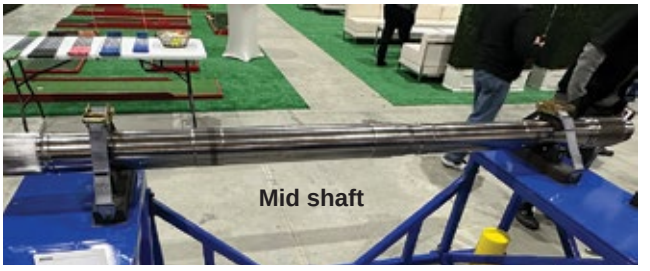
Two PE6000s were completed before the conference began, with one, installed at a WattBridge generating facility in Houston, having accumulated more than 100 starts and 750 hours of runtime. By then, eight units already had been spoken for.

Jeff Canon, ProEnergy's president and CEO, summed up the company's mission thusly: "We aim to deliver exactly with the world needs right now—low-cost, dispatchable generation. Our company was founded on finding a better way; for us, this meant giving flight engines new life and becoming an OEM for aeroderivative turbines."


LPT case


S0-4 LPC blades S0-4 LPC stators


S0 LPC disc


Mid shaft

Key components reverse-engineered and manufactured by ProEnergy to ensure PE6000 success included those shown here: LPT case, Stage 0-4 LPC blades and stators, Mid shaft, Stage 0 LPC disc

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3. Resilience panelists cover a wide range of industry concerns

With three of the four resilience panelists, and the moderator, drawing paychecks from organizations with business ties to the state of Texas, it's not surprising that the Texas Energy Fund (TEF) was revisited several times during the 90-min session Wednesday afternoon. Note that resilience is defined here as the ability to withstand shocks without permanent damage or to adapt easily to misfortune or change.

The TEF, a/k/a Proposition 7, approved by Texans while the 2023 ProEnergy Conference (PEC2023) was in progress, allocates $7.2 billion for new construction, or upgrades, that result in at least 100 MW of dispatchable generation by June 2029. The program, which would be managed by the Public Utility Commission of Texas (PUCT), also earmarks a tidy sum for microgrids and backup power, plus grid modernization in non-Ercot areas. (Ercot is the acronym for the Electric Reliability Council of Texas.)

TEF aims to improve grid reliability—defined as the power-delivery system's ability to meet conditions satisfactorily—especially during extreme weather, thereby responding to blackouts like those suffered during Winter Storm Uri in February 2021. While viewed as a significant step in gas-turbine powerplant development, some doubt the PUCT's ability to oversee the program, especially when it comes to assessment of default risk.

The panelists indicated there was controversy over the requirement for generation to be dispatchable, with neither solar nor wind considered dispatchable, and batteries also excluded. Keep in mind that Texas has more than twice the installed wind capacity of any other state.

Winterization was a hot topic especially given the state's 2021 storm experience. Discussion touched on research of past weather patterns, implementation of corrective actions, and business continuity plans.

The importance of cold-weather preparation was highlighted, focusing on audits and inspections to ensure compliance with winterization standards set by regulatory bodies. The effectiveness of audits and documentation for ensuring compliance with standards, and for maintaining operational readiness during extreme weather events, was a sub-topic.

Noted was that while compliance with standards is essential, winterization programs must focus on operational readiness and the ability to continue operations so revenue can be generated during adverse weather conditions.

Other discussions touched on the following:

- Who manages compliance tasks? One thought was to manage compliance internally but to rely on contractors for specific tasks.
- How do you motivate workers during extreme weather conditions—hot and cold?
- Investment in critical spare parts and inventory management are important given supply-chain challenges.
- Panelists emphasized the need for efficiency, communication, and proficiency among team members to handle challenges effectively.
- Cycling powerplants present challenges that could lead to increased maintenance and equipment failures.
- Synchronous condensing/generation was batted around given plant retirements and the increase in renewable energy resources.
- Reflections on battery technology, its limitations, and the need for dispatchable resources in energy generation closed out the session.

Resilience panel

Moderator: Mark Axford, president, *Axford Consulting*
Mark Henry, director of reliability services, *Texas Reliability Entity*
Joel Stahn, VP operations and technical services, *Onward Energy*
Steve Worthington, plant manager, *Arizona Public Service Co*
John Clutts, turbine specialist, *Allied Power*

Mark Axford, Mark Henry, Joel Stahn, Steve Worthington, John Clutts—L to R

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4. Meeting the market challenge: Navigating regulations, market design, profitability

Business Environment, the first panel on the 2023 ProEnergy Conference agenda, Wednesday morning, November 8, was introduced by Christer Björkqvist, managing director of ETN Global. The Energy and Turbomachinery Network, based in Brussels, is a nonprofit organization dedicated to supporting a global cooperative platform for dispatchable, secure, affordable, and sustainable energy solutions.

Björkqvist's remarks were in alignment with the meeting's focus on aero engines—the LM6000 in particular—which are respected for their operational flexibility. He said the increasing integration of variable renewable energy sources necessitates the need for dispatchable energy to ensure grid stability and reliability. Data from the International Energy Agency supported Björkqvist, showing a continuous increase in renewable-energy integration across different regions.

The speaker went on to stress the importance of incentives and market mechanisms for supporting the transition to dispatchable energy, noting that industry research points to the years 2030-2035 as critical for having significant dispatchable capacity in place. He mentioned storage solutions, including batteries and electrolyzers for hydrogen production, as essential components of the energy transition.

In wrapping up his introduction, Björkqvist reiterated the urgent need for dispatchable, low-carbon energy solutions, calling for increased collaboration and technical innovation to meet this demand.

The panelists interact. Overall, discussion among the panelists underscored the complexity of transitioning to renewable energy sources while maintaining grid reliability and affordability—highlighting the importance of market mechanisms, infrastructure investment, and policy incentives. Takeaways from the panel discussions included the following:

- Consensus: The challenge of intermittency with renewables often is underestimated. Gas turbines are crucial elements of the energy supply system because of their flexibility and reliability in addressing this challenge.
- Ancillary services were described as essential for effective integration of renewables into the grid. They are considered vital for adapting to variability in demand and in ensuring grid stability.
- Despite advancements in renewable technologies, there still is a need for dispatchable electricity to meet growing demand while ensuring reliability in power supply.
- There was discussion on market designs and incentives for dispatchable generation, with a reference to Proposition 7 in Texas (see Sidebar 3) as an example of incentivizing investment in dispatchable generation.
- Challenges in market design and infrastructure limitations, particularly in regions like California and Europe, were highlighted as barriers to building new generating capacity.
- There was discussion on the increasing value of capacity ancillary services and its implications for electric customers. A philosophical question arises as to whether electricity is a right or a luxury, and how the market can tolerate cost increases while ensuring reliable electricity for the general public.
- Public perception plays a significant role in financing decisions for energy projects, particularly regarding fossil-fuel investments. Regulatory uncertainty and public pressure can affect the availability of financing for gas projects, leading to higher costs and risks for investors.
- Community engagement is crucial in gaining approval for energy projects. Utilities emphasize the importance of garnering community support through outreach efforts to facilitate project approval and mitigate opposition from environmental groups.
- There's a need for proactive risk management and planning in the energy sector to address potential crises and ensure reliable energy supply. Reactive responses to crises, as seen in California, are insufficient, highlighting the need for forward-looking strategies.

Moderator: Landon Tessmer, VP commercial operations, *ProEnergy*
Siraj Taj, principal, *ST Power Services Consultants*
Tina Lee, VP asset management, *WattBridge*
Evan Schenkel, VP, *Goldman Sachs*
Christer Björkqvist, managing director, *ETN*
Chris Jimenez, director of energy services, *Arizona Generation & Transmission Cooperatives (AzGT)*

Landon Tessmer, Siraj Taj, Tina Lee, Evan Schenkel, Christer Björkqvist, Chris Jimenez—left to right

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5. Attracting, training new hires for O&M positions a major challenge

Discussions stimulated by the O&M panelists (box) at PEC23 provided insights into the complex dynamics of electric generation—including the evolving regulatory landscape, technological advancements, operational strategies, and the importance of industry-wide collaboration. Highlights follow:

- Challenges abound in navigating regulatory requirements, especially concerning renewable energy resources, wind in particular.
- Renewables affect electric-generation patterns differently in various regions, and electric-power producers are challenged to adapt to these variations, which can impact unit dispatch, outage schedules, equipment reliability, etc.
- Discussion on the use of remote monitoring and diagnostics in managing plant operations revealed that some users rely on remote monitoring systems to track plant performance and identify issues proactively. However, there are challenges—such as finding skilled personnel for this purpose and in integrating automation into control systems.
- Collaboration and networking within the industry are important to enable the sharing of best practices, spare parts, and operational insights necessary for optimizing plant performance and addressing common challenges.
- The importance of remote operations was emphasized by Brian Roth. It involves troubleshooting, operational management, and advancements that leverage technology for more efficient and effective operations.
- Roth also discussed the need for a change in mindset towards remote operation—advocating for divergent thinking and encouraging the exploration of new ideas and approaches rather than sticking to traditional methods. This could drive a cultural shift within some organizations.
- Ed Jackson addressed workforce challenges—including staffing issues attributed to an aging workforce and imminent retirements. He discussed strategies for attracting and training new talent—for example, by partnering with aviation schools and providing hands-on training. Hiring in rural areas can be especially challenging, he said, emphasizing the importance of competitive salaries.
- The panelists collectively encouraged power producers to adapt to technological advancements, foster a culture of innovation, and implement proactive strategies to address workforce challenges in order to remain competitive.
- Work ethic was highlighted as a crucial factor in hiring decisions. There's a concern that the current workforce may not always demonstrate the level of work ethic expected, requiring changes in hiring practices and a focus on evaluating the initiative and dedication of candidates.
- Another challenge: Policy and regulatory changes that might suggest a need for sensitivity training. Bear in mind that policy changes may be necessary to address workforce dynamics and ensure employee satisfaction and productivity.
- The panelists placed strong emphasis on the value of hands-on training for developing the skills and knowledge needed to handle real-world challenges effectively.
- Participants acknowledged generational differences in the workforce and the importance of adapting management and training strategies accordingly. Different generations may have different work values and expectations.
- The panelists were in general agreement that finding skilled labor—O&M personnel in particular—is challenging. There's a high demand for powerplant operators, but the supply of qualified personnel is low. This scarcity contributes to hiring difficulties and requires creative solutions—such as cross-training programs and the sharing of operators across sister plants. This strategy helps ensure that staff members have a diverse skill set and can handle various tasks.

O&M panelists

Moderator: Scott Schwieger, GM, *Combined Cycle Journal*

John Clutts, turbine specialist, *Allied Power*

Ed Jackson, plant manager, Exira Generating Station, *Missouri River Energy Services,* and president, Western Turbine Users Inc, the world's largest organization of aero turbine owners and operators

Giuseppe Bonforte, reliability engineer, *Renovit SpA*

Brian Roth, VP O&M, *ProEnergy*

Scott Schwieger, John Clutts, Ed Jackson, Giuseppe Bonforte, and Brian Roth—left to right

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GTEN 2023 SYMPOSIUM

Net zero: Can't get there from here without gas turbines

The 2023 symposium of the Gas Turbine Energy Network (GTEN), held last October in Banff, Canada, widened the lens on the urgent need for gas turbines to help get the world to what policymakers call net-zero, a future time when no additional carbon is being added to the atmosphere.

It's easy to forget that gas turbines not only produce much of our electricity these days, thousands of them drive the pipeline compressors which transport the natural gas burned in power stations, homes, industrial plants, commercial buildings, etc. Once rendered carbon neutral, the GT could anchor many other applications as well.

GTEN's stated purpose is to "connect the gas-turbine industry to the future." Its vision is to be the most trusted source of gas-turbine knowledge in Canada, part of a world-class community of experts. The organization, which meets biennially, functions as a technical advisory group serving both the energy industry and governing bodies. It evolved from Canada's IAGT (Industrial Application of Gas Turbines) a year or so before the onslaught of Covid-19. Long-term subscribers to CCJ may remember our coverage of that group.

The keynote presentation at the last meeting, by Christer Bjorkquist, ETN Global, posited "three truths" of net zero: Climate change is real, net zero needs hydrocarbons, and there's an immediate need for dispatchable low-carbon solutions. GTs are central to truths two and three. At the same time, Bjorkquist and others made it clear that the gas-turbine community needs to "shift the [erroneous] technology perspective" held by the general public policymakers that net zero can be achieved without GTs.

While this article highlights material from the conference specific to aeroderivative GTs, several ETN reports are likely to be of general interest to the CCJ community: "Hydrogen Gas Turbines" (slated for an updated edition in 2024), the 2022 report, "H2 Deployment in Centralized Power Generation," and last year's "R&D Recommendations Report." A future CCJ article will provide capsule summaries of each presentation.

Visions, triptiks, roadmaps. While the general hydrogen-fueled GT development roadmap projects 100% H_2 firing in most GT models within 5 to 10 years, Colleen Rimlinger and Egidio Pucci of Baker Hughes reported that their company has been developing the fully H_2-fired NovaLT model since 2009.

The company provided an Air Products & Chemicals combined-cycle facility three such units at the end of last year. Some of the characteristics of this nominal 20-MW unit: DLN, lean premix, pilot-stabilized, double axial counter-rotating swirler (DACRS) premix, fuel staging, 39 fuel injectors, and

16 fuel staging valves. It is also able to start fully on hydrogen.

Donald McDonald, Siemens Energy Canada, revealed a compressor drive, SGT-A35, in development that blends waste heat from the natural-gas compressor letdown and the GT exhaust into the DLE combustor to reduce carbon. He noted that it would be at least six years before the unit would be 100% H_2-capable with DLE. Currently, it can handle 15% H_2 (by volume) with the DLE combustor. Dig deeper on this and other presentations by visiting http://www.gten.ca/events.html; or simply scan the QR code provided here.

Enbridge, a power producer, and Siemens recently concluded a test program for this design, which included a hydrolysis unit to supply the hydrogen. The hydrolyzer is powered by the electricity generated from the turboexpander/generator. Up to 40% H_2 blends could be achieved using this scheme.

Landon Tessmer, ProEnergy Services, confined his remarks to peaking GTs dispatched around the vagaries of available wind and solar. His company offers the LM6000PC, enhanced specifically for owner and O&M objectives (p 88). The SCR system eliminates the tempering air fan and the electric ammonia vaporizer.

The turbine anti-icing system takes ambient air from the GT enclosure and directs it to the inlet filter housing. Fogging is used instead of chillers for power augmentation (the slides include a comparison of these alternatives and a financial analysis). Turbine enclosure doors were widened for better access, and the generator compartment also was modified for better access.

Tessmer reported that during winter storm Uri, when 60% of Ercot's power resources were knocked out, ProEnergy's H O Clark station, with multiple LM6000PCs, was 100% available, operating for more than 140 hours during the storm and its aftermath.

Blade life. Wall thickness is the key to aero-GT blade life, as Daniel Pinelli, Liburdi Turbine Services, stressed in his remarks. Liburdi has been using a process known as "Full Solution Rejuvenation" (FSR) since the 1970s to extend the life of GT blades beyond the OEM's limits. In metallurgist lingo, the process "reforms the gamma-prime precipitates of the material to the as-manufactured state."

Hollow blades are another matter. There are no repair options for restoring thickness to rotating blades. Therefore, preserving wall thickness is critical to maximizing blade life. Unfortunately, some repair processes can reduce the thickness of these blades, prevalent in modern GT designs. Liburdi uses a technique called Computed Tomography, based on X-ray imaging, to obtain accurate wall thicknesses. Once these are known, experience, but especially mechanical and thermal modeling, can help dictate estimated remaining life and continued operation.

Pinelli concluded by stressing that OEMs, repair shops, and owner/operators need to work together to maximize blade life.

Aero GT overhaul 101. If you have staff needing training in managing a GT overhaul project, be sure to peruse "Aero GT Overhaul 101," by Steve Willard, TransCanada Turbines, a full-service shop licensed for both GE and Siemens aero-GT models. TCT's parent owns and operates over 400 gas turbines. The tutorial covers the bid process; field service, site considerations, and shipping; logistics; transport risks and responsibilities; project management; depot activities; testing; and engineering. CCJ

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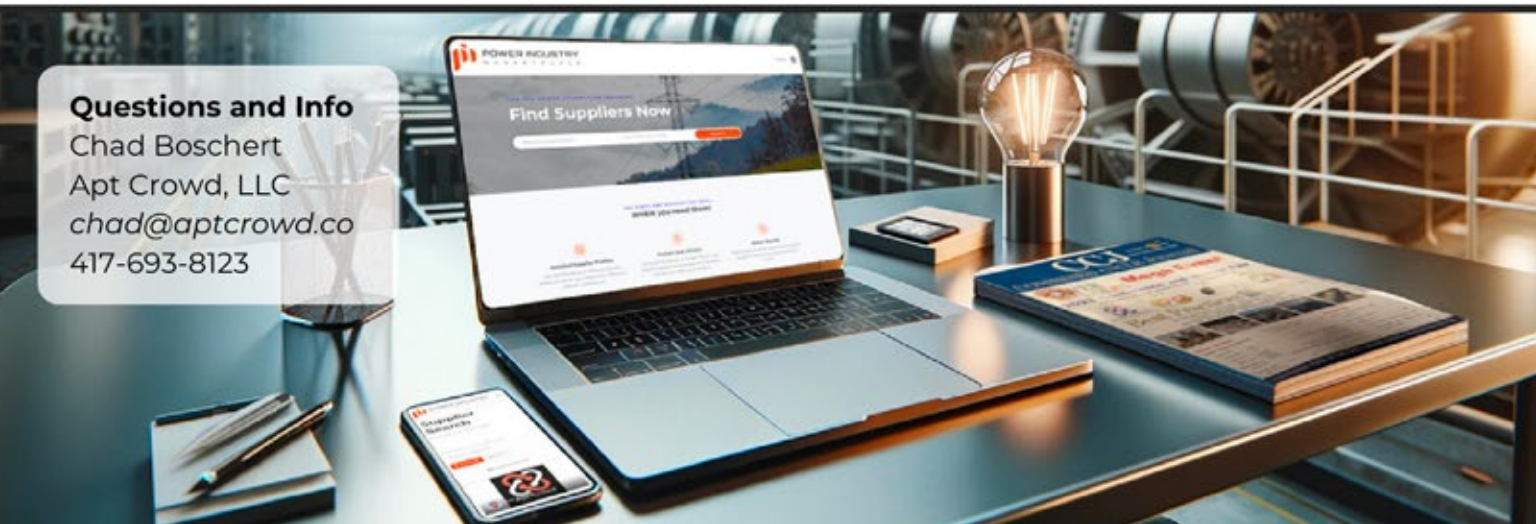

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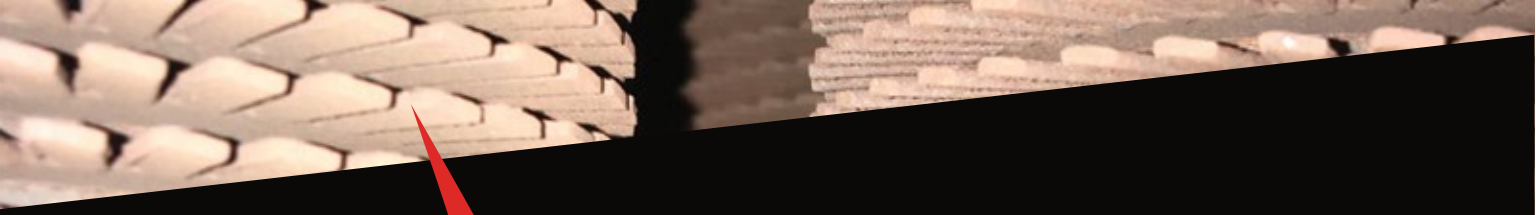

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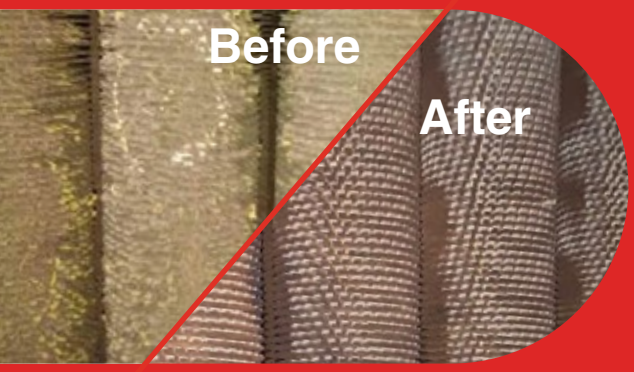

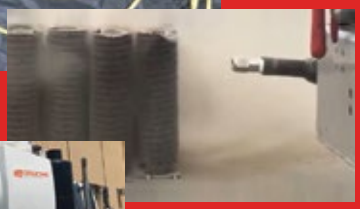

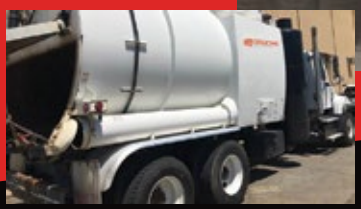

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