$15
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COMBINED CYCLE Journal

A VIBRANT CONFERENCE LINEUP FOR USERS

7F USERS GROUP
Details on p 6
2023 Conference and Vendor Fair
Renaissance Atlanta Waverly • May 15 – 19

HRSG FORUM
2023 Conference and Vendor Fair
Renaissance Atlanta Waverly • June 12 – 15

Turn to p 40 for 2023 program highlights.
ABHUG 2022 conference report starts on p 44
Advances in materials and inspection technologies, p 54

Legacy Turbine Users Group

7EA Users Group
Frame 6B Users Group™
FRAME 5 Users Group

2023 Conference and Vendor Fair
Sheraton Grand at Wild Horse Pass (Phoenix) • July 17 – 20

Turn to p 72 for 2023 program highlights and 2022 conference reports from each participating user group

SIEMENS energy
Large Gas Turbine Conference
June 5 – 8 • Renaissance Orlando at SeaWorld® Orlando, Fla

D5-D5A Users
Annual Conference and Vendor Fair
June 6 – 7
Westin Chattanooga
Chattanooga, Tenn

ACC Users Group
Air Cooled Condenser Users Group
Annual Conference and Field Trip
June 20 – 22
Innsbrook Technical Center • Glen Allen, Va

OVATION USERS' GROUP
Annual Conference and Exhibit
July 23 - 27
Westin Convention Center Hotel • Pittsburgh, Pa

Turn to page 85 for more detail on each of these meetings

Best Practices Awards

2022 Best Practices Award — CCJ COMBINED CYCLE Journal

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- Mark Axford's annual aero-market analysis 65
- Treat your lube oil like it's an asset. 67
- How your gas turbine came to be. 68

STUG celebrates a decade of service to the industry

Time flies. It seems like only yesterday that the Steam Turbine Users Group was formed by representatives of nine electric power producers. But that occurred in 2013. Five of those nine still serve on the steering committee—including Jay Hoffman and Jake English who were elected the first chairman and vice chairman, respectively. Interesting too, is that in an industry where personnel switch employers relatively frequently only one committee member is at a different company than he was in 2013.

That's stability, and one important reason STUG meetings are so valuable to steam-turbine owners and operators industry-wide. The committee members who plan the annual conference programs and lead the discussions have deep knowledge of the installed equipment and how it has performed over the years.

To illustrate: Consider the valuable insights provided by the three presentations below available in the STUG library on the Power Users website at https://powerusers.org:

- Improving Steam-Turbine-Major Outage Efficiencies by leveraging experience shared by colleagues on lessons learned, outage scope and duration, etc.
- L-0/L-1 Inspection Findings and Lessons Learned for Operation and Future Maintenance Planning offers invaluable guidance on two turbine stages of great concern to many users.
- Vendor Shop/Field Considerations for Future Maintenance Planning to Avoid QA/QC Issues. The advice shared is of value to virtually everyone with steam-turbine responsibilities.

STUG's upcoming 10th Anniversary meeting (August 28-31 at the Omni Atlanta Hotel at CNN) offers compelling presentations/discussions for those responsible for improving the reliability, availability, and performance of their plant's steam turbines. Here's a peek at the hot topics that likely will be included on this year's program:

- How best to deal with stop-valve stem erosion on GE combined-cycle steam turbines. The planned multi-utility panel discussion is expected to cover OEM originals versus OEM upgrades versus third-party upgrades/alternatives and share experiences on the effectiveness of installed upgrades (GE and third party) based on recent valve inspections.
- Crossover expansion-joint failures and subsequent changes to recommended inspections.
- Managing the O&M of aging assets (including steam turbines at coal-fired and combined-cycle plants) given the increasing impacts of renewables on system operation. Discussion is expected to cover ARD replacement, L-0 trailing-edge erosion, valve seat cutting, and more.

Keep up with program developments on the Power Users website, where you also can register for the meeting, book your hotel room, etc.

A look back. STUG was born out of necessity. In the early days of the Power Users organization, the primary focus for most steering committees was tackling and managing-through the many issues plaguing the global gas-turbine fleet. As such, less and less time was available during most conferences to cover the combined-cycle steam turbines, generators, and balance-of-plant equipment. This may have been acceptable given the young age of that equipment relative to major maintenance.

However, by the early 2010s, Power Users recognized the growing number of steam-turbine issues—not just within the combined-cycle fleet, but also with the aging fossil fleet of traditional standalone steam turbines.

The STUG steering committee formed in 2013 was charged with "taking the temperature of the steam-turbine industry" by consulting with both users and vendors, and to host a conference aimed at addressing several of the day's hot topics. The group's inaugural conference was held in Richmond (Va) in August 2014. More than 60 users and 20 vendors participated.

Since then, STUG has continued to grow in both size and value. Today, STUG meetings are co-located with the annual conferences of the Combined Cycle, Generator, and Power Plant Controls Users Groups under the Power Users' umbrella. This "Combined Conference" is attended by about 200 users annually.

The 2023 STUG Steering Committee
Chairman: Matt Radcliff, *Dominion* (2019)
Eddie Argo, *Southern Company* (2013)
Jake English, *Duke Energy* (2013)
Jared Harrell, *OxyChem* (2023)
Jay Hoffman, Tenaska (2013)
Connor Hurst, *Tampa Electric* (2020)
Mark Johnson, *Florida Power & Light* (2020)
John McQuerry, *Calpine* (2013)
Lonny Simon, *OxyChem* (2013)
Brandon Steward, *Southern Company* (2023)
Seth Story, *Luminant* (2018)

Past members of the STUG Steering Committee
Jess Bills, *SRP* (2013-2021)
Gary Crisp, *NV Energy* (2013-2020)
Bert Norfleet, *Dominion* (2013-2019)
John Walsh, *Sundevil Power* (2013-2016)

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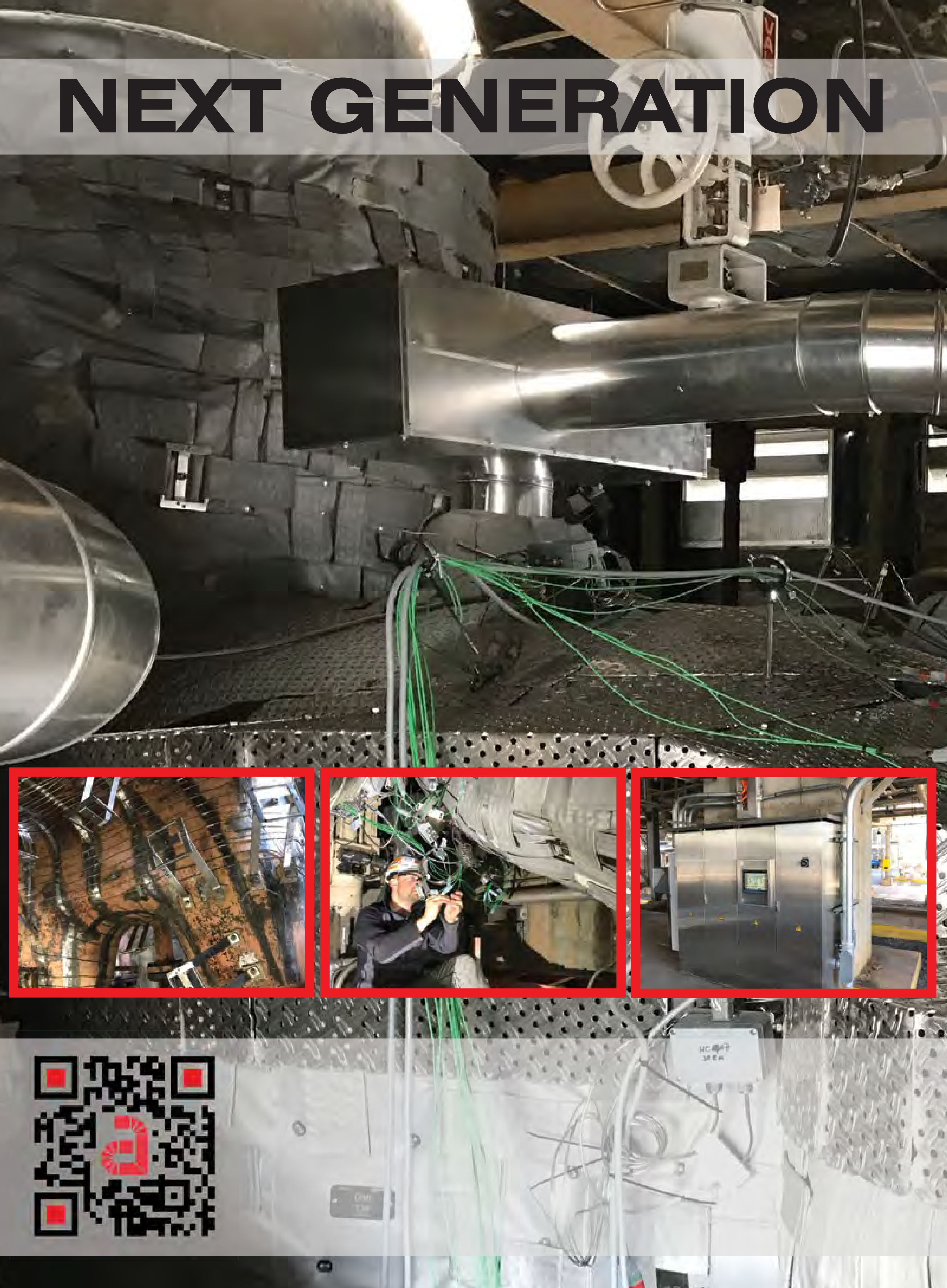
NEXT GENERATION




TURBINE WARMING
Operational Advantages
• Eliminate Cold Starts
• Maintain Hot-Start Conditions
• Faster Starts
• Mitigate Case Distortion
• Advanced, Customizable Control
Maintenance Advantages
• Easy Access to Critical Areas
• Quick & Easy Removal / Reinstall
• Enhanced Operator Safety Features
Economic Advantages
• Gain Competitive Market Advantage
• Seamless Turnkey Solution
• Reduced Fuel Consumption
• Increase Profitability
Contact: Pierre Ansmann
pierre.ansmann@arnoldgroup.com
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7F USERS GROUP

2023 Conference and Vendor Fair

Renaissance Atlanta Waverly • May 15-19

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ExxonMobil

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PSM a Hanwha company

GOLD

Advanced Turbine Support

APG

Chevron

Doosan

Lectrodryer

eone Utility Systems

Generating Solutions

GasPath Solutions

Reuter-Stokes a Baker Hughes business

Sulzer Sulzer Turbo Services

SVI Bremco

Waygate Technologies

The world's largest user organization supporting owner/operators of 7F gas turbines promises a robust in-person event when the group gathers at the Renaissance Atlanta Waverly, May 15-19, for its 2023 conference and vendor fair.

This year's program features vendor solutions on both Monday (May 15) and Tuesday (May 16) morning, followed by traditional user-only general sessions in the afternoons, and vendor fairs from 4 to 7 p.m. Wednesday is dedicated to user-only general sessions. Thursday is GE Day. The Friday morning session has been expanded to include both the OEM's traditional deep-dive knowledge-sharing program and two special user-only sessions.

The vendor solutions presentations Monday and Tuesday morning are arranged in three 30-min sessions with four services providers presenting simultaneously in each session. Four platinum-sponsor presentations, aggregated in a fourth 60-min session, conclude the morning programs.

Monday, attendees can listen to half-hour presentations by GTC Control Solutions (a division of AP4 Group), HRST, Liburdi Turbine Services, PSM, C C Jensen, EthosEnergy, JASC, Turbine Generator Advisers, Riverhawk, and SVI Industrial; plus, hour presentations by AP4 Group, Arnold Group, ExxonMobil, and Shell Oil Products.

Tuesday's half-hour presentations are by Allied Power Group, C C Jensen, National Electric Coil, Nord-Lock Group, Integrity Power Solutions, Lectrodryer, NRG Faist, Sulzer Turbo Services Houston, Carbon Reduction Systems, Marioff, and PSM; plus hour presentations by AGT Services, Industrial Air Flow Dynamics, MD&A, and PSM.

The general sessions Monday and Tuesday afternoon and all day Wednesday include a lineup of presentations and discussions by and among users on safety, combustion, auxiliaries, rotors, exhaust systems and components, and other topics.

Vendor fairs Monday and Tuesday showcase the products and services from five- to six-dozen companies each day. The generous three-hour exhibit hall program allows you to visit all the companies on your punch list while taking advantage of the heavy hors d'oeuvres and open bar.

GE Day topics were not available prior to publication.

The Friday program has been greatly improved by the Steering Committee. It now offers a GE program and two user-only sessions. The GE program focuses on advanced gas turbines, forgotten upgrades, and troubleshooting of the Customer Portal; the non-GE sessions, DLN tuning and TIL review/tracking.

SILVER PLUS

Trinity Turbine Technology, L.P.

SILVER

3angles · Avail Infrastructure Solutions · Cutsforth · Dekomte · Emerson · Filter-Doc · Faist · JASC · Rochem · Veracity Technology Solutions · Taylor's Industrial Coatings · TTS Power · TOPS Field Services, LLC · Universal Plant Services · Viking Turbine Services

BRONZE

AAF International · ATS Applied Technical Services · Badger Expansion Joints · Cust-O-Fab Specialty Services, LLC · EagleBurgmann · EthosEnergy · ZOK · Groome Industrial Service Group · Hilco · IC Spares · ITH Bolting Technology · Koenig Engineering Inc · MeeFog Systems · Mitten Field Services · Moog · National Electric Coil · Republic Turbines · Tetra Engineering · Toshiba · TSL Turbine Services, Ltd.

Technical program at a glance

Monday, May 15

0845, Vendor solutions 1—ap4, HRST, Liburdi, PSM
Controls upgrade case studies
Mods improve HRSG efficiency
GT repairs to reduce waste
Manage the 7F rotor wave

0930, Vendor solutions 2—Jensen, EthosEnergy, JASC, TG Advisers
Oil, your hidden asset
Effects of increased cycling
Liquid-fuel reliability
Extreme temperature readiness

1015, Vendor solutions 3—HRST, Liburdi, Riverhawk, SVI/Bremco
HRSG tube plugging
GT failure analysis/avoidance
Coupling-stud measurement
Turbine exhaust system upgrades

1100, Vendor solutions 4—ap4, Arnold, ExxonMobil, Shell
LCI controls reliability
Steam-turbine warming
Turbine triage plan
PAG-based EHC fluid

1300, Compressor session
S17 issues, Pkg 3 and 5 upgrades
T-fairing distress (TIL-2212)

Tuesday, May 16

0845, Vendor solutions 5—APG, Jensen, NEC, Nord-Lock
Improved DLN 2.6 effusion plate
Demystifying varnish
Recent generator findings
EzFit coupling-bolt solutions

0930, Vendor solutions 6—IPS, Lectrodryer, NRG Faist, Sulzer
7F exhaust-frame mods
Generator fast-purge package
ISO 29461-2 GT filters
Combustion optimization

1015, Vendor solutions 7—CRDX, Marioff, PSM, Sulzer
H_2 fuel for gas turbines
Water-mist fire suppression
Digital twins
Bump in the night

1100, Vendor solutions 8—AGTS, IAFD, MD&A, PSM
Collector system maintenance
Duct-liner plate, HEP
Rotor life assessment
Combustion and full-GT solutions

1300, General session

Wednesday, May 17

0800, User presentations 1
DLN 2.6+ and AFS
End-cap-liner failure analysis

1015, User presentations 2
Creep failure of 7F.03 R2 blades
Mark VIe synch issue

1300, User presentations 3
Life extension, rotors and more
Panel: Liquid-fuel operations

1515, User presentations 4
7FH2 stator findings
7FH2 generator findings
Exhaust replacement
BOP 7F tech overview
Compartment gas leak

Thursday, GE Day

0800, Session 1
Safety moment
Adapting to change
Powering the future

1000, Session 2
State of the 7F

1100, Breakout 1
Compressor and turbine
GT 101 flange to flange
Controls philosophy

1300, Breakout 2
Rotor management
Generator, electrical systems
Combustion

1415, Breakout 3
Exhaust frame, issues/solutions
Supply-chain overview
GT auxiliary systems

1530, Breakout 4
Top Five TILs
Field service, live outage
Troubleshooting controls

Friday, May 19

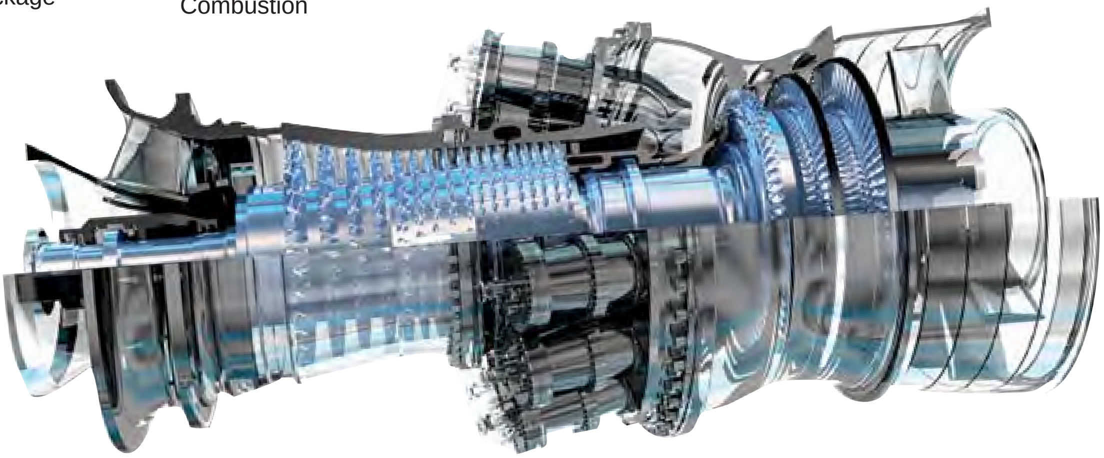
0800, Parallel presos 1
Gas turbine 401 (GE/users)
TIL review/tracking (users only)

0915, Parallel presos 2
Forgotten upgrades (GE/users)
DLN tuning (users only)

1030, Final preso
GE portal issues, deep dive

7F Users Group 2023 Steering Committee

Chairman: John Rogers, *SRP* (2019)
Vice Chairman: Dave Such, *Xcel Energy* (2006-2019; 2022)
Luis Barrera, *Calpine* (2014)
Sam Graham, *Tenaska* (2007-2018; 2022)
Riz James, *Dominion Energy* (2021)
Clinton Lafferty, *TVA* (2020)
Doug Leonard, *ExxonMobil* (2020)
Ed Maggio, *TVA* (2013)
Justin McDonald, *Southern Company Generation* (2013)
Timothy Null, *Eastman Chemical* (2019)
Brian Richardson, *FPL* (2022)
Zach Wood, *Duke Energy* (2020)



7F USERS GROUP

Monday exhibitors, alphabetical order

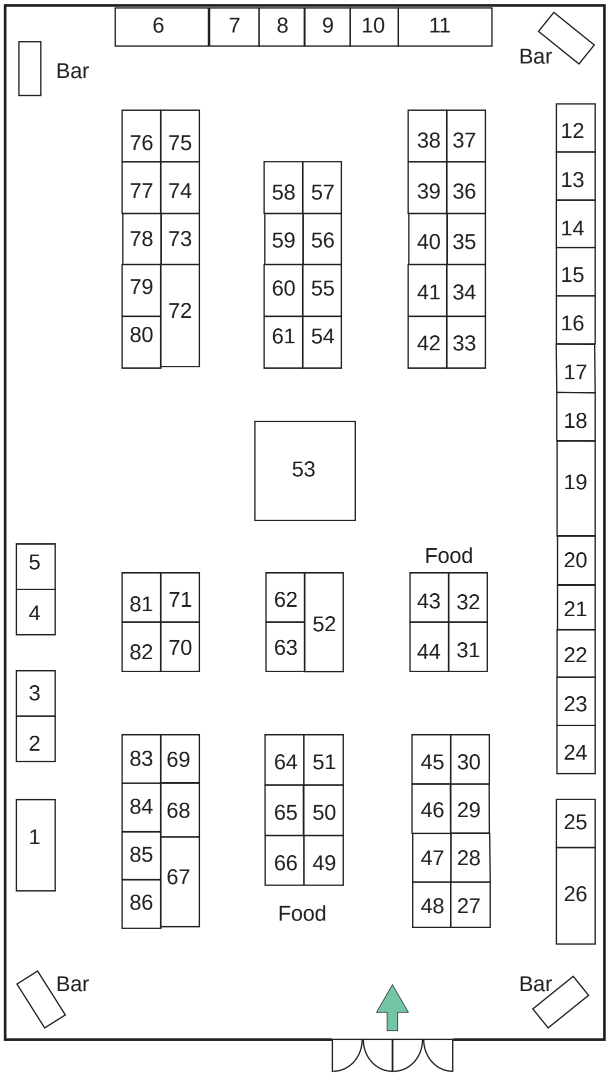
Company — **Booth**

3angles Inc 54
AAF International....17
Advanced Turbine Support....9
AGT Services Inc....66
Allied Power Group....1
AMETEK Power Instruments...79
AP4 Group....6
Applied Technical Services....77
ARNOLD Group....11
AVAIL Bus Systems....71
Badger Industries....39
BBM-CPG Technology....36
Bearings Plus....41
C C JENSEN Inc....21
Camfil Power Systems....73
Carter Machine Works Inc....24
Chevron....42
Conval Inc....56
CTTS....59
CUST-O-FAB....15
Cutsforth Inc....40
Dekomte De Temple LLC....75
Doosan Turbomachinery Services Inc....52
EagleBurgmann Industries LP.20
Emerson....62
Environment One Corp....86
EthosEnergy....34
ExxonMobil....48
Falcon Crest/Zokman Products 78
Filter-Doc Corporation....30
Freudenberg Filtration Technologies....84
Gas Path Solutions....76
Gas Turbine Parts & Services Inc.... 70
Groome Industrial Service Group....25
HILCO Filtration....16
HRST Inc....44
IC Spares....55
Independent Turbine Consulting LLC....60
Industrial Air Flow Dynamics Inc....27
Integrity Power Solutions LLC...2
ITH Engineering....49
JASC....80
K Machine....3
Koenig Engineering Inc....63
Lectrodryer LLC....47
Liburdi Turbine Services Inc....74
Macemore Inc....35
MD&A....53
Mee Industries Inc....50
Miba Industrial Bearings....13
Mitten Field Services LLC....31
Munters Corp....69
NEC....58
Nederman Pneumafil....68
Nooter/Eriksen....4
NRG Faist....8
OILKLEEN....23
ORR Protection Systems Inc...85
Paragon....28
Parker Hannifin....14
Power Services Group....65
Powerflow Engineering Inc....83
Powmat Ltd....51
PSM....26
Rapid Belts LLC....82
Republic Turbines....12
Reuter-Stokes....18
Riverhawk....7
Rochem Technical Services....10
Schock Manufacturing....5
Shell Lubricant Solutions....67
Stork Turbo Blading Inc....22
Sulzer....72
SVI/BREMCO....33
Taylor's Industrial Coatings....29
Tetra Engineering Group Inc....46
TOPS Field Services LLC....57
Toshiba America Energy Systems....37
Trinity Turbine Technology....64
TTS Power....32
Turbine Generator Advisers....45
Turbine Services Ltd....61
Universal Plant Services....43
Veracity....81
Viking Turbine Services Inc .38
Waygate Technologies....19

Vendor Fair

Monday, May 15, 4 – 7 p.m.
Tuesday, May 16, 4 – 7 p.m.

Cobb Galleria Centre, Exhibit Hall D



Flow of traffic from Waverly Hotel
(hallway connection)

Monday exhibitors, booth number order

Booth — **Company**

1....Allied Power Group
2....Integrity Power Solutions LLC
3....K Machine
4....Nooter/Eriksen
5....Schock Manufacturing
6....AP4 Group
7....Riverhawk
8....NRG Faist
9....Advanced Turbine Support
10....Rochem Technical Services
11....ARNOLD Group
12....Republic Turbines
13....Miba Industrial Bearings
14....Parker Hannifin
15....CUST-O-FAB
16....HILCO Filtration
17....AAF International
18....Reuter-Stokes
19....Waygate Technologies
20... EagleBurgmann Industries LP
21....C C JENSEN Inc
22....Stork Turbo Blading Inc
23....OILKLEEN
24....Carter Machine Works Inc
25....Groome Industrial Service Group
26....PSM
27....Industrial Air Flow Dynamics
28....Paragon
29.. Taylor's Industrial Coatings Inc
30....Filter-Doc Corp
31....Mitten Field Services LLC
32....TTS Power
33....SVI/BREMCO
34....EthosEnergy
35....Macemore Inc
36....BBM-CPG Technology
37....Toshiba America Energy Systems
38....Viking Turbine Services Inc
39....Badger Industries
40....Cutsforth Inc
41....Bearings Plus
42....Chevron
43....Universal Plant Services
44....HRST Inc
45....Turbine Generator Advisers
46....Tetra Engineering Group Inc
47....Lectrodryer LLC
48....ExxonMobil
49....ITH Engineering
50....Mee Industries Inc
51....Powmat Ltd
52....Doosan Turbomachinery Services Inc
53....MD&A
54....3angles Inc
55....IC Spares
56....Conval Inc
57....TOPS Field Services LLC
58....NEC
59....CTTS
60....Independent Turbine Consulting LLC
61....Turbine Services Ltd
62....Emerson
63....Koenig Engineering Inc
64....Trinity Turbine Technology LP
65....Power Services Group
66....AGT Services Inc
67....Shell Lubricant Solutions
68....Nederman Pneumafil
69....Munters Corp
70....Gas Turbine Parts & Services Inc
71....AVAIL Bus Systems
72....Sulzer
73....Camfil Power Systems
74....Liburdi Turbine Services Inc
75....Dekomte De Temple LLC
76....Gas Path Solutions
77....Applied Technical Services
78 Falcon Crest/Zokman Products
79..... AMETEK Power Instruments
80....JASC
81....Veracity
82....Rapid Belts LLC
83....Powerflow Engineering Inc
84....Freudenberg Filtration Technologies
85..... ORR Protection Systems Inc
86....Environment One Corp

Tuesday exhibitors, alphabetical order

Company — **Booth**

AAF International....17
Advanced Turbine Support....9
AGT Services Inc....66
Allied Power Group....1
Alta Solutions....79
American Chemical Technologies Inc....69
AP4 Group....6

Applied Technical Services......77
ARNOLD Group.......................11
AVAIL Bus Systems.................71
Bosch Rexroth.........................45
Braden Filtration LLC...............82
Caldwell Energy Co LLC 28
Chentronics 44
Chevron 42
Conax Technologies 22
Core Tech Industrial Corp........56
CRDX - Carbon Reduction Systems 7
CUST-O-FAB 15
Dekomte De Temple LLC 75
Direct Turbine Controls Corp...41
Doble Engineering Co 68
Donaldson 13
Doosan Turbomachinery Services Inc 52
Durr Universal Inc....................49
EagleBurgmann Industries LP.20
Environex Inc...........................85
Environment One Corp............86
EthosEnergy 34
ExxonMobil 48
Gas Path Solutions..................76
HILCO Filtration.......................16
HPC Technical Services 30
Hy-Pro Filtration.......................14
IC Spares.................................55
Industrial Air Flow Dynamics ...27
JASC 80
Lectrodryer LLC.......................47
Marioff NA................................62
MD&A 53
Millennium Power Services 73
Mitten Field Services LLC........31
Mobile Excitation Services.......51
Moog..70
NEC 58
Nord-Lock Group 54
NRG Faist.................................8
Outage Support Resource.......21
Pinnacle Parts and Service Corp 50
Polar Clean..............................78
Power Valves LLC 83
Precision Iceblast 63
PSM...26
Republic Turbines....................12
Reuter-Stokes..........................18
Roper Pump Co.......................65
Servocon Alpha 4
Shell Lubricant Solutions.........67
Sohre Turbomachinery Inc 36
ST Cotter Turbine Services Inc 23
Structural Integrity Associates ...5
Sulzer 72
SVI/BREMCO 33
TesTex Inc...............................24
TOPS Field Services LLC........57
Toshiba America Energy Systems 37
TTS Power...............................32
Turbine Logic...........................59
Turbine Services Ltd................61
UNEW Inc................................64
Universal Plant Services..........43
Veracity...................................81
Viking Turbine Services Inc 38
Voom LLC................................25
Waygate Technologies.............19
W L Gore & Associates Inc......60
Woodward Inc..........................10
Young & Franklin Inc 39

Tuesday exhibitors, booth number order

Booth	Company
1	Allied Power Group
4	Servocon Alpha
5	Structural Integrity Associates
6	AP4 Group
7	CRDX - Carbon Reduction Systems
8	NRG Faist
9	Advanced Turbine Support
10	Woodward Inc
11	ARNOLD Group
12	Republic Turbines
13	Donaldson
14	Hy-Pro Filtration
15	CUST-O-FAB
16	HILCO Filtration
17	AAF International
18	Reuter-Stokes
19	Waygate Technologies
20	EagleBurgmann Industries LP
21	Outage Support Resource LLC
22	Conax Technologies
23	ST Cotter Turbine Services Inc
24	TesTex Inc
25	Voom LLC
26	PSM
27	Industrial Air Flow Dynamics Inc
28	Caldwell Energy Co LLC
30	HPC Technical Services
31	Mitten Field Services LLC
32	TTS Power
33	SVI/BREMCO
34	EthosEnergy
36	Sohre Turbomachinery Inc
37	Toshiba America Energy Systems
38	Viking Turbine Services Inc
39	Young & Franklin Inc
41	Direct Turbine Controls Corp
42	Chevron
43	Universal Plant Services
44	Chentronics
45	Bosch Rexroth
47	Lectrodryer LLC
48	ExxonMobil
49	Durr Universal Inc
50	Pinnacle Parts and Serviceº
51	Mobile Excitation Services LLC
52	Doosan Turbomachinery Services Inc
53	MD&A
54	Nord-Lock Group
55	IC Spares
56	Core Tech Industrial Corp
57	TOPS Field Services LLC
58	NEC
59	Turbine Logic
60	W L Gore & Associates Inc
61	Turbine Services Ltd
62	Marioff NA
63	Precision Iceblast
64	UNEW Inc
65	Roper Pump Co
66	AGT Services Inc
67	Shell Lubricant Solutions
68	Doble Engineering Co
69	American Chemical Technologies Inc
70	Moog
71	AVAIL Bus Systems
72	Sulzer
73	Millennium Power Services
75	Dekomte De Temple LLC
76	Gas Path Solutions
77	Applied Technical Services
78	Polar Clean
79	Alta Solutions
80	JASC
81	Veracity
82	Braden Filtration LLC
83	Power Valves LLC
85	Environex Inc
86	Environment One Corp

Regenerating a refinery cogen's Frame 7EA rotors

Phoenix Rotor™ gives facility the best of both worlds

KEY POINTS

- Units returned to 200,000 factored fired hours
- Lengthy outages avoided
- CapEx savings of around 40% compared with a new rotor from the OEM

THE CHALLENGE: Going beyond rotor end of life

Gas turbine rotors have a finite lifetime. Heavy-duty gas turbine rotors in particular, like the GE Frame 7EA. Back in June 2007 (and later updated in 2011), the OEM issued a safety-critical Technical Information Letter (TIL) placing restrictions on running these units beyond 200,000 factored fired hours (FFH) or 5,000 factored fired starts (FFS).

TIL-1576 cites the risk of catastrophic failure and serious injury to nearby personnel. You could also face insurance claims being denied if you operate your units beyond these limits.

But for a power generation facility, the gas turbine is the key component. It's the heartbeat of the entire operation.

So, plants with rotors approaching one or other of these end-of-life limits are faced with a tough decision: Do they buy an expensive new rotor from the OEM? Or do they purchase an aftermarket rotor that might not fit the operating timeline of the plant … and which often isn't backed by warranty?

That was the position our client found itself facing in 2018.

But, in fact, those weren't the only two options available.

THE SOLUTION: Marrying the old with the new

Our client owns a cogeneration facility in the Gulf Coast area that supplies electricity and steam to an adjacent refinery. One of their GE Frame 7EA gas turbine unit rotors was a year or two away from reaching its end of life. But our client realized they would be operating that unit well beyond the estimated eight years offered by an aftermarket rotor.

The plant was looking for a life extension option that was low risk, cost-effective, flexible, and minimized downtime. It just so happened we had recently developed the ideal solution.

Our Phoenix Rotor™ gives clients the best of both worlds: long-term operation without the high costs of purchasing a brand-new unit from the OEM. Using new and CPO™ (certified previously operated) components, our hybrid 7EA rotor is certified for 200,000 FFH. In essence, it adds an additional 25 years to your unit.

Our client was open to our Phoenix Rotor solution but, given the magnitude of the decision, due diligence was a must. What they already had with us, however, was a relationship of trust built up over many years.

Going back to 2005, we had performed all their outages. We had carried out all their parts repairs and maintenance. And they relied on us for just about everything on their 7EA gas turbines. That included handling the purchase and installation of valves when they had changed from hydraulic to electric controllers.

Building on that platform, we walked our client through the know-how that informed our engineers' thinking. We answered all their questions. And we gave them a warranty, demonstrating how much we stood behind our solution.

THE IMPACT: Adding another quarter of a century

With the client giving us the green light, we delivered and installed their first Phoenix Rotor on time. They then operated our rotor for a season without any issues. So pleased were they that they gave us the green light for a second rotor, which we installed the following year.

Now, nearly four years later, both rotors have been running without any issues. As have another eight Phoenix Rotors we've since installed for other clients.

Each of our rotors has given our client cost savings of around 40% compared with purchasing a new rotor from the OEM. And with a replacement they could drop in as soon as their old rotor was removed, they've avoided the potential for lengthy outages.

Not only have we regenerated the heartbeat of our client's plant, but in the process we've cemented a relationship built on trust. By taking the time to listen to their wants and needs, we've shown them we truly are a partner who understands their business.

Learn more about rotor life extension and EthosEnergy's other rotating equipment services and solutions at ethosenergy.com

EthosEnergy

Supply-chain, end-of-life issues merge with seasonal reliability concerns

A conference like the 7F Users Group's may seem like a bunch of gear heads getting their collective, figurative hands dirty, but what goes down can have serious consequences for the nation.

Last year's event, organized under the www.powerusers.org banner, was the first ever for 41% of the attendees according to a spot poll taken during the first user-only session. Those "newbies," and the rest of the audience, were enriched by four days of hard-core component presentations, many focused on supply-chain and machine end-of-life (EOL) issues, and engineering/repair approaches to address them.

If you didn't walk away with the feeling of an impending capital-parts-supply and service crunch, you probably weren't listening carefully. After all, many of these components are approaching their 20-25-year service lives, seemingly within a short window of a few years. Which makes perfect sense.

What many of the newbies probably don't realize is that during the gas-turbine order "bubble" of 1997-2003, 7F owner/operators were paying up to a million dollars *just for a place in the manufacturing queue for one of these machines.* While market bubbles tend to be followed by market busts, and that one was no exception, it's pretty obvious that a market "frenzy" for turbine and compressor wheels and rotors, generator rotors and rewinds, gearboxes, life assessment and extension services, etc, would follow 20-25 years later.

What no one could have predicted is that a global pandemic would disrupt global supply chains concurrently. Or that modeled long-term climate disruptions, increases in average temperature, drought conditions, frequency of severe storms, ocean water levels, etc, may be proving true.

Experience suggests that market disruptions like this are often short-lived. Markets adjust. New providers enter the market. Electricity demand slows with the economy. But the short-term consequences could be severe, especially if you consider that NERC and others are anticipating structural challenges in meeting peak electricity demand this summer in some parts of the country. You can read a summary of NERC's 2022 Summer Reliability Assessment Report to understand the situation.

While predicted searing summer temperatures are cited, supply-chain issues are also flagged, along with coal-fired units being shut down and many others (transmission capacity, cybersecurity, variable renewable resources, etc). EOL issues with the gas-turbine fleet (peakers and combined cycles) are not mentioned, at least not directly, yet the nation's ability to meet peak demand is quite dependent on the thousand or so 7F units operating today.

Now consider a few of the sound bites from the conference:

- "Generator emergent work during outages is up 30% in the industry."
- About "90% of the 7F turning-gear gearbox fleet is 20+ years old."
- "GE doesn't have enough 'wheels' to go around, there are not enough wheels in the marketplace."
- "We [user with dozens of machines] had nine unplanned compressor events in 2021."
- "Who's driving the bus in the [OEM's] shop?"
- "It's not just the [OEM], it's the other shops as well."
- Referring to one OEM, "all controls related lead times are minimum 42 weeks."

No one wants to be accused of "crying wolf." But if NERC's forecasts are close to the mark, it won't take too many 7F units in forced outage or suffering from supply-chain constraints getting back online to make this an insufferable summer in many areas.

User presentations

Compressors

The user portion of the conference leaped out of the gate on the first afternoon with a session on compressors and a most untimely failure of an unflared compressor rotor in a 20-year-old machine at a 2 × 1 site (with DLN 2.6 and AGP) with 115,000 fired hours and over 1600 starts at time of failure. An S4 blade sheared off, and a R5 blade liberated. Thankfully, the machine trip was fully automated and orderly.

When the machine was opened up, R2 to R3 clashing was observed, and the liberated debris had collected around the turbine R1 nozzles. Analysis of the S4 blade revealed a 0.018-in. pit along with foreign deposits. Hypothesis on the failure mechanism was that a crack initiated at the S4 leading edge, then grew across the blade, and high-cycle fatigue (HCF) excited the crack to liberation.

There was no evidence of vane lock, but the OEM reported that as the root cause. In fact, the presenter conceded that a true root cause was "not really identified." No evidence of vane lock was observed on the sister unit.

With hindsight, the presenter suggested that they should have performed a full end-of-life (EOL) NDE on the compressor during the last outage. He said an average of 60% of the compressor blades were inspected during the spring 2021 outage, but also that "a 0.018 in. pit is not easy to spot" during a routine outage inspection.

Of the options before them, the owner/operator elected to couple the original turbine rotor to a new unflared compressor rotor, which included the enhanced Package 5 upgrade (the failed unit had a Package 3), along with new R1 turbine nozzles. Total time offline: Eight weeks.

Of most importance to the audience are the corrective actions taken to prevent a similar event on the sister unit, including the following:

- Increase offline water washes to three times annually.
- Conduct the Package 3 upgrade (including the R0 stage) and consider replacing the carbon-steel stator rings for the 0-4 stages with stainless steel to reduce lock-up potential.
- Increase 100% borescope activities to twice a year.
- Inspect filter housing (with associated maintenance) twice annually.
- Ping test the R0 (using a third party, in this case EPRI) to check for lockup (the "only physical test available for lockup").
- Use HEPA filters.

The presenter noted that the HEPAs made a "night-and-day difference after one summer run."

The audience expressed much interest in the "smoke test" used at the site to detect housing leaks. It's apparently common "for new installs" but a show of hands revealed that not many do it at operating sites. Presenter cautioned

that "you need to find the right juice" to fuel the smoke generating machine.

Other details ferreted out during the Q&A:

- The OEM states that a blade must be replaced if a "pit" is discovered" but no action if required if only a "blemish." Which begs the question: What to do in the gray area in-between?
- Joints at the turbine bellmouth were not caulked and sealed properly after the outage.
- The site uses lake water for cooling; SO_2 could be present from decomposing biomass.
- Online water washing is done every 48 hours; inlet filters are replaced every two to four years.

Colloquium

The compressor session continued with two experts, both repping owner/operators with many 7FA units, who offered a general review of their experiences and perspectives on compressor issues, rather than a specific site incident.

One of the experts, responsible for a few dozen machines, reported nine unplanned compressor events in 2021, "significant issues" with their 12 unflared compressors, and perhaps most notably, experiencing "all the unflared compressor issues on their flared units." As he explained, "Our issues in 2022 are the same as in 2016 (the last time he presented at 7F), except that the frequency of incidences has been reduced with Package 2 and 3 retrofits."

This owner/operator has been using non-OEM teams for 90% of its borescope inspections (BI) over the last 15 years, because the OEM "is difficult to schedule" and the third parties submit far better reports. He urged his compatriots to schedule BIs at the beginning of the outage, to provide some lead time if parts or repairs are necessary.

The other expert echoed this sentiment, stating that they schedule two BIs per year for each machine, a "heavy" in the spring, and a "light" in the fall, and none of them are performed by the OEM. An audience member added that they have dedicated techs self-perform their BIs. On the other hand, "ATS and GE are really the only two players" for a complete NDE.

If you are curious about how many "pictures" come from a BI, one user said between 600 and 1000, which may require photo management software to keep organized.

Clearly, the supply chain is unsettling for compressor blades. According to these experts, the OEM requires a 42-week lead time, while one prominent non-OEM supplier is now looking at 58 weeks out. That's over a year for anyone quaking in their boots about an forced outage this summer relating to compressor blades. Remanufactured blades are available from a third party with only a 14-week lead time.

Many TILs were name-dropped during this part of the session, almost like a trip down memory lane. Among them was TIL-1907 addressing R0 stub shaft inspections. The expert asked for a show of hands on who was experiencing stub-shaft issues, and only a few were visible. One of his units experienced a "substantial cracking"—two cracks and two indications—on a stub shaft. His team opted for a PSM solution instead of the OEM Package 3 and reported that it "has run really well" since 2008. PSM stator blades have no shims, he added.

He reported a similar situation for the S17 mechanically attached shroud, and migration of the shrouds to where they are approaching the rotor. One of his sites took a forced outage on the OEM's Gen 1 revision, and they opted for a PSM solution rather than the OEM's Gen 2 or 3. After ten years of running hours, the PSM solution held up better than the OEM's, he reported.

Qualified versus experienced

During the Tuesday afternoon session on a grab bag of topics, including safety, one user relayed a lesson that we're all probably guilty of relearning time and time again, especially in this time of intense pressure on supply-chain and personnel: "Qualified" is not the same as "experienced."

In other words, your OEM or service team may include technicians and workers who have been properly trained but haven't been fully vetted in the field. This undoubtedly was the basis for the comment made by the presenter that "there has been a rash of safety infractions in the last three years."

The presentation began with a few skits to reinforce the need for stop-work authority (SWA) for employees and contractors. SWA should be exerted when there is an unsafe condition or a change to conditions, when there is uncertainty or lack of knowledge about the task, and when employees are not using basic common sense—such as when two workers "compete" on a task.

A fair portion of the preso focused on safety professionals (SP). You want one who works in harmony with the staff, not one who "checks the boxes." Carving out time for SPs, staff, and contractors to walk the site together and observe, with no punitive consequences, is one way to achieve this. For example, do your contractors know where all the safety equipment (eye washes, fire hoses, sirens, etc) is located?

Users with large fleets deploy their own SPs, rather than rely on the contractor's. One such user reported that they had three of their SPs onsite for a 65-day outage.

Make sure you don't overlook inspections of safety equipment and ensure they are working properly. Mobile and overhead cranes are other critical equipment that should be inspected, especially before high hazard lifts. Double check all operating data (such as counterweights, angles, etc) pay particular attention to ropes and tag-lines, and "get involved" with your crane contractor. Conduct annual inspections for all overhead cranes.

Then, a thermal-performance engineer reviewed a loss analysis conducted on a 3 × 1 combined cycle, which had lost 24.6 MW over nearly two years. The analysis by the OEM was different than the owner's internal effort, but the qualitative conclusion was the same: The steam turbine is the culprit, specifically a 7.6% loss in high-pressure (HP) steam flow.

The HP turbine's pressure ratio increased gradually from 3.16 to 3.36 over the period, with an attendant isotropic efficiency loss of 4%. Duct burner heat input was restrained by steam-flow blockage increasing the throttle pressure.

During the 2021 fall outage, the HP stages were found to have large scale foreign object damage (FOD), most severe on stages 1-3, less severe on stages 4 and 5. Evidence of a significant presence of small solid particles was also noted throughout the HP and intermediate-pressure (IP) turbines, with significant erosion at stages 9 and 10.

Suspected as the source of the FOD and SPE are the gate-guided main-steam isolation valve, which showed damaged/missing metal from a 2017 borescope inspection, and the HP bypass valve, which was also discovered to have metal missing from the piping and diffuser areas during a 2021 borescope inspection.

A leading controls expert from the user community then led attendees through a "lightning round" of miscellaneous issues:

- After an inquiry to the OEM failed to garner a response for six months, problems with compressor offline water-wash isolation valves (water ingress into exhaust and accumulation under the exhaust plenum) was solved, or improved, by implementing a logic change to close the compressor bleed valves (CBV) during

the offline washes.

- TIL-2319 (November 2021) addresses excessive gas flow at startup caused by an incorrect control constant. The expert noted that the "nominal setting of 15% is very misleading" and others should pay more attention to the upper spec limit of 25%.
- When upgrading "Toolbox" within the Mark VI controller, make sure you clean up old versions, especially short cuts that operators use.
- If you have CBVs sticking during shutdown and resulting in unit trips as a result of water/debris (from GT compressor) buildup on valve seats, try installing drain legs/steam traps to evacuate the material, and remove CBV trip from the trip counter.
- Using demineralized water to flush liquid fuel lines after LF operation when the unit has cooled can function as a "poor man's purge system." This user installed additional valves downstream of the LF system check valves, which led to sticky check valves.
- To address CBV actuation during startup, consider changing the logic from relying on both sets of limit switches on the same valve to indicate proper functioning (or the machine will trip) to relying on either set of switches indicating the appropriate position. Then, check to verify both sets of CBV switches prior to the next startup.

Closing out the session was a review of an exciter (EX2000) thyristor failure: The SCR stack failed and "blew up," which was "pretty ugly when removed." The failure, which occurred during steady-state conditions, could not be attributed to anything but component age.

The 2 × 1 site (7FA-SC machines, DLN 2.6, and D11 steam turbine/generator) had done a "digital front end" (controls, communications, electrical components) upgrade to the exciter but the power bridge components (fuses, thyristors, capacitors) remained the same. There had been some troublesome "interface board issues" during the migration to the new DFE, which kept tripping the unit.

The Power Answer Center (PAC) case response from the OEM regarding "preventable actions" included the recommendation to replace thyristors and fuses on load-following units every 10 years, every 20 for baseload units. There was no reference to a GEK or a TIL in the PAC case response.

Emergent generator rewinds are not just happening to units near EOL, as the first preso Wednesday morning revealed. The unit in question is a 7FA generator with a 2010 commercial operating date (COD) but this owner/operator now has three generators in its fleet "with the same issue": Stator-bar insulation damage. Another large operator noted from the audience that it has two generators of similar vintage with similar issues.

The presenter asked the attendees if they keep spare stator bars, a spare stator, or full generator, and only a few raised hands. He then said that his company is now planning to have a spare stator and stator bars on hand.

The outage during which the damage was discovered had to be prolonged because the OEM did not have the manpower available for the inspection at the beginning of the outage. Upon inspection, 60% depth damage in the conductive armor region and 85% depth damage in the suppressor-bar region were noted.

The OEM proposed a temporary repair, with continuing potential for flashover, but would only guarantee the repair for six months; the owner/operator was not confident that the OEM had experience with this repair strategy, and the OEM's past workmanship "had been a problem." Next option was a full stator rewind but the OEM would not have stator bars available until the fall. Not only that, the OEM refused to "stand behind" stator bars supplied by others.

MD&A, which had the parts and the experience, was brought onboard to perform the rewind, although the OEM "ultimately guided the full stator rewind."

Turbine, combustion systems

Off-repeated in the social-media world: "It didn't happen if there's no photo." The same presenter as above, addressing combustion parts, repair, inspections, and QA/QC, most certainly had photos, damning, occasionally gruesome photos, of the OEM's "poor workmanship" referenced above. Examples include these:

- DLN 2.6 dual- fuel nozzles – damaged Swagelok nuts, tubing missed torque markings.
- DLN 2.6+ combustion liners – nonconformance of TBC (thermal barrier coating) thickness.
- AGP stage 3 nozzles – lack of corrosion protection, diaphragm rust during shipping.
- AGP stage 1 shrouds – improper E-seal installation and damaged, loose tiles.
- AGP stage 2 nozzles – multiple cracks on uncoated areas of trailing-edge cooling-air holes.
- AGP stage 3 shrouds – contamination with sandblast media.
- R4 stage 2 nozzles – burrs on diaphragm purge cooling outlets, "hockey pucks."

The presenter went on to say that the OEM "recorded everything incorrectly on the balance map," TBCs were often one third of what is specified, and it was not unusual to see grit in the box when shipped.

Even when parts were returned to the OEM for specific identified issues, they came back with separate issues. For example, multiple trailing-edge cooling holes had cracks, then were not reworked after the repair. The presenter's frustration at this point was palpable.

Meanwhile, the audience shared similar stories, one mentioning that install times were tripled over the outage schedule, another that measurement ranges were "questionable." A third mentioned a stub shaft on an unrepaired spare rotor with Package 5 blades that had to be sent to Canada, extending the outage by nine weeks, and causing the site to push outage work into the fall. A fourth claimed that the OEM confused before-cleaning photos with after-cleaning photos of shrouds.

The presenter did not let up as his engagement with the audience thickened. One asked whether other suppliers were posing similar problems, and one response was that the others present different issues, such as better QA/QC but limited information imparted to the customer, or the same issues, just not as severe.

The presenter added that "we check 20% of the parts from other suppliers, but 100% of the parts from the 7FA OEM," that "we've sent back four sets of stage 3 shrouds and buckets," and "the primary rotor shop is not able to produce suitable records." Perhaps this comment sums up the sentiment in the room: "Who's driving the bus in Greenville?"

FlameSheet™, GTOP experience. Returning to site-specific experiences, the next preso reviewed an implementation of PSM's FlameSheet and GTOP technologies at two sites. Most of the detail focused on control issues: The overriding moral of this story: "Don't convert control systems and combustion systems during the same outage!"

The one facility, with Mark V controls, installed FlameSheet 2.0, Autotune 3.0, and GTOP 3.1 during a fall outage, with a 10-day commissioning period. Excessive startup CO emissions was the main issue here, but two days of startup tuning by PSM "appears to have resolved this issue."

The other facility, with Ovation controls, installed AT 3.0, GTOP 3.1

during the Spring 2021 outage. Issues here were more involved and more numerous. For one, the site experienced extraordinarily high CO emissions (up to 1200 ppm) during cold starts, even with new control settings learned from the other facility. CO catalyst age and design are part of the problem, and replacement catalyst has been budgeted and scheduled.

Control issues arise from documentation which is confusing on reconciliations, updates, and version control. In some cases, you have to manually "push" reconciliation to other "drops," locations where control and HMI interfaces are accessed. In other cases, updates are automatically reconciled in other drops. Making control system changes while tuning a new combustion system that "is a massive departure from the [original] DLN 2.6" was, in hindsight, not a good idea; the control-system OEM, PSM, and site personnel resulted in "too many hands in the pot."

With the unit operating inconsistently in this period, the site experienced a flow-sleeve/transition piece side-seal failure mid-May 2022 after it tripped on flashback. Subsequent BI inspection revealed flow sleeves damaged "all the way around the circumference," while disassembly revealed that the flashback was real. The RCA was still underway at the time of the conference.

The presenter pointed out that the turbines at the two sites differ in that the one with Mark V controls does not include turning vanes on the compressor, while the other ones do. He concluded by saying that PSM was providing "excellent customer service," most trips attributed, or partially so, to the control settings which reverted or were altered after PSM left the site; FlameTop 6 has performed very well; and FlameSheet provides excellent flexibility in AGC and under fuel variability, but that the on-going issue with long-term reliability remains unresolved.

One example of that customer service: When starts were failing because of ambient conditions, PSM was able to revise the settings within three hours.

Axial Fuel Staging (AFS) upgrades. A variety of upgrades were implemented at a utility site with several units, one sporting a 1996 COD. The upgrades include various combinations for each unit of DLN 2.6, DLN 2.6+, AGP, extended turndown valves, Package 3 compressor, AFS, unflared Package 3 compressor, and unflared 7FA.01 replaced by flared 7FA.04. The dot 04 unit was acquired as a "blue light special."

Until these upgrades were implemented in fall 2020, the utility self-performed or used third parties for all outages between 2005 and 2020. Preso focused mostly on the AFS subsystem, intended to lower CO emissions at colder flame temperatures, and lower NO_x at higher firing temperatures.

The AFS poses a "difficult install," and requires a dozen or so algorithms in the controls to protect against leaks, noted the presenter. A frozen sensor line caused a runback on one of the units. Concerns were expressed about the potential for cracks in the hard tubing and transition pieces. Implicit question: Can they last 32,000 operating hours?

The AFS hardware, which "presents difficult maneuvers for millwrights," also includes vibration dampeners, without which "the hard tubing would be lost." Original dampeners had potential manufacturing defects, and required inspection. They were scheduled to be replaced fall 2022. Bolts on the rigid TPs may also be an issue, the presenter added.

FlameTop 3.0 project update. An industrial 2 × 1 combined-cycle cogeneration plant built in 2000 reported on its FlameTop 3.0 upgrade for one GT in 2018 and the other GT in 2020. FlameSheets were installed in both units in 2015. These were serial numbers 1 and 2 for the 3.0 version, according to the presenter.

After the upgrade, the combined cycle added 25 MW to its output, and achieved 40% turndown (50% was the goal) with less than 130% of full load efficiency at 50%. CO and NO_x emissions surpassed goals. FlameTop also eliminated the need for seasonal tuning.

After 28,000 operating hours with FlameSheet on the first unit, the hardware "looked very good," and FlameSheet hours are now approaching 60,000. The expectation was to reach 32,000 hours before taking a planned outage. The site got close—to 28,000 hours—before an outage was necessary for a repair.

Regarding FlameTop 3.0 (GTOP 3.0) ops, several trips were triggered by the flashback protection system and an increased sensitivity to fuel condensate was noted. Mitigation included installing a newly designed pilot cartridge that allowed for high Mode 2 operation, modified fuel main injectors to improve condensate margin, and new control logic for runback to Mode 2 instead of an engine trip for flashback protection.

Since these modifications on the one unit in 2019, no runbacks have occurred or flashback detection trips. The first unit modified had 22,000 operating hours at conference time, the second unit 10,000.

Turbine section issues. A roundtable discussion of user concerns/issues with the turbine section came next. The topics ranged from nozzles to thermocouples (t/cs).

One user lamented a loss in performance after an HGP outage, but more that there were no good answers from the OEM, much less reports and data. The smaller cooling holes with HGP nozzles were suspected, along with non-conforming TBC thicknesses. Part of the analysis was to compare five different nozzle sets from different shops; "lots of variation was found." Flow testing of the first-stage nozzles suggested debris in the cooling holes.

In discussing refurbished stage 3 nozzles and TIL 2045, an audience member cautioned to "make sure the OEM brings you the functional mock-up interface (FMI) documentation."

NDE on turbine wheel lockwire tabs at a site identified cracks on five of them; a second site reported seven cracked lockwire tabs, and a third reported "one or two tabs which had to be fixed." "Nothing in the shop repair reports covered lockwire tabs," said another.

Failed exhaust t/cs vexed several users. The Mark VI does not indicate failed t/cs, said one user. Another user with a large fleet noted that they get two emails a day about t/cs. More robust t/cs and wires have been issued by the OEM, but "most of the issues are in the control logic and with insulation falling off." The OEM is seeking partners to demo a new t/c design.

"Is the PSM version of non-optical flame detection being used?" asked a user. One plant experienced a full plant trip caused by optical flame detectors. Typically, four flame detectors must be available to pass startup permissives, in addition to the optical flame detectors. Another had to change the logic on the GE version because of purge air entering the flame detectors while running on liquid fuel.

An attendee asked if anyone was upgrading gas control valves to all-electric now that the dot 05 and the HAs come with all-electric, low differential-pressure valves. An audience member noted they have over 30 units with electric valves.

The OEM is starting to send TILs out addressing four-way-joint casing leaks, said a user, recommending that users plug them with vinyl tape to keep debris out during outages. Another noted that high leakage rates around the compressor exhaust casing causes high temperatures in the compartment and subsequent trips. Changing gaskets can avoid these leaks.

Turbine wheel cracking. Sand-

wiched between two roundtable sessions was a user presentation on turbine wheel cracking. This user has 29 F-class machines at sites purchased by the utility after COD, with subsequent changes to their operating profiles. Three HGPs outages are conducted annually across the fleet.

In one rotor with 98,000 fired hours and 1069 starts, a crack was found in March 2021. At a second site on a third HGP inspection, a unit with 70,000 fired hours and 1916 starts showed two positive crack indications on original cooling slots. This rotor was removed and replaced with a spare. At a third site, a unit at 65,000 hours and 1350 starts had seven positive indications on lockwire tabs, a situation which "may condemn the rotor." This user also experienced a compressor wreck at a fourth site.

Needless to say, the frequency of crack indications is expected to rise as fired hours accumulate. The owner/operator is developing a contingency plan "to deal with more than one event at a time" and suggested others with large fleets do the same. Part of that plan is the purchase of two spare flared rotors, and one spare unflared rotor.

This user expressed concern that the OEM may have to send rotors to a shop in Canada for repair or marry compressor rotors with GT rotors. The latter brings up compatibility issues among rotors, distance pieces, journal bearings and sizes, coupling babbitts, and other components. Finally, the user learned that the OEM will not send a wheel to your warehouse without the accompanying work to fit it up to the machine.

Then the turbine section roundtable discussion continued, with brief mentions of TILs 2156 (AGP stage 2 nozzle mod), 2181 (stage 1 nozzle creep degradation model), 2284 (balance weight groove entry slot recommendations), and 2302 (dot 04 and dot 05 stage/nozzle seal housing assembly recommendations), the last addressing "missing dowels." One user cautioned that, in exchanging turbines, the "new" rotor may not have had certain necessary or desired procedures done to it.

The subject of the exhaust section closed out this session. A new TIL for exhaust TCs "essentially says inspect, pull exhaust casing, and replace the seals," and he asked how other users are responding to it. An audience member responded that you need to inspect the sleeves from the inside, and if one is missing, replace it.

One user reported he needed "both fans to cool off the back end." Another mentioned air leaks around every strut, although the flex seals are in good shape. They check the C-channel with a borescope.

A user cautioned that welding up the inner skin is bad practice, seal welding the split line "is the worst thing you can do" because every time you weld 347 stainless, you use up material in that area. Another states that his site is replacing the OEM "robust exhaust" in the fall because "it is always cracking."

Rotors wrap it up

The final user-only session, with one extended preso by a large fleet owner/operator, addressed rotor life assessment (RLA) and life extension (RLE). Goal for this overseas user is to determine if rotors can operate reliably beyond 144,000 factored fired hours, perhaps to 170,000 FFH. Reason: All the plants operate under PPAs (power purchase agreements) committed to between 160-175K FFHs.

This user operates 18 7FA.03s, 10 7FA.04s, and 14 9FA.03s. The presenter said that all of these units will require RLE over the next two to eight years. The first 7FA RLE was performed in 2015. If you think dealing with the OEM and third parties state-side is difficult, imagine being located where there is only one OEM shop in the region, and the OEM "has no presence."

The meat of the preso was an assessment methodology that included (1) a number of potential failure modes, or risk factors, ranked on the basis of severity, detectability, and probability of occurrence; (2) a mechanical degradation analysis of a similar rotor in another country with a similar operating profile— baseload, low starts—that had run over 150K FFH; and (3) a metallurgical analysis of a spare 9FA turbine spool operated at a higher starts level.

Regarding (2), no abnormal indications were found nor evidence of carbide "necklacing" at the grain boundaries. Results of the analysis of the spare turbine spool were expected in 3Q/2022.

The session concluded with a wrap-up of the 7F top issues, and an overarching comment by the session leader: "We're all in the same bind – there's not enough wheels in the marketplace." Other audience and session leader comments worth reflecting on:

- There are insurance implications if your turbine rotor operates beyond 144K FFH.
- If the OEM condemns your rotor, so does the insurer.
- We had a rotor that made it to 152K FFH.
- Is the OEM even motivated to go beyond 144K FFH or 5000 starts?
- The compressor rotor has no life limit.
- What about the quality of the forgings built during the GT bubble of 1997-2004?

Finally, this last comment probably sums up the sentiment and the mood of the crowd: "Make sure you take the serial numbers down before your rotor goes to the OEM shop—we had someone else's compressor married to our turbine rotor."

Dig deeper

Presentations made at the 2022 7F Users Group meeting by owner/operators (above) and vendors (below) generally are available on the Power Users website. However, access is restricted to those who are registered on the Power Users Forum. To sign up, go to www.powerusers.org, click on "User Forum, Apply" and complete the form provided. It only takes a few minutes.

Vendor presentations

AGT Services

Jaime Clark kicked off the conference's vendor presentations by addressing stator core closeness in gas- and steam-turbine generators. Perhaps to jolt the audience awake, even after breakfast and coffee, Clark noted that there's a "huge uptick" in stator-related problems and later in his remarks quantified and expanded on his assertion: Generator emergent work during outages is up 30% in the industry for hydrogen-cooled units.

The litany of issues Clark addressed should make users quake in their boots until you realize that "the 7F generator fleet is 20-25 years old on average and the life of a stator is 20-25 years by design." One big common phenomenon: The whole core gets longer after thousands of cycles, he explained; as you might suspect, peaking and load-following units are most affected.

Most of the looseness is compression-based, not related to vibration or thermal conditions, and "the problems are at the turbine end, not the collector end."

Owner/operators of the MHI-built 7FH2s (in round numbers, 50 to 60 worldwide) perhaps *should be* quaking in their boots. These units are "losing teeth and failing," Clark said, adding that MHI issues "can be catastrophic" and full stator rewinds are required. TIL-2260, which addresses these issues with MHI units, was revised

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in February 2021 to include findings from root-cause analyses.

Clark reported data on post-2260 repairs for six MHI turbine ends (TE) and TE coolers his shop was involved with, and found that two TEs were missing no iron, one was previously missing iron, and three with AGT repairs had no prior adverse reports or issues. Three of the TE coolers showed 100% looseness at the core outer diameter for the full length of the core, and presence of iron oxide at the inside and outside diameters. These units required belly-band tightening, stator re-wedge, and full core re-torque to 3000 ft-lb.

All GE 7FH2s will show signs of turbine-end iron looseness, Clark stated, and Model 324 units coupled to steam turbines are showing signs of outside space block (OSSB) migration (Fig 1). OSSB can cause a unit to "go to ground," experience a phase fault, and melt iron and copper.

Why the OSSB issues? Clark explained it with three factors: (1) Axially loose core, predominantly on the turbine end, (2) poor bonding of OSSBs to core compression flange, and (3) after startups, the core expands radially and axially, tearing the "relatively thin" OSSB dovetail out at the key bar. On cool down, the core compression flange retracts but leaves the OSSB where it was. This repeats every operating cycle. Eventually, the OSSB cuts through the bottom filler and into the bottom bar groundwall insulation, resulting in a stator ground.

Viewing the photos Clark provides in his slides, along with additional material on repair strategies and causes of damage, will enhance your understanding of these issues.

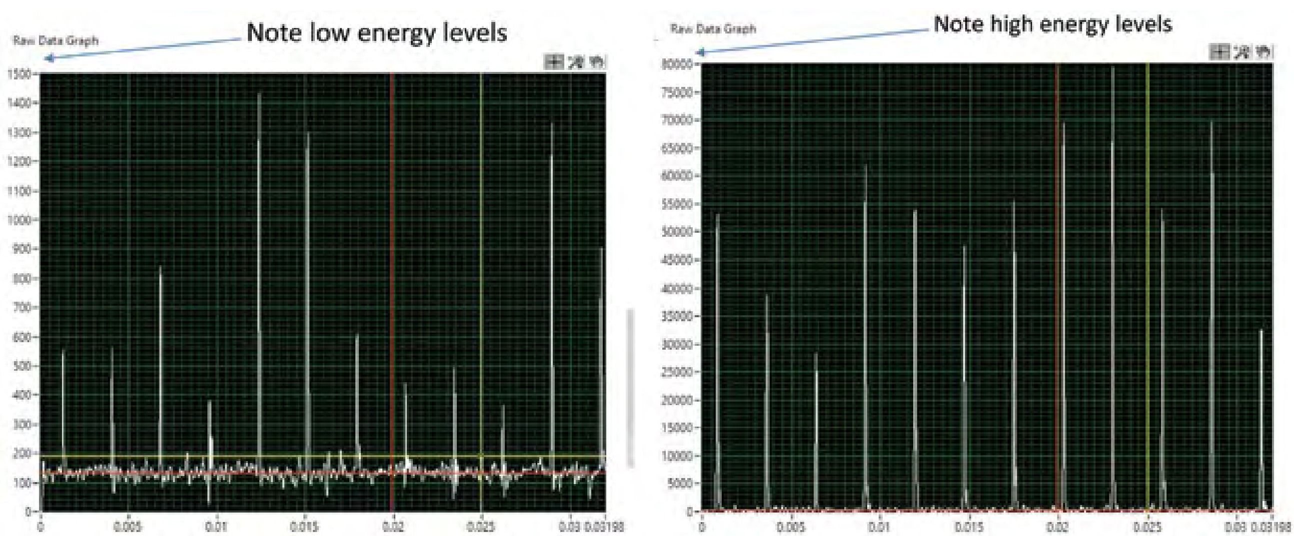
1. OSSB in Model 7FH2 and 324 generators can cause a unit to "go to ground," experience a phase fault, and melt copper and iron

Cutsforth

Jay Brennan and Chris Delavega described the company's Insight CM condition monitoring software, which emerged from a broad program at a major utility to develop new predictive technologies. Insight CM combines offline and online data on electromagnetic interference (EMI), electromagnetic signature analysis (EMSA), rotor flux, brush condition, shaft grounding (voltage and current readings), motor-current signature analysis, vibration, partial discharge, and thermal conditions to detect potential issues and avert failures.

Different generators experience different issues as they age, even the same model with the same commercial operating date (COD), they said, evidenced in a case study (Fig 2) in which one generator showed micro-voltages under 10,000 while a sister unit showed "an order of magnitude difference." The latter experienced a failure of slip-ring insulation.

In responding to questions, the pair noted that Insight CM collaborates with other data monitoring systems to include, for example, seasonal operating characteristics. Also, information from the Insight CM may lead a subject matter expert (SME) to investigate turbine mechanisms in seeking root causes of issues. The system does require a dedicated server.



2. EMI levels differ by almost two orders of magnitude for same generator model with same COD. Rule of thumb: If below 1000 microVolts, no problem; if between 1000 and 10,000, address in long-term planning; if above 10,000, address in short-term planning

National Electric Coil

Veteran user group expert Howard Moody offered pointers on how to effectively rewind high-voltage generator stators, and referenced TILs 1211 (Hitachi units) and 2260 (MHI units). In most cases the stator core is reused, he said, the exception being MHI's.

Issues addressed included looseness, dusting, greasing, and end-winding components of consolidated dry ties; endwinding vibration and resonance, in particular distinguishing between the two; and cracking of rigid phase leads at or near connections. He stressed the importance of staying out of the resonant exclusion zones when making repairs or replacements, 115-135 Hz for 60-Hz machines, 95-115 Hz for 50-Hz machines. NEC offers upgraded and redesigned components for stator rewinds.

Important details on each of these issues, repair mitigation strategies, are available in Moody's detailed slides.

Towards the end of his presentation, Moody dwelled on "tangent delta testing" for dielectric dissipation factor on new stator bars and coils as a means of "identifying insulation issues." Tan delta is an excellent differentiator of insulation quality, he claimed, and applies to "most insulation systems/processes applicable to 7F turbines," although he also mentioned that including it in specs has met resistance in the industry.

A recent study revealed single-coil VPI (vacuum pressure impregnation) insulation systems for 7FH2 generators exhibited the best overall performance based on the Tan Delta Test and over 19,000 records. Other insulation systems/processes evaluated in the study were: Resin-rich vacuum treatment under hydrostatic pressure (RH), resin-rich pressed and cured in heated plate molds (RR), and global vacuum pressure impregnation (GVPI).

If tan delta is of interest, get hold of Standard 60034-27-3 issued by the IEC (International Electrical Commission), hailed by Moody as "aggressive" on beneficial use of the method. The IEEE, he noted, is "getting there" but has not yet issued its own standard.

Gas Path Solutions

Michael Busack began by saying, "the next few years will be a battle of capital money versus work required in the industry," but the implicit message perhaps was for users not to neglect more mundane components like those for the inlet filter house—replacement hoods, moisture separators (Fig 3), filters, flow meters, doors, and other hardware, plus evaporative-cooling

3. Moisture separator and other components for the inlet filter house, should not be neglected as gas-turbine plants approach the end of their design lives. Z bars, spacer, and hardware rust over time and begin to come apart media, which tends to "be ignored by plants."

Filter hoods and frames are "the first things to fail" in the housing; Busack had several slides showing proper removal and replacement/installation of these key components. He also cautioned those who have upgraded the capability of their GTs that the filter grid can take only so much pressure before the tubesheet and support grids begin to deflect. Some dot 05 upgrades also require an additional air-filter module, he added.

Gas Path's main business had been exhaust diffusers for 7Fs, but, in addition to filter housings, Busack listed inlet plenum expansion joint belts and inlet trash screens as other areas they can address for users.

Arnold Group

Norman Gagnon and Pierre Ansmann reviewed details of the company's steam turbine warming and insulation systems which, among many other things, "can hold the turbine above the alarm setpoint temperature for 4.5 days or a 100-hour shutdown." This keeps the unit ready for a warm start (see "Warming system, advanced insulation increase operating flexibility, reduce asset stress, cut costs," CCJ No. 72 (2022), p 88).

While most of the technical details are probably familiar to many user-conference attendees and best understood by first-timers through the pictorial offered in the slides, one piece of "news" offered by the duo is that Arnold is seeking beta sites to test its new HRSG drum warming technology.

Other bullet points of note:

- Among the many advantages of warming systems (Fig 4), include "babying" of aging turbines affected by bowing and/or vibration issues.
- While Arnold has active partnerships with several OEMs, the company "is tight" with GE; all H-class shell warming systems are supplied by Arnold.
- Removing and reinstalling the heating panels does not add to outage critical-path time because they are held on by only a few bolts and configured for easy removal and reinstall.
- The system does require its own electrical power distribution cabinet equipped with AC cooling, although the PLCs can be "built into" the plant control systems.
- Each heating panel has two cables for 100%, or duplex, redundancy.
- More than five dozen warming systems have been installed on gas and steam turbines over the last five years.

MD&A

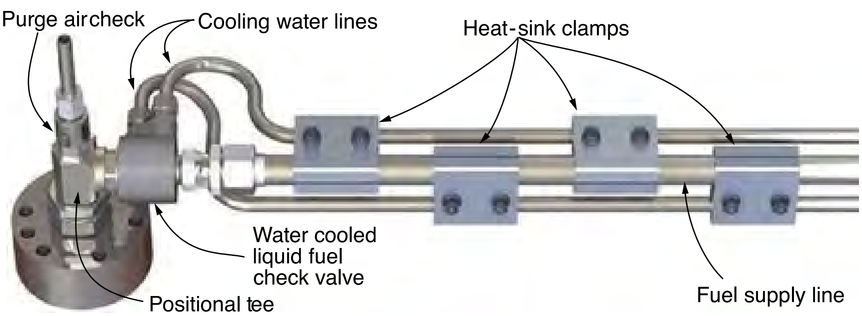
James Joyce kicked off the Tuesday morning vendor presentations, addressing three topics important to owner/operators of 7FH2 generators:

4. Siemens steam turbine is fully equipped with electrical-based warming system and advanced insulation to dramatically reduce combined-cycle startup time

Spring migration, collector changeout, and flex link systems.

All styles of 7FH2s—Gen 1, Gen 2, Gen 3, and 324s—are affected by amortisseur spring axial movement under the body wedges of the generator rotor (addressed in TIL 2106), which can cause blockage of cooling air passages. If a whole row moves, Joyce added, it can halt cooling to *all* the rows. MD&A has a patented corrective repair, described as the insertion of a "top hat" which locks all the slots together so they can't move, that can be done "with relative ease."

5. Flex links are being stocked by several vendors; universal size at left can be machined to fit different models and configurations, then holes are drilled for installation (right)



6. Third-generation fuel-system improvement protects against coking of liquid fuel. JASC's ZEE system allows operational testing of the liquid fuel system without burning any oil

Joyce then moved on to a case study of an onsite repair of a collector ring completely destroyed (without affecting field windings) by flashover induced by carbon buildup. The old deformed rings were removed, and replaced with new ones fabricated in the shop, keeping the bore copper sleeve intact. Users should visually inspect brushes for carbon buildup and remove it if found, then change the polarity.

TIL 2106 also recommends visual inspection for cracking in flex-link connections (Fig 5) during an outage. There's no standard borescope inspection technique for this, especially the bolt threads. MD&A (and others) stock pre-2014 and post-2014 (following an OEM mod) "universal-sized" flex links with "standard stainless-steel bolting." Really old units may have to mitigate asbestos in the conforming putty. Electrical testing should be performed pre- and post-replacement, and users are encouraged to "change polarity, swapping wire leads, once every minor outage."

JASC Controls

Schuyler McElrath described his company's new, patent pending, Zero Emissions Equipment (ZEE) for achieving dual-fuel reliability, in other words operational testing of the liquid fuel system (LFS) without burning any fuel. ap4 is JASC's partner on the technology, essentially a data acquisition, control, and flow simulation system along with a few new fluid handling components.

Water-cooled three-way purge valves (Fig 6), which combine functions of liquid fuel movement and purge air supply, are part of the package. JASC has been manufacturing and supplying these valves for years, so there's nothing new or dramatic in the hardware.

Both firms are seeking a site for a demo. Sites in Texas and the Northeast are prime candidates because regulators there are urging a move back to dual-fuel capability for reliability when gas supply is choked off because of weather or other factors.

Unfortunately, noted McElrath, 7F turbines have unique system problems in the LFS, such as:

- The fuel stop valve does not seal in the reverse direction.
- Carbonization occurs when stagnant fuel is trapped in pipes that can reach 550F inside the casing, changing the fuel's viscosity.
- The LFS deteriorates over time from water entrainment and corrosion.
- Fuel filters get damaged from leaking components.
- Users experience excessive fuel flow systems faults.

Water cooling these valves solves the coking/carbonization problem, said McElrath.

Koenig Engineering

Tim Connor essentially gave his audience a list of 10 maintenance items users should be aware of for the 900+ 7F aging gearboxes and turning-gear systems out there, over 90% of which are more than 20 years old. The list, and the percentage of units affected, included:

- Reducer output shaft lip seals, 100%.
- Hardened or cracked primary lip seals, 100%.
- Shaft grooves at lip-seal locations, 100%.
- Output coupling damage, 95%.

7. Doosan Turbomachinery Services has capabilities that few others can offer. Examples include D11 drop-in replacement at left, rotor straightening at right

8. Electric gas valves offer significant advantages over hydraulically actuated valves, ranging from basic maintenance to environmental and safety

Clutch output-shaft bearing wear, 90%.
- Clutch output-shaft grooves, 33%.
- Damaged clutch input components, 33%.

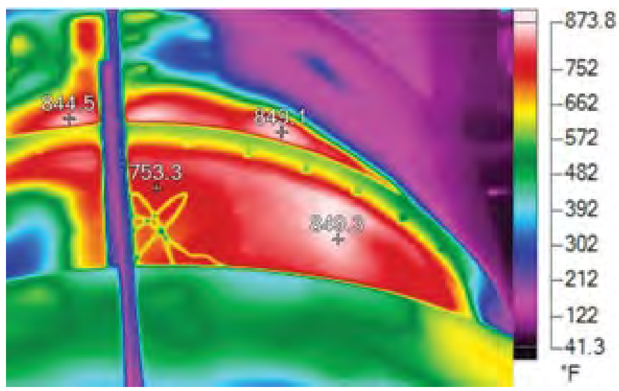
Doosan Turbomachinery Services

Alex Ford and Jacob French, representing the rebranded Doosan Enerbility, first gave an overview of the company's LaPorte (Tex) repair and overhaul facility, then proceeded to outline in detail the parts and services they can provide for 7F combustion-system inspections (CI), hot-gas-path (HGP) inspections, major inspections, and steam-turbine support.

Much of the presentation reviewed what HGPs, CIs, and majors require and when (in terms of total starts and hours), what they look for during inspections, and what typically they find – information likely well known to 7F user conference veterans, but perhaps useful to the 40+% first timers at this meeting. Check out the slides if you are in the latter category.

Doosan suggested here that users should keep "at least one spare gas-turbine rotor for your 7F fleet, as well as spare bearings and seals." For steamers, the company offers a "full D11 drop-in solution with modern valve designs" (Fig 7) and other up-to-date components, many of which are also available through Doosan's "Dart Parts" program.

Generally, GT services are available through the dot 04 model, although during the Q&A, the presenters did say they were "in the early stages of dot 04 bucket parts and service. An ominous note on the worldwide supply chain: Compressor through-bolts are available but it could take a year to deliver them to sites, even as the presenters recommended having at least two sets on hand.



9. Temperatures of outer duct surfaces between the gas turbine and HRSG, as indicated by this thermographic scan, can range from typical ambient (40F to 80F, for example) to 800F in areas with obvious and severe internal plate liner damage

Turbine Controls & Excitation Group

TC&E, part of ap4, connected plant performance to instrumentation and valve issues, then urged listeners to conduct regular plant performance audits and establish a tracking system, keep instruments properly calibrated, and consider replacing hydraulic gas valves with electric models (Fig 8). The meme REAL, or reliability, efficiency/emissions, affordability, and longevity, was flashed several times to reinforce the message.

7F global fleet data suggest that 40% of the reported reliability issues could have been avoided with valve and instrument upgrades. I&C equipment failure events cause up to a week of downtime, up to $100,000/hr in lost revenue, and $10-50k of indirect costs per event. Global fleet data also suggest that moving to electric gas valves can extend maintenance intervals to 96,000 hours and reduce the risk of turbine trips.

The advantages of the GE-approved Parker Abex Jet-pipe servo valve, offered by TC&E for gas control, stop ratio control, and steam-turbine servo applications, were described to close out the presentation. Compared to the current OEM supplied valve, the Abex has a larger internal orifice size, reducing risk of plugging; larger second-stage spool diameter and surface area to keep it moving properly even if varnish builds up; and service life of five to six years compared to the 18-24 months of service life typical of the OEM's valve.

I.A.F.D. Service Group

While IAFD offers engineering solutions to many plant components, material here was limited to liner plates (ducting between GT and HRSG and HRSG casing) and HRSG inspections. But first, the answers to a few trivia questions posed in the slides:

- A GE 7FA + HRSG has between 22,000 and 27,000 ft² of liner-plate surface area.
- Almost 800 "hardware setups" hold the round duct liner (between the GT and HRSG) to the casing.

The graphics-rich presentation includes slides showing damaged internal liner areas, examples of nonuniform thermography (Fig 9) used to inspect for damage online, external discoloration revealing hot spots, broken internal retainers, and repair/upgrade photos. Upgrade options include increase quantity of studs for retention, uniform patterns for even distribution, compartmenting insulation on round ductwork, and over-insulating cavity space.

Two slides in the HRSG engineering section, also replete with photos, amount to a punch list of items to consider for both offline and online HRSG inspections.

Sulzer

Billy Bottera, superintendent for gas turbine rotors, divided his presentation thusly:

- A case study of how the Sulzer shop in La Porte, Tex, helped a customer get through an emergency rotor repair/upgrade situation (Fig 10).
- A detailed review of Sulzer's shop and in-service capabilities, including a laundry list of repair techniques; coatings; rotor life inspections, assessments, and NDE; and

10. Simple-cycle rotor from a must-run 7FA arrived at Sulzer's shop 17 days after the company was first alerted to the outage event and only eight days after it was awarded the contract for repair the shop's large rotor lifting and machining equipment.

The case study involved one of three simple-cycle 7FA+e must-run grid-support units at the customer site which was forced out of service and, upon borescope inspection, was found to have severe damage in compressor rows 14 through the EGV. Interestingly, the units are under an LTSA but the vendor could not deliver within the site's time constraints of six weeks or less back in service.

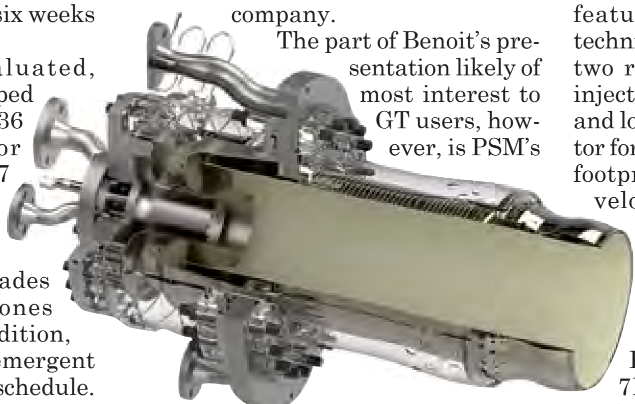
Sulzer inspected, evaluated, repaired, balanced, and prepped the unit for return within 36 days from when the rotor arrived at the shop. R17 hybrid design compressor blade/spacers were replaced with full robust root manufactured blades. R14-16 blades also were replaced with ones having robust roots. In addition, Sulzer was able to address emergent findings while remaining on schedule. All applicable TIL inspections were also accomplished—such as suitable contour, peen, and polish of R1 and R2 cooling slots.

PSM, a Hanwha company

Jeff Benoit, VP of clean energy solutions, laid out his company's long-term strategy for reaching carbon-free gas-turbine combustion through progressively higher fractions of H_2 firing. Parent Hanwha's portfolio includes solar energy, electric energy storage, and site energy services, while PSM/Thomassen's expertise lies in gas-turbine design and services.

Expansion into H_2 production, storage, and distribution represents future value-chain opportunity for the company.

The part of Benoit's presentation likely of most interest to GT users, however, is PSM's "HyFlex" high hydrogen combustion platforms, one of which is the company's well-known FlameSheet™ combustion technology (Fig 11), which today is already capable of 60% H_2 (by volume) firing while, says Benoit, maintaining less than 9 ppm NO_x and CO, turndowns to 30% load, and 32,000-hr/1250 start maintenance intervals.



11. FlameSheet technology, in commercial operation on 14 units at the time of the 2022 7F Users Group meeting, serves as the anchor for PSM's development strategy towards carbon-free gas-turbine operations; it is adaptable to multiple GT design platforms

Prototyped in 2005, FlameSheet features novel flame stabilization techniques—such as four fuel circuits, two recirculation zones, trailing air injection to improve fuel/air mixing, and low-differential-pressure combustor for improved heat rate and smaller footprint. Also high pre-mixer exit velocities for tolerance of highly reactive fuels (such as H_2), and aerodynamic trapped vortex to ensure wide flame stability margin.

Latest projects include a FlameSheet-equipped Frame 7F firing up to 40% H_2, scheduled for commissioning at the end of 2022, and a Frame 7E FlameSheet machine burning 50% H_2 in 2023 for Kowepo, one of Korea's top five power generation companies. PSM is also participating in the DOE's Energy "Earthshot" program to drastically reduce the cost of H_2 production and firing.

Getting started, 1991

The contributions of users groups to the commercial success of gas turbines cannot be overstated. These machines are relative newcomers to the power generation sector of the electric power industry and without a proactive and collaborative user community, the development of today's large, efficient, reliable, low-emissions gas turbines certainly would have taken longer than it has.

It is even conceivable that a utility industry dominated by large steam plants might never have embraced gas turbines as an alternative to coal-fired and nuclear central stations had the dedicated user "pioneers" not been so successful in helping the OEMs correct early design deficiencies.

Historical perspective. The first industrial gas turbine commissioned for electric generation, rated 3.5 MW, began operating at Oklahoma Gas & Electric Co's Belle Isle Station in June 1949—seven decades after generators driven by steam engines first produced electric power at Thomas Edison's Pearl Street Station in New York City.

For the next 15 years or so, gas turbines were pretty much viewed as a novelty by regulated electric utilities, which produced about 90% of the nation's electricity until deregulation of generation began in the 1990s. Prevailing attitudes on the value of gas turbines in an integrated electric system began to change following the Northeast Blackout in November 1965 when they helped boot-strap the grid back into operation. Until that time, gas turbines primarily were associated with non-critical peak-shaving applications.

One result of the blackout was a run on black-start units—mostly General Electric Frame 5s and Pratt & Whitney FT4s. That first market bubble lasted into the early 1970s, raising the profile of gas turbines and stimulating the development of larger machines. The design effort on GE's Frame 7 series of engines began about a year after the blackout and the first unit was installed as the 1970s dawned. The MS7001A had a 1650F firing temperature and was rated 47 MW—about three times the output of the latest-model Frame 5s offered at that time.

Design development and market acceptance of the Frame 7 product line proceeded rapidly. The nominal 75-MW 7E was introduced with a firing temperature of 1985F only 10 years later (1980). An even bigger step was taken in the ensuing decade. The first F-class machine, rated 147 MW and having a firing temperature of 2300F, shipped to Virginia Electric & Power Co's (Vepco) Chesterfield Power Station in 1988; christened Unit 7, it was declared commercial in June 1990. Sister unit Chesterfield 8 began commercial operation in 1992 (May), the year the 159-MW 7FA was introduced with a 2350F firing temperature. Some early design improvements in the MS7001F that followed are summarized in the table.

When the 7F Users Group conducted its first meeting in November 1991, Chesterfield 7 was the only F-class machine running in the US. It had 9000 hours of operating experience. Four utilities were represented at that forum in Baltimore: Vepco, Baltimore Gas & Electric Co (BGE), Florida Power & Light Co (FPL), and Potomac Electric Power Co (Pepco). There were 14 attendees.

The meeting began with short reports by the utilities. Each had at least one gas turbine on order, with expected commercial operating dates ranging from June 1992 into the late 1990s (no specific year). Interestingly, all engines would have dual-fuel capability and only two of the nine gas turbines planned would be used in simple-cycle service.

The opening status reports indicated that two of the participating utilities were repowering existing steam plants to form their combined cycles. Also, that two companies were planning to install diverter dampers on their GTs to maximize operating flexibility. The first 7FA going into service would be equipped with dry, low-NO_x combustors because of emissions restrictions where that plant was to be located. Gas turbine controls would be either Mark IV or Mark V; DCS systems were from Westinghouse Electric Corp, Foxboro Co, and Honeywell Inc.

Of considerable interest to attendees was the Vepco report on Chesterfield 7's operating experience. Learning from the experiences of colleagues can save time and money, so this information was of particular value to anyone with a unit on order. For the first meeting that meant everyone in attendance.

Chesterfield 7's performance numbers were positive. For example, the equivalent availability of the prototype engine since COD was 85.79%. Two clarifying points: The unit was "out of the money" for about half of its 3500+ non-operating hours. Importantly, half the hours Chesterfield 7 was out of the money, the fuel-gas compressor was unavailable and the high cost of alternative oil was the reason for it being uneconomic to operate the unit.

The speaker noted, in particular, the unit's run from the beginning of April until the end of October (1991) when Chesterfield 7 was dispatched right behind the nuclear units and ahead of all coal units—including three mine-mouth operations. The message was clear: F-class gas turbines were competitive mainstream generation assets right out of the box.

Compressor fouling and how to deal with it is a subject discussed at most user-group meetings. Vepco engineers reported no load degradation on Chesterfield 7 based on weekly performance tests. The unit was not equipped to perform online water washes and offline washes had been done only three times since COD. Interestingly, one of the utility participants had specified a coated compressor rotor for its gas turbines; the Chesterfield 7 compressor was uncoated.

Specific issues mentioned in the Vepco presentation essentially were of two types:

- Manufacturing and field errors/oversights unrelated to new technology—such as a generator rotor shipped from the factory with shorts in it and metal shavings found in the steam turbine because of an inadequate steam-line blow.
- Challenges presented by the higher gas temperatures and pressures associated with F-class technology and cycling operation, such as loss of turning vanes and cracking of vent piping in the heat-recovery steam generator (HRSG).

Engine vibration on startup and wear and tear on exhaust thermocouples were two more subjects that received meaningful discussion time. In its first year and a half of operation, Chesterfield 7 lost an average of one exhaust t/c daily; the unit has 27 thermocouples.

Over the last three decades the operating paradigm of the combined-cycle fleet has changed dramatically: Engines have gotten larger, firing temperatures hotter, emissions regulations more restrictive. Yesterday's solutions generally are not adequate for today's cycling regimen and higher gas temperatures and flows. Challenges persist and new solutions are necessary. A user group's work is never done.

The maintenance session at the first meeting reflected very orderly utility thinking on overhauls in the days before deregulation and OEM long-term service and parts agreements. It's an interesting contrast to the factors and formulas owners are governed by today. A Vepco participant noted that combustion inspections had been based on a yearly schedule and that was going to change to an 18-month interval because Chesterfield 7 was being dispatched fewer hours than originally thought.

One of the other utilities offered a firm schedule for maintenance outages based on best available information from the OEM. It called for an 8000-hr interval between combustion inspections, 24,000 hours between HGP inspections, and 48,000 hours between majors. The speaker noted that the company had developed a schedule that predicted parts replacements and refurbishments for 30 years. Recent meetings have reflected dramatically different maintenance schedules.

Here's what was the 1991 thinking on combustion inspections: A five-day outage would be sufficient with new spares on hand for immediate replacement. If reconditioning of parts was necessary, extend the outage by two weeks. A typical CI at Chesterfield 7 called for up to eight persons per shift—six working on the combustors, the others handling miscellaneous work items.

Learning on the job. Cracking of nozzle tips at around 4000-5000 hours was one of the early problems at the first Frame 7 plant, thereby preventing Chesterfield 7 from achieving its desired CI interval. One of the first lessons learned was that all fuel nozzles are not created equal. Station personnel did not realize the OEM balanced the entire set of 84 nozzles to optimize machine performance until they swapped out cracked nozzles with new ones and experienced higher-temperature exhaust spreads.

Unit operation. Vepco shared with the group its startup procedure, which took about an hour when the gas turbine was cold: Fire the GT, synchronize at 10 MW, match boiler steam and turbine metal temperatures prior to rolling the steamer. Gas-turbine ramp rate was 8 MW/min.

Transferring from gas to oil at full load was no problem, the representative said. It took about two and a half minutes to complete. However, switching from oil to gas was more difficult and required up to about twice as long for a successful transfer than going from gas to oil. Speaker said the gremlin probably would be found in the regulator in the gas main—possibly the valve was too small or its response time too slow. On a gas-compressor trip, the unit flamed out before the transfer to oil could be completed.

"Comparing notes" is a big benefit of user-group participation. One participant began talking about the two atomizing-air coolers provided with his package for redundancy. Someone else said GE had eliminated the second cooler in their package. Interesting, because there really did not appear to be sufficient operating experience to support such a decision. Why not err on the conservative side so early in the lifetime of F-class units? First participant jumped back into the conversation noting that the OEM had not run separate drains off the coolers and cautioned against linked drains. Ganging of drains is well known for causing major issues on HRSGs.

Thermal shock in steam-turbine bypass lines was recognized as a potential problem at the dawn of F-class units. One utility avoided the possibility of this occurring by maintaining steam flow through the bypass at all times.

Sharing is a big part of the user-group value proposition. Every plant needs procedures—startup, operations, and maintenance. The three utilities that soon would be starting up their first F-class units acknowledged a desire to work collaboratively in the development of procedures not yet available. An action item taken was for

Some milestones in the development of the 7F gas turbine

Original model	New model	Year	Description	Firing temp, F	Pressure ratio
7191F	7F.01	1988	Prototype	2300	13.5
7211F	—	1991	First production model (same as 7191)	—	—
7221FA	7FA.01a	1993	—	2350	15
7231FA+	7FA.02	1996	—	2400	15
7241+e	—		Non-Snowflake	2420	15.5
7241+e	—	2001	Snowflake	—	—
7241+e	7FA.03	2009	Enhanced compressor	—	—
—	7FA.04	2010	Advanced HGP (similar to 7FB)	—	—
—	7FA.05	2012	Advanced compressor (14 stages)	—	—
7251FB	—	2002	—	2500+	18.5

each of these companies to develop a list of procedures available together with a list of those still required and by when.

Then the participating utilities agreed to extend an openness toward helping each other develop construction and startup schedules as well as cost estimates. Finally, a master contact list was developed with names, titles, and phone numbers (email came later) of people at every project with responsibility for scheduling, cost control, procurement, engineering, and general project information.

Staffing and personnel development and training generated significant discussion as you might imagine. It takes years of experience with a new engine model to right-size your staff. Today, 7FA owner/operators may be running their plants with 20 or fewer permanent personnel and would chuckle at the thinking in 1991—before deregulation, as noted earlier.

One of the utilities had six people on a shift for two 1 × 1 combined cycles; another planned to have four per shift (2 × 1 arrangement) and was considering a maintenance staff of 40 to 45. A utility planning two 2 × 1s focused on five operations shifts of four people for each unit and 40 to 45 total staff for the first combined cycle and an additional 15 to 25 when the second unit was completed.

Closely related to the then-and-now staffing comparison is personnel training. During a discussion on that topic one participant noted that his company had a training program for operators that ran 39 months. That was typical for regulated electric utilities back then. At user-group meetings in the deregulated era you often hear considerable angst over the retirement of senior personnel and the lack of suitable candidates to fill open positions.

One reason for the shortage of qualified operators, electricians, instrument techs, mechanics, etc, is that small independent power producers don't have the financial resources or the time—and in some cases, the inclination—it takes to develop personnel qualified to operate and maintain today's high-tech turbines.

As the first 7F Users Group meeting closed, it's reasonable to assume no one in the room could have imagined that three decades later:

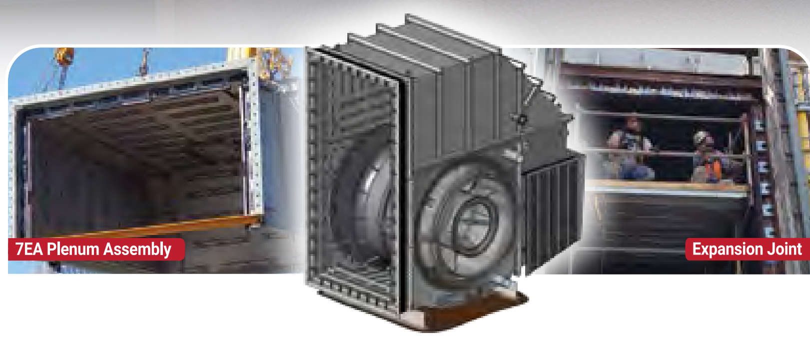
- The organization would still be in existence and that its annual conference and exhibition would have grown to become the world's largest venue for F-class technology and business discussions.
- Three of the four utilities represented at the meeting would no longer be in the business of electric generation under the names they had in 1991.
- Unregulated generating companies, which did not exist in 1991, would control about half of the nation's power-production capability and more than 60% of all gas-turbine-based generation.
- One of the 1991 attendees would participate in the 20th anniversary meeting and two participants would be serving on the steering committees of other gas-turbine user organizations at that time. Continuity of technical leadership is vital to progress. That's service user groups like the 7F provide the electric power industry at no cost.

End note. Only one of the participants in that first 7F meeting is still active in the industry, based on CCJ research. The well-respected Pierre D Boehler, employed by Pepco at the time, is now senior SME (subject matter expert) for gas turbines in NRG Energy's Engineering & Technical Services Group—the result of mergers that absorbed plants and people from GenOn, Mirant, and, of course, Pepco. He provides technical support for a fleet of GE and Siemens Energy units, ranging from aging Frame 7s to late-model F-class engines, on matters concerning maintenance overhauls, operating issues, upgrades, etc. CCJ

Plenum Assemblies and **Diffuser Replacement & Repairs**

Over 75 years industry experience to guide your repair or rebuild project

- Design
- Procurement
- Fabrication
- Project Management
- Installation



Inlet Systems

- *Fabric Inlet Expansion Joints*
- *Acoustical Liner Repairs and Replacement*
- *Inlet Dampers*
- *Inlet Silencer Panels & Ducts*
- *Inlet Bleed Heaters*
- *Inlet Dehumidification Skids*

Air Filtration Systems

- *Full or Partial Filter Grid Replacement and Repair*
- *Replacement Weather Hoods*
- *Filter House Replacement*
- *HEPA Filter Grid Upgrades*

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

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

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

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

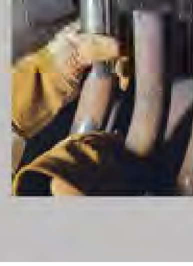
The TTT's self- fit-up and alignment, allows for a faster and more reliable joint alignment. With T91 tube material for example, conventional butt welds require time-consuming fit-up alignment equipment, as T91 material needs to be at a 400 to 450 degrees Fahrenheit pre-heat temperature prior to any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

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

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







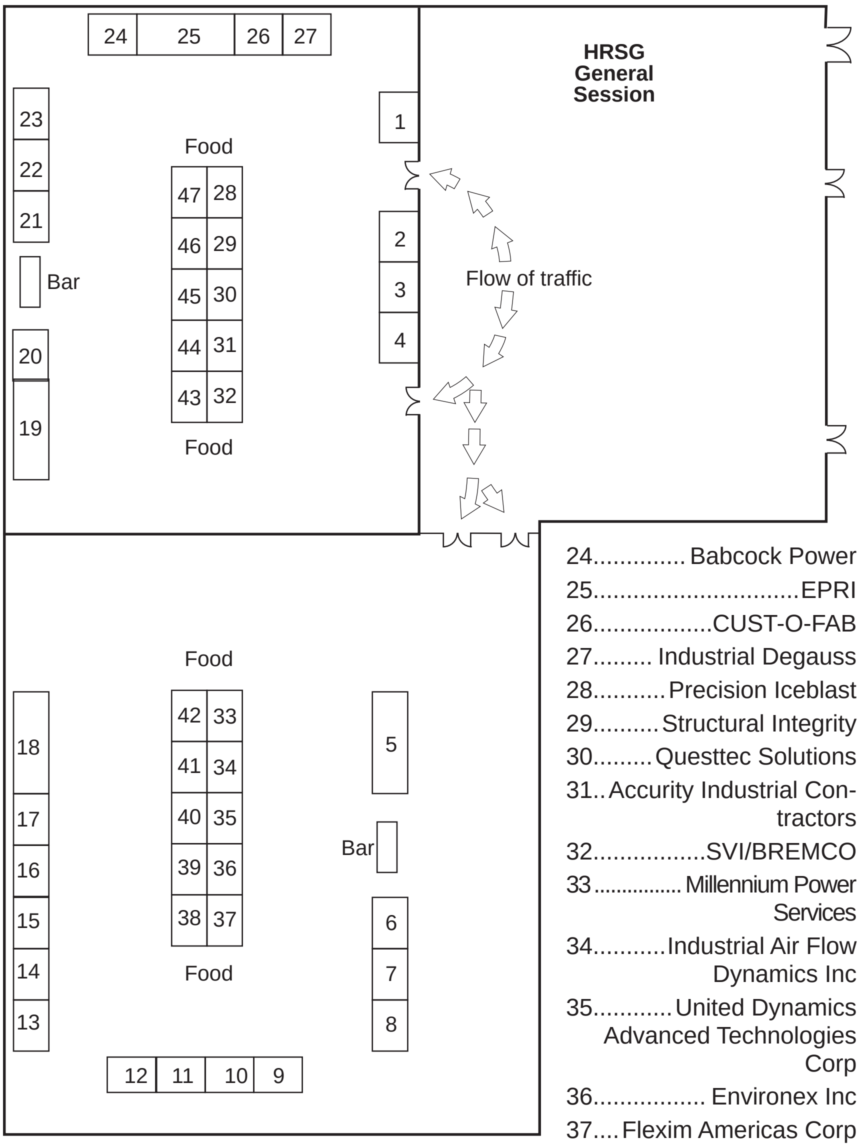
Vendor Fair

Monday, June 12, 5 to 7 p.m.

Tuesday, June 13, 7 to 8, 10 to 10:30 a.m. and noon to 1, 3 to 3:30 and 5 to 7 p.m.

Wednesday, June 14, 7 to 8, 10 to 10:30 a.m. and noon to 1 and 3 to 3:30 p.m.

Grand Ballroom



Exhibitors, alphabetical

Company	Booth
Accurity Industrial Contractors	31
Advanced Valve Solutions USA Inc.	23
ARNOLD Group	19
Babcock & Wilcox Chanute	11
Babcock Power	24
Badger Industries	3
Clark-Reliance LLC	17
Constellation Clearsight	14
Conval Inc.	44
CUST-O-FAB	26
Dekomte de Temple LLC	1
Deltak Inc.	9
EagleBurgmann Industries	47
Environex Inc	36
Environmental Alternatives Inc	12
EPRI	25
Flexim Americas Corp	37
Fucich LLC	40
GE Gas Power	20
Groome Industrial Service Group	21
HYTORC	22
IMI Critical Engineering	39
Industrial Air Flow Dynamics Inc.	34
Industrial Degauss	27
Intertek AIM	13
JDV USA	41
KSB SupremeServ	46
Millennium Power Services	33
MISTRAS Group	7
MOGAS Industries Inc	10
Nooter/Eriksen	4
Power & Industrial Services Corp	2
Precision Iceblast	28
Questtec Solutions	30
SE Energy	6
Structural Integrity	29
SVI/BREMCO	32
TEAM VMS	45
TesTex Inc	38
Thompson Industrial Services	43
TOPS Field Services LLC	8
United Dynamics Advanced Technologies Corp	35
US Cleanblast/Premium Plant Services	42
Viking Vessel Services	5
ZEPCO LLC	18

Exhibitors, booth number

Booth	Company
1	Dekomte de Temple LLC
2	Power & Industrial Services Corp
3	Badger Industries
4	Nooter/Eriksen
5	Viking Vessel Services
6	SE Energy
7	MISTRAS Group
8	TOPS Field Services LLC
9	Deltak Inc
10	MOGAS Industries Inc
11	Babcock & Wilcox Chanute
12	Environmental Alternatives Inc
13	Intertek AIM
14	Constellation Clearsight
17	Clark-Reliance LLC
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19	ARNOLD Group
20	GE Gas Power
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24	Babcock Power
25	EPRI
26	CUST-O-FAB
27	Industrial Degauss
28	Precision Iceblast
29	Structural Integrity
30	Questtec Solutions
31	Accurity Industrial Contractors
32	SVI/BREMCO
33	Millennium Power Services
34	Industrial Air Flow Dynamics Inc
35	United Dynamics Advanced Technologies Corp
36	Environex Inc
37	Flexim Americas Corp
38	TesTex Inc
39	IMI Critical Engineering
40	Fucich LLC
41	JDV USA
42	US Cleanblast/Premium Plant Services
43	Thompson Industrial Services
44	Conval Inc
45	TEAM VMS
46	KSB SupremeServ
47	EagleBurgmann Industries

Register today for the first in-person HRSG Forum in three years

HRSG Forum debuts under the Power Users umbrella, June 12-15, in the Renaissance Atlanta Waverly Hotel & Convention Center. Chairman Bob Anderson, who has moderated the lion's share of power-industry meetings focused on the information needs of HRSG owner/operators for the last 25 years, will be at the front of the room. Although the pandemic kept Anderson off the live stage for the last three years, he continued to serve the user community, broadcasting worldwide via the web on Channel CCJ.

The upcoming meeting and vendor fair will be packed end-to-end with information of incomparable value to users, consultants, and services providers. All three segments of the industry qualify for participation in all sessions.

The long-awaited event begins on Monday, June 12, with two special workshops; a traditional conference program—one reminiscent of past HRSG meetings with Bob Anderson—airs Tuesday and Wednesday. EPRI Day is Thursday, focusing on the research organization's comprehensive work in the fields of HRSGs and high-energy piping.

Here's an overview of the four-day conference:

Day One

The morning workshop, starting at 8 a.m., focuses on water, specifically the importance of film-forming substances (FFS) in the modern world of powerplant operations. Barry Dooley of Structural Integrity (UK), who will be sharing Day One moderator duties with Anderson, will make the introductory presentation and bring attendees up to speed with a backgrounder on FFS, relatively new technology for powerplants in North America. Dooley, a member of CCJ's Editorial Advisory Board, has been sharing his FFS experiences with the periodical's subscribers for the last five years.

Several speakers—users and chemical suppliers—follow Dooley, digging into the details of powerplant experiences both here and in other countries. They are:

- D Hubbard, AEP (retired), "Do you need an FFS? How do you know?"
- B Opsahl, Nalco, and M Coffman, Wise County Power Plant, "Wise County increases asset protection of its HRSG using Powerfilm 10000, a non-amine FFS."
- D Stuart, ChemTreat, "Use of film-forming amines to mitigate corrosion in combined cycles."
- E Zubovic, Veolia, "Impact of film-forming amines on condenser efficiency."
- K Marshall and M Mowbray, Kurita America, and A deBache, Kurita Europe, "Cetamine treatment in an HRSG in Spain leads to energy and water savings through total iron control."

The afternoon workshop, moderated by Jeff Henry of Applied Thermal Coatings, respected worldwide for his knowledge of boilers, materials, welding, and the ASME Code, will speak to the following:

- Tools for supporting the safe, efficient operation of aging high-energy piping.
- Creep damage experienced by operation of elevated temperatures.
- Structure of welds and damage in welds at elevated temperatures.
- Characterizing indications found in welds and their size and orientation.
- Understanding repair objectives.
- Proper excavation of damage.
- What the industry-wide loss of expertise means for plant owners and operators.

Before packing your bags for the HRSG Forum meeting in Atlanta, be sure to do your homework. Absent a textbook, thumb through back copies of CCJ to jog your memory. The more you know, the better organized you are, more value you'll extract from the meeting. There aren't many opportunities to access directly the knowledge retained by Anderson, Dooley, and Henry, as well as other experts on the program—without later receiving an invoice.

A networking reception from 5 to 7 p.m. closes the Monday program. Vendor booths are open during the reception.

Day Two

- Tucker Yord, SVI/Bremco, "HRSG steam-vent silencer safety inspections."
- Marshall Hicks, Viking Vessel/Tuff Tube Transition, "Innovative tube repair technology."
- Denis Funk, Flexim, "Ultrasonic detection of spray-water leakage."
- Kurt Bedar, NDE/PRD Consulting, "HRSG safety/relief valve maintenance."
- Bernard Frezza, Athens Generating (NAES), "Valve monitoring/maintenance program."
- Eugene Eagle, Dukc Energy, "HRSG damage monitoring system."

A vendor fair from 5 to 7 p.m. completes the Tuesday program.

Day Three

- Barry Dooley, Structural Integrity, "Update and stats on HRSG cycle-chemistry control and FAC."
- Mark Steckman, UDA Technologies, "NDE and inspections for the aging HRSG fleet."
- Ghazi Al Shammari, Saudi Electric, "HRSG tube-failure analysis at the Qurayyah combined-cycle powerplant."
- Yogesh Patel, TECO, "Replacing HP evaporators."
- Jacob Boyd, St. Charles Energy Center (CAMS), "Wireless monitoring system for high-energy piping."

No evening activities are planned.

Day Four

Learn from the details shared by EPRI from its HRSG and piping program—including the following:

- Industry challenges, in particular the loss of expertise and what this means to plant owners, operators.
- Recent activities with high-temperature components.
- Safety alert: State of knowledge and screening methodology for header endcaps.
- Mitigating damage related to attemperators/desuperheaters.
- Recent activities with low-temperature components.

Meeting adjourns at 4 p.m.

Global organizations supporting HRSG Forum

ABHUG 2023

2022 Conference Report

By Steven C Stultz, Consulting Editor

The Australasian Boiler and HRSG Users Group will conduct its 2023 meeting in Brisbane in November. Dates, venue, and other details will be available at www.ccj-online.com as they become available.

The Australasian Boiler and HRSG Users Group (ABHUG) held its 2022 conference last November, in Brisbane, Australia. Participants joined from Australia, Germany, New Zealand, Singapore, UK, and US. There were 24 technical presentations and a workshop on film-forming substances. Selected highlights follow.

We are not alone

A unique element of all associated HRSG conferences (ABHUG, European HRSG, and the US HRSG Forum) is hearing and discussing the latest trends in thermal-transient and cycle-chemistry issues facing all HRSG owners and operators worldwide.

Conference Co-Chairman Anderson (see Steering Committee box) presented a summary of thermal-transient survey assessment results conducted worldwide. This appraisal now includes 64 combined-cycle plants surveyed from 2009 through 2022, tracking 31 key operational and equipment issues that are within owner/operator control.

One very important concern is that only six of those plants has a formal boiler-tube-failure root-cause program in place. A proper program includes tube-sample removal to define failure mechanisms, complete determination of root cause, and upper management agreement with the time and expense involved to remove the failure sample. Industry-wide use of such a program could easily improve.

That said, some surveyed areas are showing progress. For example, routine attemperator hardware inspection has increased, although it remains low at only 12% of the plants. Also improving are stable operation of attemperators and some areas of plant control system monitoring.

The most important takeaway, explained Anderson, is that leaking attemperator spray-water valves continue to cause more steam pipe and HPSH/RH tube failures than any other issue surveyed. That's too bad because it's a relatively easy thing to detect and repair. The major culprit is a plant's use of Master control valve/Martyr block valve logic. Just reversing this logic—and of course repairing already damaged valves—will prevent or delay repeated leak-by.

Also, during the meeting, Co-Chairman Dooley offered an update on cycle-chemistry control where he reviewed a list of repeat cycle-chemistry situations found in more than 260 plants worldwide. Such common situations, which can include corrosion-product transport, air in-leakage, low levels of alarmed instrumentation, and lack of proper shutdown protection, lead to plant damage.

These updates from a global perspective, becoming hallmarks of the associated HRSG events, tell owner/operators they are not alone in their plant challenges. The interactive conferences are ideal for sharing details and discussing them with other plant users, equipment and service providers, and industry consultants.

Anderson and Dooley continue to collect and analyze these statistics and trends.

Steering committee

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

David Addision, *Thermal Chemistry,* New Zealand*
Matthew Sands, *CleanCo*, Queensland**
Russell Coade, *HRL Technology Group,* Victoria*
Michael Drew, *Australian Nuclear Science & Technology Organisation (ANSTO), NSW**
Armand du Randt, *Genesis Energy,* New Zealand*
Stuart Mann, *AGL*, Victoria**
Keith Newman, *Synergy,* Western Australia**
Charles Thomas, *Quest Integrity,* New Zealand**

* Consultant ** Energy provider

Darling Downs

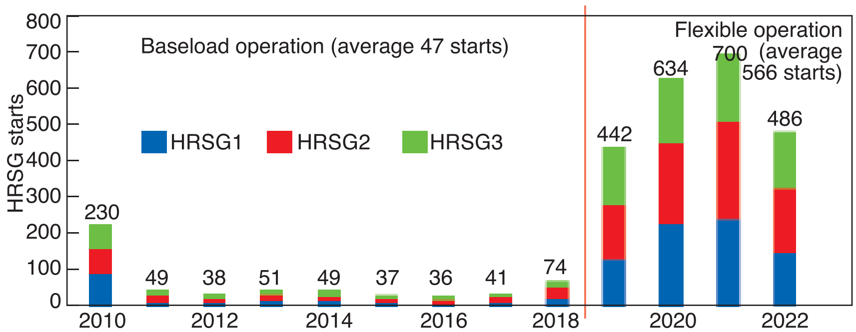
The Darling Downs Power Station in Dalby, Queensland, is a 3 × 1 coal-seam-gas-fired 630-MW combined cycle with GE 9E gas turbines, a two-stage GE 270-MW steam turbine, and air-cooled condenser—all commissioned in 2010. Origin Energy's Ashwin Shinde discussed the past four years of movement into flexible operations, specifically plant alterations and changes to both operations and maintenance.

The three horizontal-flow, dual-pressure HRSGs (Fig 1) were supplied by NEM, Netherlands. Water chemistry is ammonia-based AVT(O).

Darling Downs was originally designed for baseload operation. By 2018, it had to begin adjusting to flexible operation (Fig 2). Average annual starts have moved from 47 in early years to 566 since 2019. Annual total-plant running hours in baseload approached 20,000. In flexible operation, the annual average reduced significantly to 11,365 (Fig 3). Startups and downtime therefore became major operating and equipment concerns.

1. Darling Downs Power Station, a 630-MW, 3 × 1 coal-seam-gas-fired combined cycle, is powered by three Frame 9E gas turbines

2. The dramatic change in baseload dispatch that occurred during the 2014 to 2018 timeframe forced Darling Downs to embrace a transition to flexible operation



3. HRSG starts illustrate how dramatically plant operations changed after 2018

This led to some physical plant changes.

The main steam control valves were modified to avoid stop-valve stem erosion. HP and LP stop-valve actuation was added in 2020 to retain heat in the HRSGs following shutdowns. Also in 2020, the chemistry control room was upgraded to more accurately monitor cycle chemistry.

The next year, HP-bypass warming-valve actuation was added along with thermocouples to closely monitor main-steam pipework temperatures.

Controls and procedures also began to change.

Sky-vent valve operation was modified to improve pressure and temperature control, and to prevent cold steam from entering hot pipework. Startup drum control was used to avoid oscillations and swelling. Superheater drain and drip-leg valve opening times and durations were changed to improve condensate evacuation. Attemperator operating philosophy was modified to control steam-to-turbine temperature matching, and ramp rates were reduced and more carefully controlled.

Minimum warmup load was reduced from 20 to 10 MW to improve HRSG warmup control. For the steam turbine, the original (OEM) temperature matching program was replaced with a lower-inlet-pressure control setpoint and higher inlet-steam-temperature roll permissive.

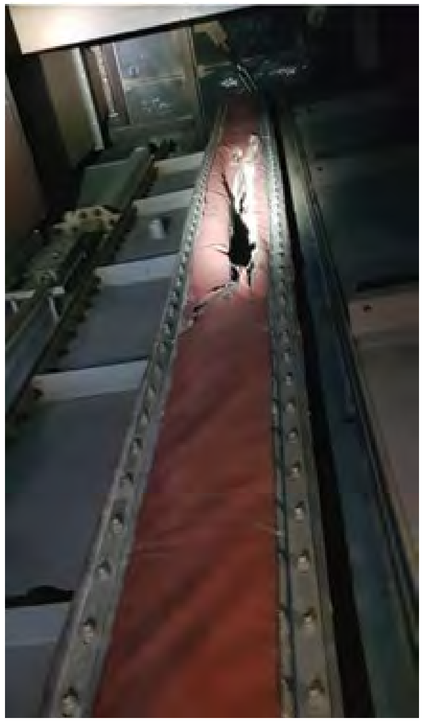
A control-loop design change was needed to improve duct-burner response to the automatic generation-control setpoint.

The main-to-auxiliary steam supply setpoint was reduced to allow for continuous operation of the auxiliary boiler and maintain vacuum during shutdown.

Maintenance schedule changes also were implemented, and a detailed risk-based inspection (RBI) program was launched—including cycle chemistry reviews.

Shinde then reviewed component failures that have occurred during the past four years of flexible operation:

- HRSG2 LP economizer drain leak.
- HRSG1 LP economizer upper header leak.
- HRSG2 inlet-duct expansion-joint failure (Fig 4).
- HRSG1 and 2 LP economizer differential-pressure-gauge impulse line sheared.



4. Inlet-duct expansion-joint failure in HRSG2

Diamantina

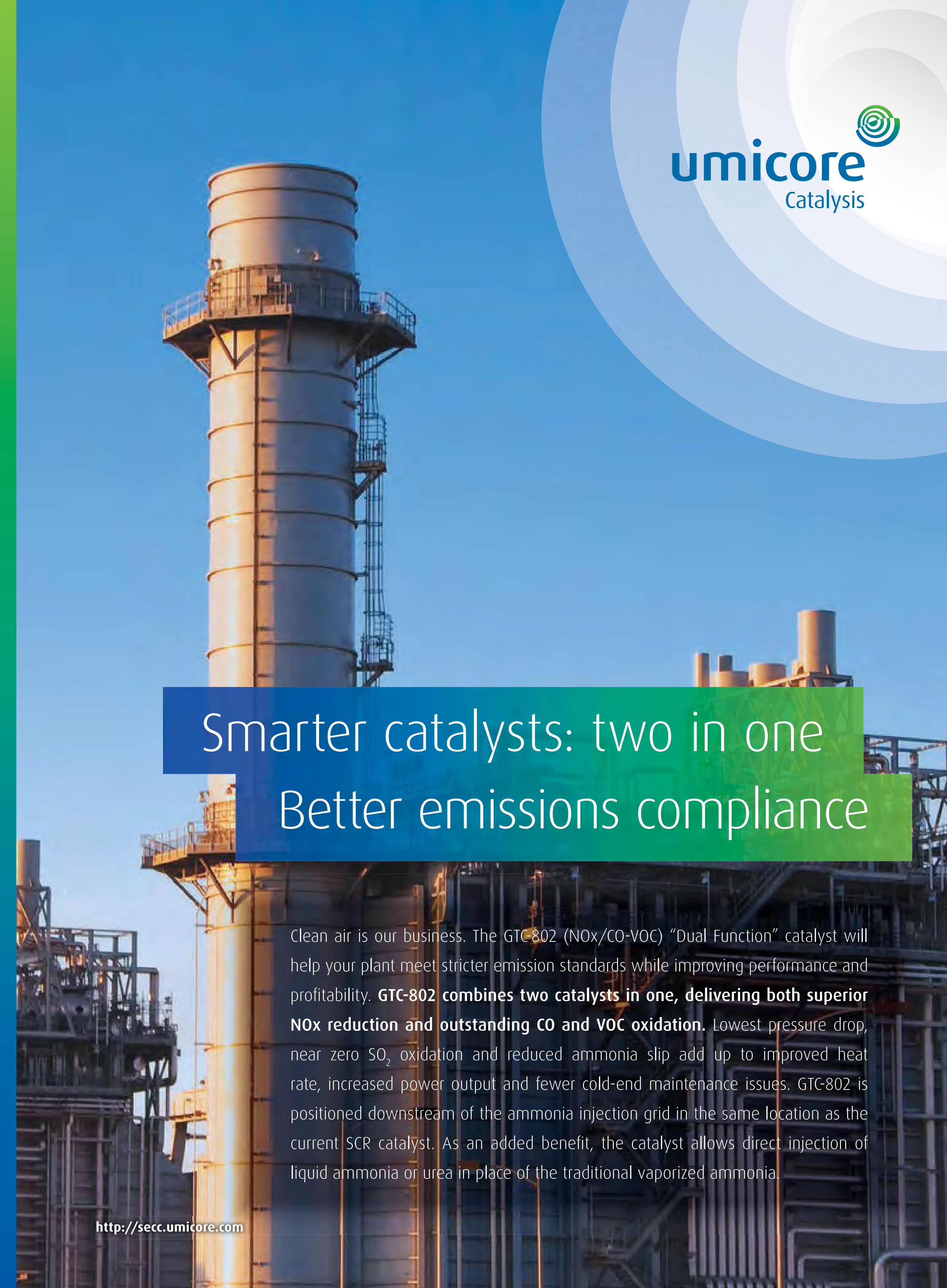
APA Group's Diamantina Power Station is a 230-MW combined-cycle site on a remote, isolated grid serving the mining industry, in Mount Isa, Queensland. The plant is operated in two 2 × 1 blocks commissioned in 2014 and has not yet achieved maximum output.

HRL Technology Group, represented by Sam Clayton, worked with APA to maximize plant output and improve flexibility, initially developing overall thermodynamic models for a range of operating scenarios.

One key issue has been high HRSG furnace exit temperature and steam-turbine degradation. Supplemental firing has not been used, and the two power blocks have operated in isolation. The two steam turbines, each rated 40 MW, have only reached 36 MW.

Improvement objectives included:

- Maximize steam-turbine output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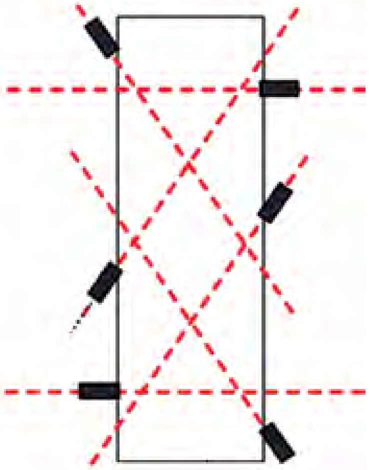
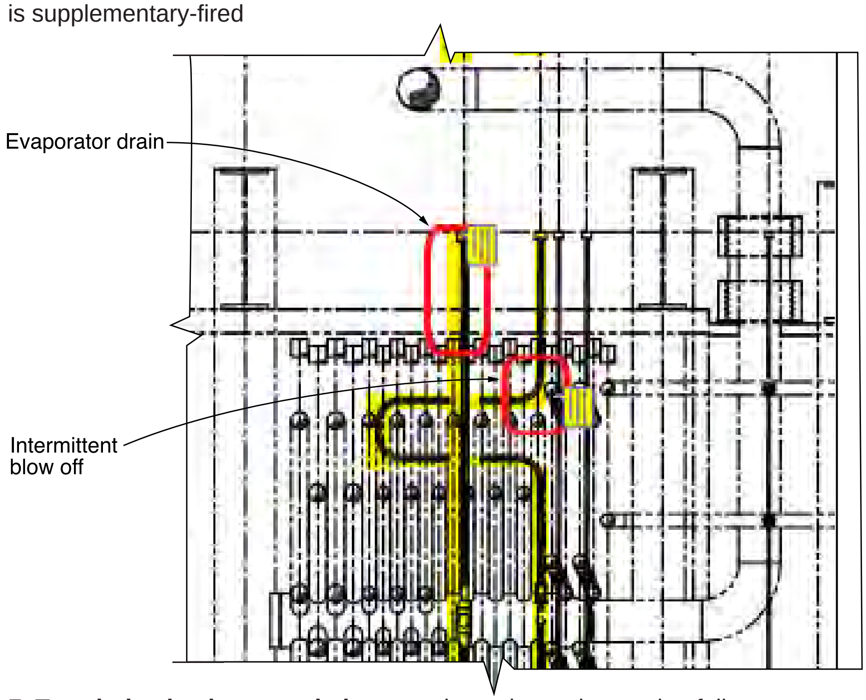
Catalysis
Smarter catalysts: two in one
Better emissions compliance
Clean air is our business. The GTC-802 (NOx/CO-VOC) "Dual Function" catalyst will help your plant meet stricter emission standards while improving performance and profitability. GTC-802 combines two catalysts in one, delivering both superior NOx reduction and outstanding CO and VOC oxidation. Lowest pressure drop, near zero SO2 oxidation and reduced ammonia slip add up to improved heat rate, increased power output and fewer cold-end maintenance issues. GTC-802 is positioned downstream of the ammonia injection grid in the same location as the current SCR catalyst. As an added benefit, the catalyst allows direct injection of liquid ammonia or urea in place of the traditional vaporized ammonia.
http://secc.umicore.com



5. Online determination of gas temperature across a plane upstream of the first superheater is by a system designed by hrl:/EUtech based on plant configuration. Note the positioning of six ports and sensors for each HRSG. Digital output from the instrumentation is integrated with the plant DCS for control of modulated supplementary firing

6. NewGen Power Kwinana is a 1 × 1 combined cycle with a 160-MW gas turbine, and 160-MW steam turbine that gets half its rated output when the HRSG is supplementary-fired



7. Two drains in close proximity experienced caustic-gouging failures

through supplemental firing of HRSGs.
- Maintain steam-turbine output for varying gas-turbine loads by modulating duct firing.
- Implement steam ranges in combination with duct firing to achieve full capacity for both STs when only three of the four GT/HRSGs are operating.

To do this, effective control of duct-firing rate and gas temperature is required for safe and effective operation, and to not overheat the final superheater tubes. Thus, advanced temperature measurements were required.

HRL joined with EUtech Scientific Engineering to integrate online monitoring of HRSG exit gas temperatures (Fig 5). The system at Diamantina is installed across a plane upstream of the first superheater.

This setup allows:
- Optical measuring; thermal radiation of CO/CO_2 is used to measure temperature.
- Temperature measurement from 750F to 3630F.
- Single-point and 2D/3D measurements using multiple sensors.
- Digital output for integration with plant DCS.
- Easy installation; robust service life.

Using six ports and sensors for each HRSG gives output with either one or two burners in operation.

A few benefits:
- Allows operation near maximum temperature limits without exceeding maximum allowable gas temperatures (protecting superheater).
- Allows maximum steam-turbine and plant load.
- Allows operation of steam turbines at steady load with operating flexibility achievable through gas-turbine and steam-flow load modulation.
- Allows control of modulated supplemental firing.

Clayton's summary: "Integration of online monitoring along with a new control strategy has enabled full modulating control of the supplemental firing system. These improvements have led to enhanced flexibility to maximize output and meet network swings in electricity demand."

Next steps at Diamantina are these:
1. Allow transfer of steam from one block to the other for full plant load with one gas turbine/HRSG out of service.
2. Operate in a more flexible mode to allow commissioning of 88-MW solar-farm capacity at Mount Isa.

Clayton also described advantages of using this same equipment to optimize combustion at coal-fired plants.

Sharing ideas for Kwinana

NewGen Power Kwinana Pty Ltd operates a 1 × 1, 320-MW combined cycle at a naval base in Western Australia. Commercial operation began in 2008 (Fig 6).

Steam-turbine exhaust steam is condensed in a seawater-cooled, titanium-tubed condenser. Boiler blowdown is recycled to the water treatment plant. Demineralized makeup water is produced via ion exchange using both raw potable and recycled blowdown water.

Water chemistry for Kwinana is AVT(O). Additional dosing of low-ppm



amine-based film-forming substance at the feedwater tank for shutdown protection began in March 2022.

Two drains in close proximity within the HP evaporator system have been experiencing repeated failures, specifically the HP intermittent blowoff (IBO) and HP evaporator drains (Fig 7). Failure causes are hydrogen damage, erosion, and caustic gouging.

Some key details:

Caustic gouging was identified as the root cause of failures in the carbon-steel pipes. However:

- Blowdown line is in the lower crawl space, away from the hot gas path.
- Pinhole failures occur at the top of the horizontal pipe. Deposits/corrosion are more likely along the bottom.
- No evidenc e of overheating or localized hot spots was observed in the bulk microstructure or from hardness testing.

The presenter, Veronica Yeo, shared specifics of the repeated failures and asked for input on a permanent solution.

An HRSG engineer/inspector present identified this as a common design error and informed the group why these failures occurred and how to prevent them. Horizontal evaporator drain pipes inside the casing are exposed to gas temperatures above saturation, so the water boils away leaving deposits that result in corrosion and failure along the top of the drain pipes.

One possible solution discussed is to route the drains downward through the bottom of the casing, so the piping remains flooded. Another is to upgrade the carbon steel material to T11 or T22. The current plan at site is to replace all drain lines with P11. Also, monitoring the temperature on the top surface of the horizontal piping will confirm the mechanism.

8. Inspection showed feedwater system protection provided by FFS

This was an excellent example of conference-participant input and group discussion.

Film-forming journey

AGL Energy Ltd, Australia's largest electricity generator, began a "film-forming journey" in 2019 at Torrens Island B. The four 200-MW gas-fired, natural-circulation drum boilers are constantly cycled and face possible "mothballing." Torrens Island A is already mothballed.

The purpose is offline protection for short- and long-term standby.

AGL's starting point was (and remains) Section 8 of IAPWS Technical Guidance Document 8-16 (2019), *Application of film-forming substances in fossil, combined-cycle and biomass powerplants.* Get your copy of this TGD gratis at www.iapws.org.

AGL's Brad Soutar explained the overall dosing program at Torrens Island:

Station A (closed)

- Dosing varied for 3-6 months prior to mothballing.
- Dose rates calculated at 1 ppm in feedwater.

Station B1 (mothballed; closure by

2024)

- Dosed for 3 months prior to mothballing.
- Dose rates calculated at 1-2 ppm in feedwater.

Stations B2, 3, and 4 (available; recent decision to retain)

- B2 setup installed.
- B3 and 4 installations in FY23.

Product used is Nalco Powerfilm™ 10000 (filming corrosion inhibitor). Initial inspections showed adequate protection of the feedwater system (Fig 8) and negligible impact on water chemistry. There has also been a reduction in corrosion-product transport during startup. Upcoming plans include more inspections to monitor effectiveness, and possibly increased dosage rates and frequencies.

AGL's Liddell power station houses four 500-MW forced-circulation drum boilers firing black coal. Units suffer significant challenges with tube failures, and frequent chemical cleaning. Dosing began in 2020.

The objective is to reduce boiler oxide growth by decreasing iron and copper corrosion-product transport. (Lindell has copper-based condensers and LP heaters.) Powerfilm 10000 is dosed after the condensate polishers with polishers in service. Dose rate is 1 ppm based on boiler full load.

Soutar discussed a few outcomes:

- No condenser resin fouling has been detected. There has been improvement in feedwater iron transport, but feedwater copper transport results are inconclusive. Boiler-tube oxide thickness has stabilized, and future testing will include oxide density.
- Future work also includes an increased dose rate to 2 ppm.
- Two other plants, Loy Yang A and Bayswater, are in the early stages of dosing and examination. Soutar stressed the need to begin with a formal, detailed review process, including accurate baseline data. He stated: "Success is seen at the end, but stems from the start."

Other specific case studies

- Kogan Creek, 1 × 750 MW, coal: Reheater tubes, and film-forming substances (FFS; CS Energy).
- Loy Yang B, 2 × 580 MW, coal: Cycle chemistry challenges for flexible dispatch (LYB Operations & Maintenance Pty Ltd).
- Mount Piper, 2 × 700 MW, coal: Unit layup scenarios including film forming substances (Energy Australia).
- Pelican Point, 2 × 1 combined cycle, 485 MW: Operating history and preservation (Engie).

Aging of P91 steel

Charles Thomas, Quest Integrity (New Zealand), noted the historical improvement in creep strength of P91 over P9 steel by adding very small amounts of vanadium, niobium, and nitrogen but also noted a "disappointingly high number of unanticipated failures." He attributed this largely to improper fabrication heat treatment (normalizing and tempering). He added that "We now see particular difficulties with Type IV cracking, and irreversible loss of creep strength in the weld heat-affected zone."

Thomas explained how aging has decreased the material creep-rupture properties, making an important point that the effect is often not considered in remaining-life assessments.

He then proposed a Larson-Miller parametric equation to manage time/temperature creep data, suggesting a "time-dependent C constant" and asking, "What if the Larson Miller Constant is not a constant at all?" The result would be a correlation between C, time, and temperature.

Work is ongoing, including an extended database, and will be presented at ABHUG 2023.

Aging high-pressure headers

HRST's Brian Craig stressed the importance of careful assessment for aging high-pressure headers. He began with a key point for all: We are seeing an increase in failures because of the accumulation of cycles and operating hours on 20-year-old equipment. Specific to HP superheater and reheater headers, he added the factor of risk to plant personnel.

"Header geometries include tube hole penetrations, branch connections, hanger lug welds, and end cap welds, all of which can create failure risk areas," Craig explained. "Some OEM header end caps are a serious concern, because of their weld joint design."

"In general," the boiler engineer said, "failure risk is elevated in units that are more than 15 years old or have more than 1000 starts."

Craig walked everyone through specific examples recently seen by HRST and stressed that "some have been analyzed for root cause, and some of them have not."

He offered an example where the end cap was correctly manufactured according to the ASME Code (and acceptable to AS1228/AS1210) but failed after more than 2000 cycles. The root cause was a lack of fusion that cannot be avoided in this design.

This led to a stress concentration at the gap root where a fatigue crack was able to initiate and propagate to failure (Fig 9).

Other end plate failures occurred in the same HRSG, and some of these liberated, posing a significant risk to personnel.

While the HRSG presented had seen a significant number of cycles, many HRSGs in Australasia (and globally) will approach these cycling levels soon and those with this particular boiler design should inspect for this type of cracking.

Craig also discussed improper test locations and alternatives.

9. End-plate failure of header in the high-pressure superheater

HP bypass-to-CRH connections

Chris Jones, Quest Integrity Aus Pty Ltd, discussed the integrity of HP bypass to cold-reheat pipe connections and described the best NDE methods for inspecting failures.

For an HRSG, the high-pressure bypass pipework can allow the gas turbine to remain on while the HRSG is pressurized (allowing main steam to bypass the turbine). But the associated pressure control valve can be subject to demanding operating conditions and erosion damage.

The failure mechanisms discussed by Jones included creep, fatigue, creep and/or stress relaxation cracking, fatigue cracks, water-hammer events, and resonance.

Jones' recommendations for inspecting areas upstream of the pressure control valve and/or isolator valve included fluorescent magnetic particle, ultrasonic, replication, and hardness testing.

KinetiClean

Jeffrey Bause, president and CEO of Groome Industrial Service Group (US), was in Brisbane to introduce KinetiClean™, a new shockwave system for

10. KinetiClean's detonating cords ensure no explosives come in direct contact with your HRSG's finned tubes

cleaning HRSG finned tubes.

KinetiClean uses a detonation-cord curtain (Fig 10) and automated high-pressure, high-volume air jet system to clean the tubes, followed by in-house debris removal and disposal services.

Benefits include reduced backpressure and increased heat rate, along with increased HRSG efficiency and flexibility. Bause presented specific case studies to support the use of this new cleaning system. He also explained Groome's capabilities for SCR/CO catalyst cleaning, repacking and replacement; AIG retrofitting and cleaning; CO acid/water washing; ACC and cooling tower cleaning; and permanent sampling grid installation.

Other specific presentations

- Expansion joints and penetration seals (Dekomte).
- Ultrasonic flowmeter to monitor for attemperator spray leakage (Anderson and Duke Energy).
- Steam-turbine nozzle plates (HRL).
- Boiler-drum operational limit analysis (ALS).
- Pulverized fuel mill failure (Energy Australia).

Cycle chemistry and film-forming substances

ABHUG 2022 featured a Workshop on film-forming substances. The latest international activities were reviewed regarding the effectiveness, applications, and risks associated with these potentially game-changing additions to HRSG and boiler cycle chemistry.

According to Barry Dooley, several takeaway messages came through including:

- FFS can be effective in protecting water/steam-touched surfaces against FAC and other forms of corrosion, therefore reducing corrosion-product transport.
- FFS should only be used after all existing cycle chemistry program shortfalls are eliminated. If a station's water chemistry is not known and optimized, experience shows that failures and damage can occur with both amine and non-amine FFS applications.
- Hydrophobicity is not a valid indication that FFS is protecting pressure-part surfaces.
- Owners take a substantial risk when feeding any product (including FFS) into the plant if the product's constituents and potential interactions are not known.

David Addison, Thermal Chemistry, repeated the critical need for due diligence for any application of FFS in a combined cycle or other type of plant.

Dooley and others also provided and discussed IAPWDS, AUSAPWS and NZAPWS updates, including relevant Technical Guidance Documents issued and offered free of charge by the association (www.iapws.org).

Acknowledgements

Exhibitors in Brisbane were Duff & Macintosh/Sentry, Flotech Controls, hrl:, Mettler Toledo, Swan Analytical Instruments, and Talcyon.

Event sponsors were: IAPWS, hrl:, Swan Analytical Instruments, and Ecolab. CCJ

Keep up with advances in materials, inspection technologies

By **Steven C Stultz**, Consulting Editor

European Technology Development Ltd (ETD) organized and conducted, virtually, the second High-Temperature Plant Materials, Inspection, Monitoring, and Assessment Conference (MIMA-2) last October (2022). Sponsors were AGTec GmbH, Austria, and the Institute of Materials, Minerals and Mining (IOM3), London.

Dr Ahmed Shibli, director, EDT Consulting, Leatherhead, England, and his staff organized and managed the event. Selected notes from the presentations follow. Conference specifics can be accessed by scanning QR1 with your smartphone or tablet.

QR1

MarBN steel

As with the first MIMA conference in 2020, Session 1 explored ongoing research with MarBN steel, a 9Cr martensitic with additions of boron (B) and nitrogen (N). Development and testing of this steel, intended for high-temperature applications, is moving quickly in both Europe and Japan, and attracting strong attention worldwide.

The goal is to increase material high-temperature strength, life, and integrity for future ultra-supercritical powerplants, and apply these benefits to all high-temperature, high-stress systems. Combined-cycle HRSG plants fall into this category.

Research continues to focus on MarBN's extremely sensitive heat-treatment processes during production. Scan QR2 for details.

QR2

A good MarBN status report was given in MIMA-1 (2020) by ETD's David Allen, who listed temperature capability of P92 as about 20 deg C better than P91 and "expected temperature capability of MarBN to be at least 25 deg C better than P92." He ended with this summary:

1. Today we can replace P91 with P92.
2. Tomorrow we could use MarBN for even greater security [material integrity and safety].

But the microalloying production process is extremely sensitive.

MIMA-2 presentations were quite specific. Steve Roberts, Goodwin Steel Castings (UK), looked at the UK version of MarBN steel (known as IBN-1) for wrought pipe manufacture noting that optimized heat treatment is required for best control of B, N and creep performance. He stated that creep rupture testing has demonstrated a creep strength that is 35% to 50% greater than P92, resulting in a potential 25 to 30 deg C increase in operating temperature, and/or more fatigue-tolerant and thinner components.

Related UK-government co-sponsored programs are Implant (multi-partner project coordinated by ETD, Innovate UK project number 105769) and Impulse (Innovate UK project number 102468), both specific to next-generation MarBN steel for fossil plant use.

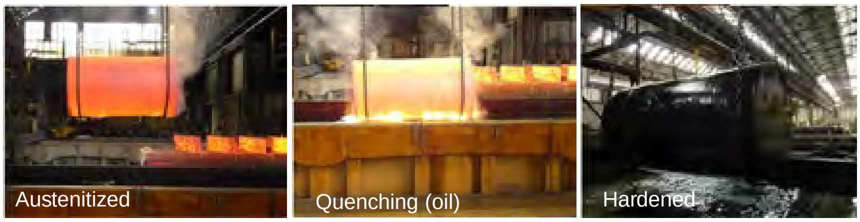
Commercialization programs are ongoing through various other government and industry co-funded programs such as Impact in the UK and Howeflex in Germany.

The German-funded Howeflex, a consortium of two turbine manufacturers (Siemens Energy and GE Power, Germany), a forge master, and two research organizations, is dealing with the upscaling of trial melt results of MarBN-family alloys for large rotor forgings with diameters of up to 1200 mm and typical weights representative of IP rotor forgings. Their presentation: Project Howeflex *MarBN rotor qualification (9Cr-3Co-3W-B-N) for load flexible application* (Figs 1 and 2). The results obtained so far indicate "promising properties" regarding the achievable forging quality and short- and long-term material behavior. Results show that:

- Large rotor forgings can be manufactured successfully with available steel-making technology at experienced forge masters.
- Mechanical properties have been determined including static strength, toughness, fatigue and creep properties, and complex

C	Si	Mn	Cr	Co	W	Nb	Ni	V	N/B ratio
0.10	0.30	0.50	9.0	3.0	2.7	0.050	< 0.1	0.20	1.2 - 1.6

1. Howeflex rotor material qualification involves holding MarBN chemical composition to a typical piece analysis (% by weight) as shown above



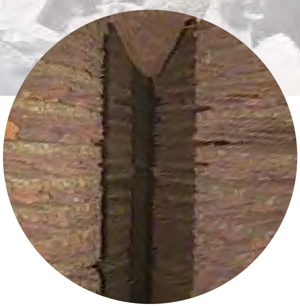
2. Howeflex quality heat treatment during manufacture has these characteristics: 1100C hardening temperature, oil quenching, air tempering at 570C, tempering at 690C with furnace and air cooling

WHEN IS 10 TONS OF DEBRIS A GOOD THING?

Recently Precision Iceblast Corporation was contracted to clean a standard HRSG located in the United States after explosion cleaning methods were utilized. The client initially experienced somewhat positive results from the explosion cleaning efforts. However, within a short time frame the client's back pressure increased near gas turbine tripping points.

Precision Iceblast Corporation removed an additional 10 tons of debris after explosion cleaning efforts. Client experienced an additional 3.5" reduction in back pressure. Client has been able to maintain the reduced back pressure after the PIC HRSG Deep CleaningTM process.

It was determined that explosion cleaning efforts were only able to clean to the fourth/fifth row of tubes leaving a large amount of the heating surface untouched.



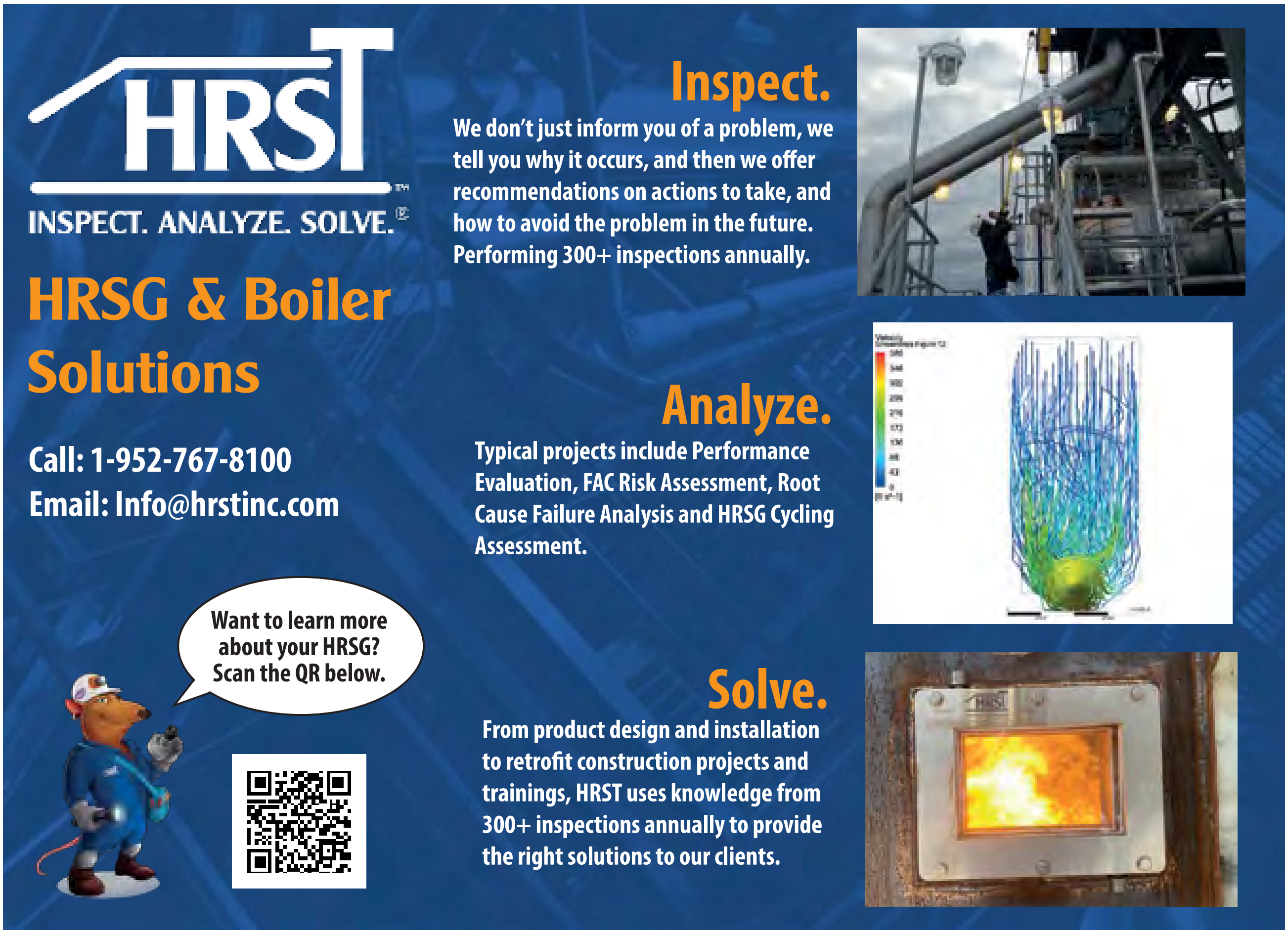
AFTER EXPLOSION CLEANING
(4TH & 5TH ROWS OF TUBES)

AFTER PIC HRSG DEEP CLEANING
(4TH & 5TH ROWS OF TUBES)

PIC HRSG Deep Cleaning

- ✓ No federal permitting required
- ✓ Dramatic reduction in heat rates
- ✓ Dramatic increase in Gas Turbine output
- ✓ Closest return to design back pressure possible
- ✓ No requirement to remove other contractors from the HRSG unit
- ✓ Scaffold required ensuring complete cleanliness allowing for borescope inspection of each level of the HRSG

www.precision-iceblast.com **info@precision-iceblast.com** **+1 906-864-2421**



creep-fatigue interactions.

- The design of rotors for flexible loading in combined-cycle applications, as well as for temperatures up to 1200F, is now possible.

An important distinction, raised during discussions, is that high-temperature research in Japan has reached and exceeded a working environment of 650C; some others target 620C.

The following presentations also focused, at least in part, on MarBN steel development:

- *Role of inclusions on degradation in creep life and rupture ductility of ferritic powerplant steels* (National Institute for Materials Science, Japan).
- *Multi-component alloying element effects on solidification segregation in cast IMN-1 based CSEF steels* (Univ of Birmingham, UK).
- *Normalizing temperature selection for creep performance of advanced high-temperature alloy IBN-1* (Loughborough Univ, UK).
- *Experience of P93 manifold welding under real fabrication conditions* (Siemens Energy, The Netherlands).
- *Development of Inconel alloy 740H and its application to supercritical CO_2 powerplants* (Special Metals Corp, UK).

Plant life assessment

A key benefit of MIMA conferences is learning specifics about life-assessment efforts for existing plants.

The Central Research Institute of the Electric Power Industry, Japan, began Session 2 with *Prediction of long-term creep life based on short-term data of used Grade 91 steels.* The focus was on how to deal with this experience limitation.

Masatsugu Yaguchi discussed life assessment using both standard and ultra-miniature samples. Both are effective, he said, but these issues remain:

1. We must assess long-term creep life using short-term data.
2. Test specimens taken from components are limited (destructive testing).

Those who want details of creep tests, along with equations, can request this presentation from ETD Consulting.

India's largest energy conglomerate, National Thermal Power Corp Ltd (NTPC), looked at residual life assessment of critical piping systems. NTPC's overall goals:

- Improve efficiencies of existing plants (71,500 MW installed).
- Operate the low-cost plants beyond their design life.
- Ensure safe operation of plants nearing design lives.

Focus is on piping systems operating in the creep range, where failures can be life-threatening and replacements have long lead times. NTPC has developed a hybrid set of code requirements using both Indian Boiler Regulations (IBR) and ASME B31.1. The company's Bhaskara Santosh, Kumar Pudipeddi, and Vineet Kumar elaborated on the methods, as well as constraints and issues faced while finding a "prudent approach."

Petroliam Nasional Berhad (Petronas) was also there to discuss the latest creep remaining-life prediction work on fired heaters in Malaysia. The premise: Most steam boilers operate within creep threshold temperatures and creep damage can only be assessed during shutdown through destructive methods. Therefore, an analytic digital solution is useful based on operating data and minimal retrofitting requirements.

Petronas is developing such a system in compliance with API 579, a program named F1RST™. This now will be validated using in-situ surface replication and hardness testing results obtained during shutdowns.

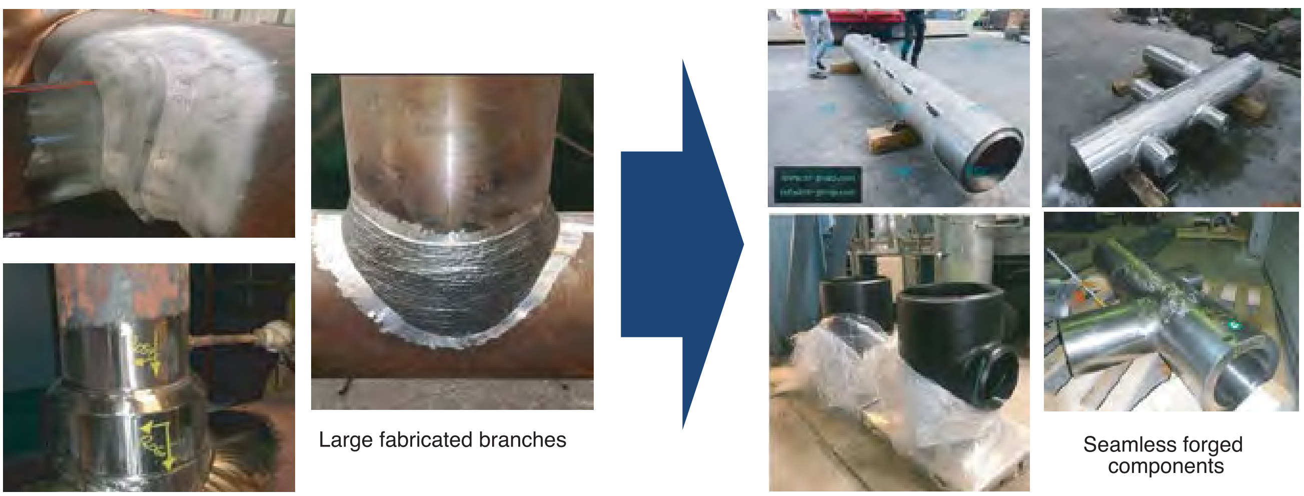
Italy's INAIL (Workers Compensation Authority) walked through eight years of research and the drafting of a new standard for assessment of martensitic steels, by the Italian Thermotechnical Committee. Work is based on both P91 and P92 research.

Inspection and maintenance

With a combined-cycle focus, David Tuey of RWE Generation (UK) discussed *Risk-based inspection and integrity management of HRSG headers and manifolds.* "Modern HRSG designs can feature many hundreds of collector headers and manifolds located on the steam/water circuits and it would not be practical to carry out widespread inspection of all locations during the operational life of a normal site," he noted.

RWE and member organizations of the Generator Safety Integrity Program in the UK are documenting a process to define best practices in applying risk-based inspection to HRSG headers. The document provides specific information on targeted inspection locations, appropriateness of specific inspection and NDT techniques, inferred condition on a hierarchical assessment of risk, sample sizes, consideration of wider fleet experience, and optimized record keeping.

One specific example used is Fig 3, noting that many large fabricated branches have proven to be a significant creep/fatigue risk. Use of forged components is a possible solution, based upon manufacturing expertise and material quality. Research on such alternatives is ongoing.



3. Large fabricated branches at left are a significant creep/fatigue risk. Use of seamless, forged components with no branch welds (right) or Type IV regions to inspect is a possible solution

Real Time Monitoring for Motors

Motor Current Signature Analysis (MCSA)

Motor Current Signature Analysis enables plants to use voltage and current signals to monitor and identify motor faults. The system trends and archives the data and waveforms for future analysis.

Monitors and trends failures:

- Rotor Bar Damage
- Misalignment
- Eccentricity
- Mechanical Looseness
- Bearing Problems

- **Benefits of MCSA Monitoring:**
  - » Early Detection Saves Money
  - » Non - invasive installation - NO outage required
  - » Lower costs compared to third party services
  - » Fewer forced outages due to equipment failures
  - » Automated data collection
  - » Plants have remote access to data
  - » Integrates into InsightCM™ making analytics easier

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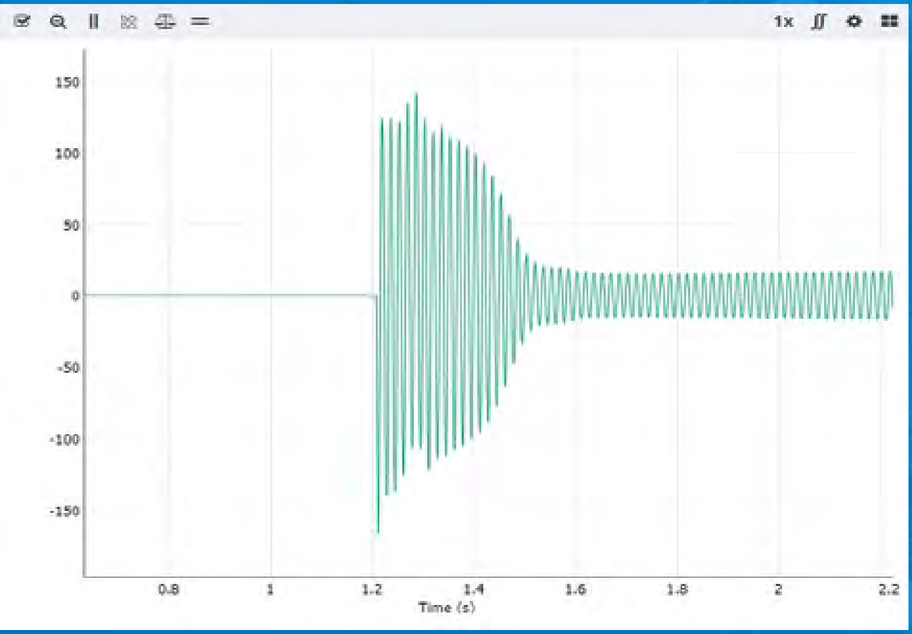
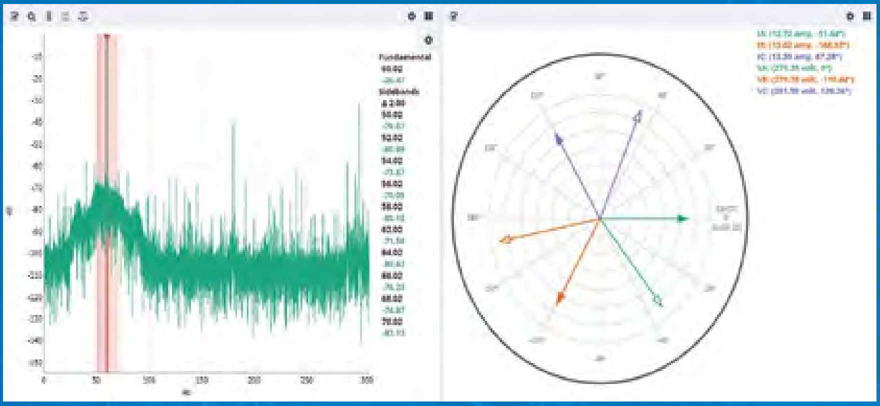
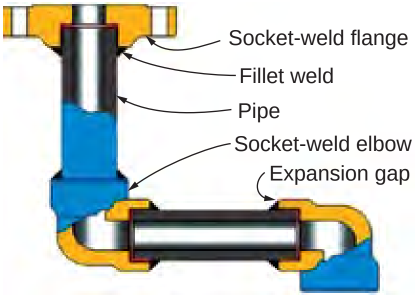
MCSA Monitoring Screenshots:



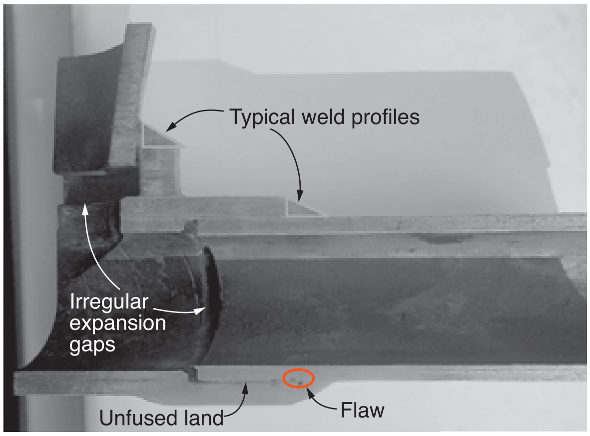


MCSA Viewers:

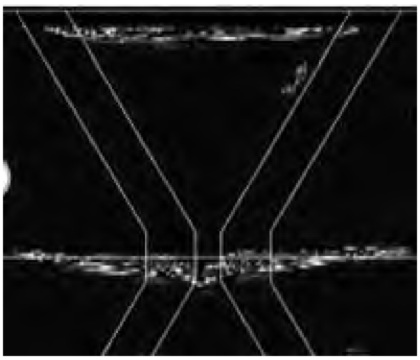
- Trend
- Waveform
- Spectrum
- High Resolution Spectrum
- Torque Waveform
- Phasor Diagram
- Envelope (Amplitude Demodulation)



4. Complex geometries require new inspection techniques



5. Socket-weld internals and makeup (typical view)



6. Full Matrix Capture requires no calibration. FMC details: An area of interest is set around the weld or individual defect under scrutiny and pixilated. The number of pixels determines the sensitivity and speed of the scan. Each pixel has its own data and when all do, FMC is achieved

It is important to note that the host ETD Consulting has completed a detailed study which evaluates various risk-based management (RBM) practices, and makes recommendations for best practices. Also, ETD's RBM procedure *RiskFit*, especially prepared for powerplants, consists of four risk-assessment levels, each of which can be carried out independently. Details are available through enquiries@etd-consulting.com. This was discussed in a presentation entitled *Evaluation of various risk-based maintenance procedures and recommendations for best practices* by ETD's Feroza Akther.

And for "the un-inspectable?" John Trelawny of Uniper Technologies (UK) attracted attention with *Inspecting the un-inspectable: A new inspection technique on complex geometries* (Fig 4). His assertion: Visualization and characterization of flaws are possible with 3D Full Matrix Capture inspection.

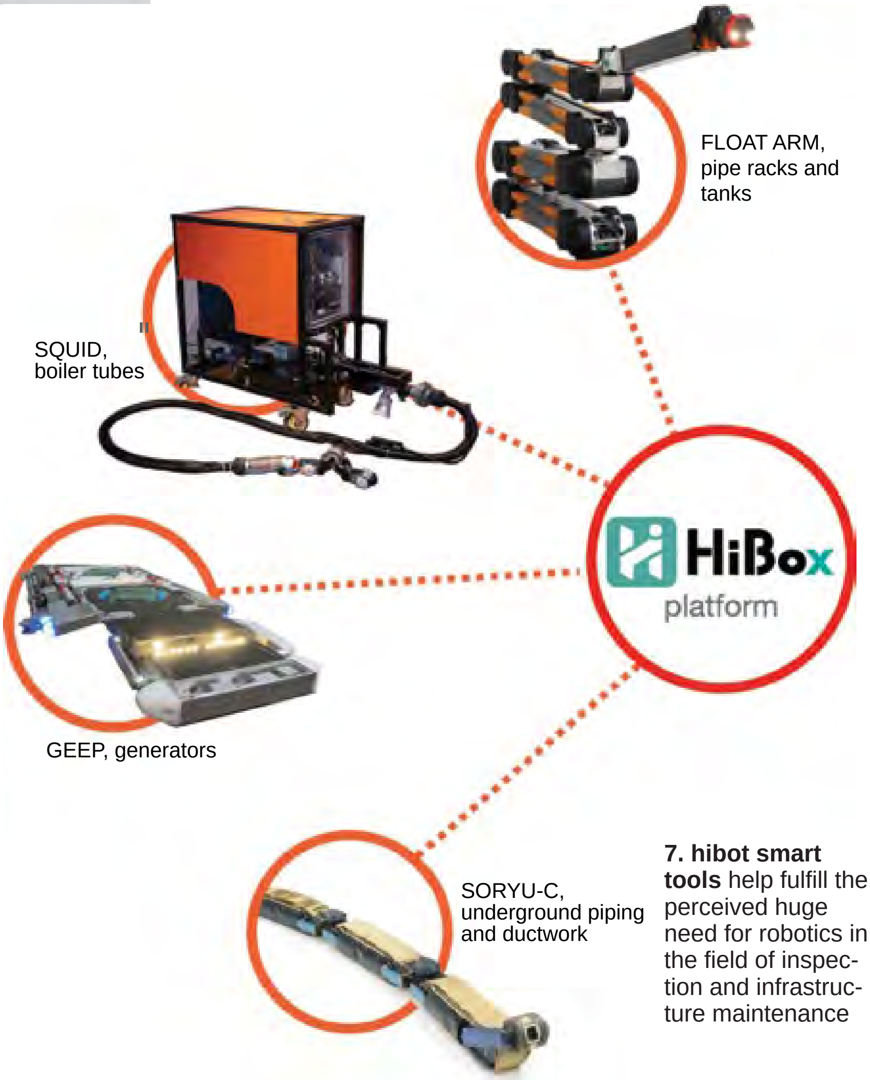
His focus: socket welds within HRSG drains built to ASME standards. One plant in 2019, he said, experienced a "violent weld failure, considered to be one of the most significant steam/water leaks in the UK." The current practice of surface inspection, he explained, is less than ideal.

The Uniper CCGT fleet contains vast quantities of socket welds (Fig 5) within the HRSG drains, vents, and interconnecting small-bore piping. One quarter of the steam leaks documented in the previous two years at one of the Uniper CCGT units have been from failed socket welds. The inspection management team was asked if a technique could be developed to locate these sub-surface flaws. This presentation detailed the work and outcomes of that development effort.

The chosen method uses Full Matrix Capture (Fig 6) and the resultant total focusing method. With this, the area of interest is pixelated, and each pixel has its own data (full matrix data). More on this phased-array technique is available within the MIMA-1 review. Access by scanning QR3 with your smartphone or tablet.

QR3

Snake or calamari? Paulo Debenest, hibot, Japan, explained that for 20 years, he and others have been working with robotic solutions to make



7. hibot smart tools help fulfill the perceived huge need for robotics in the field of inspection and infrastructure maintenance

8. Float-arm application example: Here the arm is passing through narrow gaps between pipes to reach challenging locations

9. The end effector on the float arm contains an inspection camera with 30 × optical zoom, auxiliary cameras, UT probes, gripping mechanism, etc. The “gadgets” incorporated in the end effector depend on the application

inspection missions safer, faster, and more reliable. Note that hibot is a startup operation with roots in the Tokyo Institute of Technology.

Debenest’s presentation: *Robotics applied to inspection of infrastructure: Examples of internal and external pipe inspection*. “These are not human-like robots. They are smart tools” (Fig 7). “They might be ugly, but they are all very functional,” he said.

The snake-like unit shown in Fig 8 is a float-arm concept driven by air. And where the head goes (Fig 9), the rest will follow, able to overcome obstacles in crowded environments, he explained. Another, labeled *the squid* and specifically for boilers, is driven by water (Fig 10).

This presentation focused on pipe inspections in boilers, heat exchangers, and pipelines. Specific to HRSGs this applies to pipe inspection inside (boiler and cooling water pipes) and outside (pipe racks).

Post-presentation comments were many, including “We are glad to see this is going commercial.” Commercial use has begun in Japan and is moving quickly to a new base in Europe. At least four units will be in operation within Europe in 2023.

ETD’s Ahmed Shibli had the most pointed summary comment: “Absolutely brilliant, and useful!”

Other presentations in this section were:

- *Digital transformation (DX) of boiler maintenance* (Best Materia C, Japan).
- *Risk-based maintenance for steam turbines and generators* (GE, Switzerland).
- *Inspection of pipelines with varying cross sections using a combined multidisciplinary and robotized solution* (Engie Laborelec, Belgium).
- *Possible microstructural resistant factors in P91 steel to the magnetic domain wall motion of electromagnetic inspection method* (Nippon Steel, Japan).
- *High-temperature corrosion data and mechanism of T122, Super 304H and HR3C in a 1000-MW ultra-supercritical powerplant* (Xi’an Jiaotong Univ, China).
- *Combined AC/DC potential drop for on and offline NDT for creep-life monitoring of pressure vessels* (University College London, Matelect Ltd, and ETD).

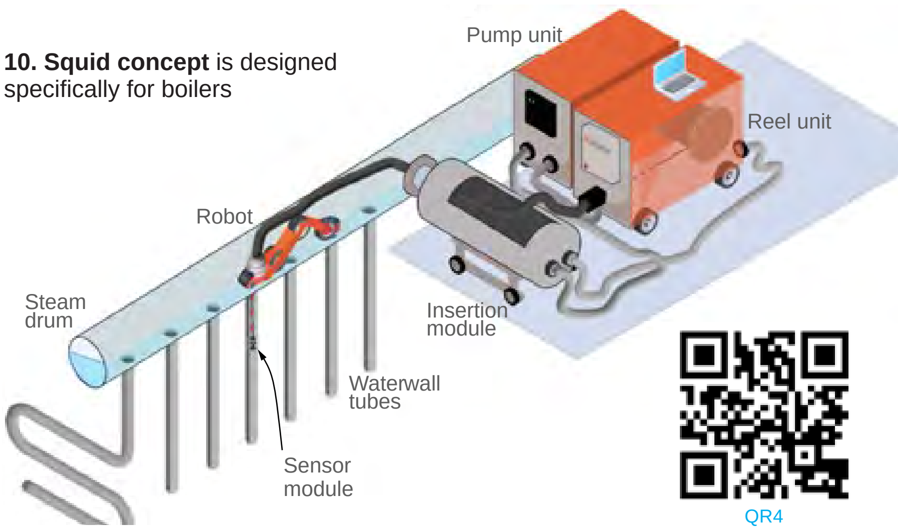
Cracking and failure

Real-time damage monitoring software was presented by ALG Global, Australia. The impetus is damage caused by cycling. RTDMS allows plant personnel to link transient operation and associated operator actions to potential damage. The software accounts for different damage types simultaneously and in real time, which includes the primary creep rupture life, high-cycle fatigue damage, low-cycle fatigue damage and coupled creep fatigue damage. This gives an increased level of accuracy and confidence in predicting asset life.

Aron Abolis explained that “RTDMS uses a highly agile and optimized code that allows for online stress and damage monitoring with set alarm points when ramp rates exceed critical limits, where coupling between creep and fatigue occurs, or where fatigue exceeds a critical limit.”

ETD’s CrackFit, a software for crack assessment in pressure vessels and turbines, has been discussed previously in CCJ, attributed to ETD Consulting and others as part of the European Commission project on high-temperature defect assessment. This tool is designed to help engineers

10. Squid concept is designed specifically for boilers



QR4

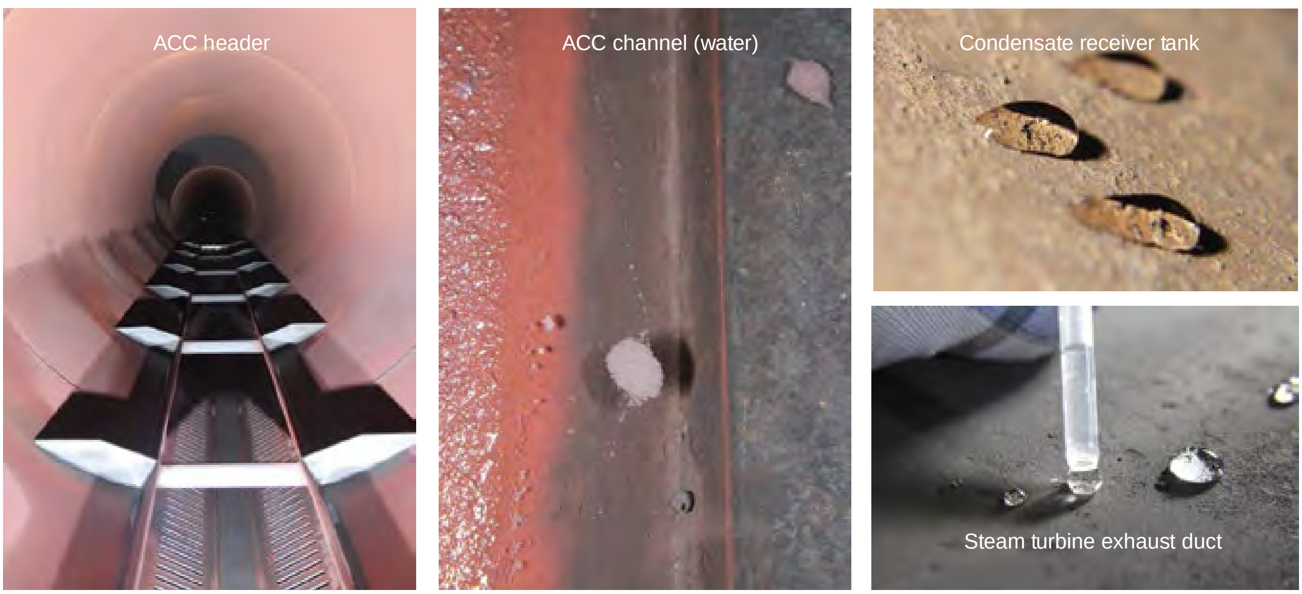
perform crack stability checks and defect/crack assessment of pressure vessels, piping, and turbine components operating at both low and high temperatures.

Crack initiation and growth for a host of components (pressure vessels, turbine rotors, plate and laboratory specimens) and commonly occurring crack geometries (embedded cracks, surface emerging cracks, various crack front shapes, etc) are incorporated into this software. CrackFit is also unique in that it contains a substantial crack growth database representing various combined-cycle/HRSG operation modes. Stuart Holdsworth of EMPA (Swiss Federal Laboratories for Material Science and Technology, Switzerland) joined this year's presentation with direct plant experience.

ETD also presented *Developing reliability framework for powerplants: Integrated RCM IV generation implementation.*

Plant flexibility issues

EMPA's Stuart Holdsworth then focused on turbines to discuss predic-



11. Anodamine dosing results

tion of high-temperature component integrity subjected to flexible operation. He discussed testing history leading now to smaller specimen sizes and ultrasonic total-focusing method techniques.

The impact of cycling was also the basis for *Cavitation during creep-fatigue loading* by Rolf Sandström, KTH Royal Institute of Technology, Sweden.

Creep rupture models have become reliable, and cavitation is recognized as playing a central role during creep fatigue. But there is a need for more adjustable parameters when applied to cycle loading.

This presentation offered details on transferring the cavitation models to cyclic loading.

Film formers Anodamine and VPI Power Limited (UK) discussed *Use of filming chemistry to improve corrosion protection of flexible operated powerplants*. The filming chemical Anodamine has been used to mitigate flow-accelerated corrosion (FAC) and other internal corrosion threats. This presentation focused on plant experience at VPI plants originally designed for baseload operation.

Dosing at one European 2 × 1 combined cycle began in February 2019. The 2021 inspections discussed were tailored to further check the efficacy of Anodamine following positive initial results from the 2019 and 2020 interim and steam turbine outages. Overall, the 2021 inspection results indicate that Anodamine is providing good levels of protection against FAC (both single- and two-phase) and that a benefit to corrosion fatigue and offload corrosion mitigation are also likely.

Internal direct and remote visual inspections have shown build-up of protective Anodamine film in areas susceptible to both single-phase (that is, condensate, feedwater, and the economizer circuits) and two-phase (that is, evaporators, steam drums, deaerator, blowdown/drains and steam turbine exhaust circuits) FAC. Further, repeat ultrasonic thickness inspection of critical areas (that is, HP and LP evaporator risers) shows a general reduction in thinning rates compared to pre-2019 levels (Fig 11).

VPI's Adrian Bailey explained "As a result of the good performance observed, it is judged that credit can now start to be taken via a reduction (gradual reduction of sample size rather than complete removal) of inspection scope for FAC damage at future outages."

His conclusions:

1. Four consecutive outage inspections show progressive improvement in surface passivation/cleanliness; off-load corrosion has been mitigated.
2. Less iron transport to boilers during two-shifting; reduced boiler blowdown rates.
3. Cleaner boiler tube surfaces; better heat transfer.
4. Clearing out of historical oxide deposits; no acid cleans needed.
5. Ongoing FAC mitigated at HP risers, according to remote inspection and NDT; huge cost saver in not replacing HP boiler risers.
6. Both operations and management recognize the benefits of Anodamine.

For more on film-forming substance development and experience, scan QR4.

Plenary

With a look toward ongoing and future operation of combined-cycle HRSG plants, Ian Perrin, Triaxis Power Consulting (US), discussed *HRSG design challenges: Material and mechanical integrity* . HRSGs are being paired with next-generation gas turbines that are larger and required to operate at higher pressures and temperatures. This is accompanied by increasing demands for rapid start and flexible operation, as well as baseload operation at high temperature and pressure.

"This puts significant demands on material selection, which must consider fabrication practicality alongside durability," he said.

Perrin outlined the key challenges:

- Grade 92 replacing Grade 91.
- Large-bore piping branches.
- Long-term tube life.
- Stainless-steel tubes and headers.
- Dissimilar metal welds.

He focused on high-temperature components.

Examples were provided to illustrate challenges and to identify where detailed analysis can help optimize designs.

Also discussed were some of the challenges related to Codes and Standards, which are struggling to keep pace with design demands and material developments. The needs for future creep-strength-enhanced ferritic materials and integrity assessment methods were also covered.

Large bore piping branches and tees are susceptible to creep failures, in part because of the proximity of welds and thickness transitions, and forged replacement components are not always what you expect, and could be difficult to inspect. Simply meeting the ASME Boiler & Pressure Vessel Code, or others like it, does not mean acceptable material integrity, particularly with some new advanced materials.

Perrin also covered stainless-steel tubes and headers, temperatures and thermal fatigue, and dissimilar metal welds.

A few summary comments and caveats:

- High-temperature materials in modern powerplants create challenges.
- Meeting the Code does not mean acceptable material integrity.
- Codes assume materials are tough, ductile, and damage tolerant. Creep-strength-enhanced ferritic steels may not be!
- High temperatures (creep) and cycling (fatigue) are often not considered at the design stage.

ETD's David Allen addressed the *Role of materials design data in life assessment of high-temperature plants*, breaking life assessments into two basic categories:

1. Specific problems where high-risk items may be damaged, faulty, substandard, or subject to excessive stress, temperature, or corrosion, and,
2. Generic concerns where all items of a specific set (for example, Grade 91 pipes and headers) may be approaching end of life.

In the second, you may need to assess *total life* rather than simply *remaining life*, he explained.

Both begin with root cause analysis.

Some interesting cautions (among many listed):

- When a high-temperature plant is designed, all Codes and Standards specify procedures which take account of materials performance data and enable the plant to be designed for a specified design life. This commonly assumes steady operation and hence ignores plant cycling issues, but is otherwise intended to be conservative.
- More recently, cost pressures and climate-change concerns have led to the development of advanced ultra-supercritical (USC) plants, and have promoted less conservative selection of materials and operating temperatures (for example, Grade 91 at above 580C, Grade 92 at 600-610C or higher). Generic wear-out risks could thence come to the fore as a USC plant ages.
- End users should take the lead on this. Manufacturers will not.
- Don't just rely on what the alloy developers did in the distant past. Do the work again, update the data, and strive toward more precise and credible conclusions.
- Drawing any valid generic inferences from data on ex-service materials is fraught with difficulties. Testing ex-service items is only useful when solely the specific sampled heat is to be assessed.
- If you conclude that generic "wear-out" may be imminent, keep in mind that replacement of high-temperature pipework and boiler header systems will take time.
- Finally, don't start by being complacent, and then flip into panic mode when something goes wrong.

The editors recommend obtaining a copy of this presentation from ETD.

Also in the plenary session:

1. *Life evaluation and research subjects for safe service of 9Cr steels used in USC powerplants* (Univ of Science and Technology, Beijing).
2. *Activities to advance residual life-evaluation techniques for highly aged powerplant boiler materials in Japan* (Tohoku Univ, Japan).

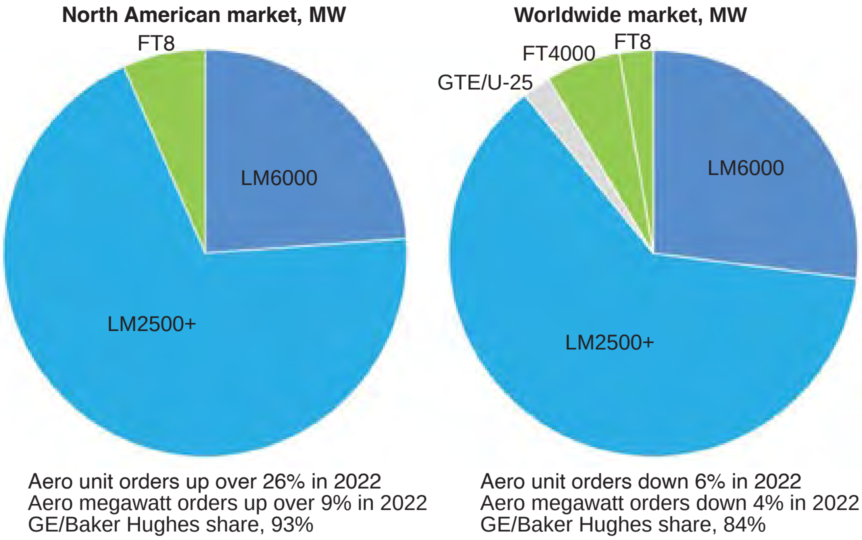
Attend MIMA-3 this fall

ETD announces the third international MIMA Conference, an in-person event, "Sustainable Power Generation: Materials, Inspection, Monitoring, and Assessment," will be held Oct 17-19, 2023 in London. Get the details at https://www.etd-consulting.com/conferences/. CCJ

Good year for aeros as US, global markets undergo seismic shifts

The war in Ukraine quite dramatically shifted the geopolitical energy scene in February 2022. In the US, the government has "declared war" on fossil fuels, yet backing alternatives with $340-billion under the guise of the oddly named Inflation Reduction Act (IRA). Even if "total activity in the aeroderivative gas turbine (GT) market has dropped off over the last 15 years," the long-term prognosis for aeros is "pretty good."

These were the salient conclusions of opening remarks given by Mark Axford, Axford Turbine Consultants LLC, and Tony Brough, Dora Partners & Company LLC, at Western Turbine Users Inc's (WTUI) 32nd Annual Conference in San Diego, March 12-15, 2023.



1. Aero GT orders sharply turned around in 2022 in North America, up 26% in units and 9% in megawatts, although were still down somewhat globally. Popularity of LM machines leaves little room for competitors. Data, for both the O&G and electric sectors, were provided by DORA Partners & Company

Brough opened by running through reams of statistics and graphs depicting the global gas turbine market. (Access to the Axford and Brough PowerPoints is limited to WTUI members and a few others. Request permission by writing Webmaster Wayne Feragen at wferagen@wtui.com.) Overall, GT orders (aeros plus frames) were up on a megawatt basis in 2022 but flat on number of units. Other Brough conclusions include the following:

- GE/Baker Hughes continues to strongly dominate the aero market (as Fig 1 reveals) with the new LM9000 machine having "long term potential."
- Solar Turbines has introduced the Titan 350, aimed squarely at the LM2500+ market.
- Activity in hydrogen has heightened but "much needs to occur on the supply side to truly impact the gas turbine market."
- Global expansion of LNG continues to rely on aeros as the critical driver.
- Solar PV is experiencing huge growth with 17 GW of utility-grade capacity added in 2022 and 30-40 GW scheduled to start up in 2023.
- LM turbine owners are seriously looking for alternative (as in unapproved by GE) service providers.
- Mobile, trailer mounted power generation, requiring "no forklift and no crane," is a growing trend.
- There have been two consecutive years of improvement in the upstream (oil/gas) market for aeros.

If Brough was the straight man, Axford's remarks were delivered with less data and more humor. He introduced himself by creating a new pronoun in an opening slide: "I identify as a turbine."

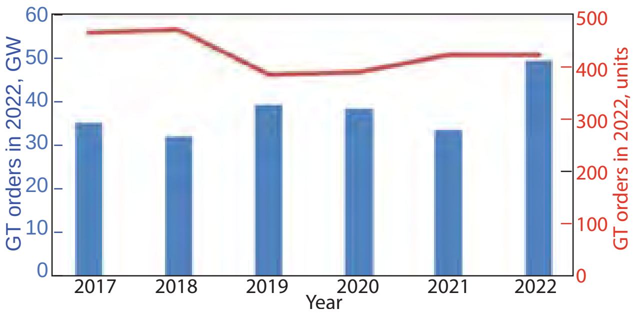
The big headline from last year was that the huge Nord Stream Pipeline carrying natural gas from Russia to Europe (via Germany), and vital to European energy supply, was blown up. This act of sabotage shifted the global energy supply picture, while later events resulting from the war in Ukraine, such as sanctions on Russia, shifted them even more.

Axford invited his audience to ponder who was responsible for Nord Stream by showing a slide with a photo and quote from President Joe Biden, a photo and quote from US National Security Council Coordinator John Kirby, both sandwiching a photo and quote from Sergeant Schulz of Hogan's Heroes, "I know noth…ing!"


Brough


Axford

Another aspect of the war on fossil fuels, said Axford, is that permits for offshore oil/gas drilling, which have to be renewed every five years, are being held up, as are permits for new drilling projects in Alaska. Axford then pressed the humor button again by playing the opening audio from "The Twilight Zone," while showing a slide and narrating, "Imagine if you will. . .a world where people believe that the temperature of the planet can be controlled by giving more money to the government."



2. Gas-turbine orders worldwide in 2022 were higher by a larger margin than in any of the past five years, although the unit count has been hovering around 400 since 2019. Data are from DORA Partners & Company

Axford then borrowed a phrase, the "trilemma," from Daniel Yergin, author and vice chairman of S&P Global, uttered at the recent CERA Global Energy Conference. It refers to the need to maintain security while providing energy sustainably and affordably.

This "energy transition," which many experts call it, is not the first one the world has been through, Axford noted, referring to, for one, the century-long transition from wood to fossil fuels. However, it is the first, he believes, in which the old energy sources are being banned or discouraged by government intervention at the same time the new ones (solar, wind, and hydrogen primarily) are being developed by the market, albeit with generous government subsidies.

"It's all too much too fast," Axford suggested.

Regarding the GT supply chain, Axford focused on these developments:

- Siemens AG spun off Siemens Energy into a separate shareholder company, officially ended the Trent line of machines, and closed the remaining Dresser-Rand factories in the US.
- GE acquired Baker Hughes (BH) in 2016, but then restructured it beginning in 2018, divested it, and today BH trades on the Nasdaq. BH exclusively supplies GE's turbines to the oil/gas sector.
- GE announced it is spinning off the gas, steam, and wind turbine businesses into a new separately listed company called Vernova; it is expected to be completed in early 2024.
- BH acquired the generator business of Brush Electric; Brush units are apparently a fan favorite of LM users.
- Mitsubishi is heads down on its large GT business; Axford wondered aloud if a spin-off of its aero division is in the offing.

Axford also spot-lighted two lesser-known names in the GT supply chain. Dynamis Power Solutions, which has been supplying DT35 mobile turbines for fracking applications and is a channel partner with BH. The company is now building the "no forklift, no crane" units for anyone who wants one. Relevant Power Solutions, also a channel partner of BH for TM2500 units, is building new trailer mounted LM2500+G4 gensets for lease or purchase. He also highlighted ProEnergy's 81 LM6000 gensets in service or on order.

An interesting factoid from the offshore wind-turbine market segment of the talk is that blades are approaching 350 feet in length. Together with the tower height, total height is approaching that of the Empire State Building!

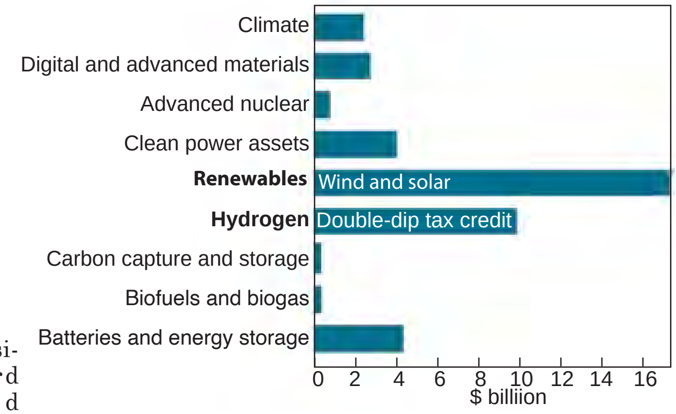
The three biggies in gas turbines—GE, Mitsubishi, and Siemens—also participate in the wind-turbine business, which Axford said "bled red ink" in 2022, and are facing "soaring materials costs," shortage of rigs for installation, and "logistical nightmares" as machine size keeps growing. In the offshore wind market, the US is way behind China and Europe.

Chinese manufacturers dominate the wind-turbine market, capturing 70% of the global business in 2022. Note that the 95,000 MW bought from Chinese wind-turbine OEMs was nearly twice the worldwide gas-turbine order book last year (Fig 2).

In the competition for GT business, Axford reminded his audience not to discount gas-engine gensets for peaking power and balancing services. Wartsila, for example, won over 500 MW of engine genset orders in 2022.

In his remarks on storage, batteries, and electric vehicles, Axford dispelled a myth out there that China has most of the world's lithium deposits. In fact, Australia, Argentina, and Chile do. What China has is the lithium refining capacity.

In other comments, he noted that lithium ore costs had been steadily declining for at least five years, but in 2020, this reversed with a vengeance. Axford forecasted that lithium-based storage would never reach the goal set for automotive applications of $100/kWh. In 2022, lithium prices dropped by 30% but were still sixfold higher than the January 2021 figures.



3. The $340-billion Inflation Reduction Act in its first 20 weeks resulted in tens of billions in "deal flow"; renewables and hydrogen, with its "double-dip" tax credit, took the lion's share. European subsidies up to 400-billion Euros are also available. Data were compiled Jan 26, 2023 by S&P Global

The storage market "needs a lower-cost alternative to lithium," Axford stressed. He apparently offered one by highlighting Form Energy and its iron-air battery (the process of rust formation and its reverse), Form's $760-million factory being built in West Virginia, its 2 × 100 MWh demo sites in Colorado and Minnesota, and the investment of none other than Bill Gates.

In covering H_2 activity, Axford predicted that in 20 years, the hydrogen market will be like the ethanol market and gasoline: blending with natural gas up to 15% on a volumetric basis, but not a big displacement of NG by H_2 (15% H_2 by volume equates to only 4.5% on an energy-input basis). Much of this will be driven by the generous subsidies for H_2 in the IRA, but especially the "double dip" tax credit (assisting a whopping $10-billion of deal flow)—one for producing green H_2 through electrolysis and one for displacing carbon-bearing material in an energy conversion process (Fig 3).

Leaving the best for last and keeping the attendees in their seats, Axford closed by forecasting that the GT market in 2023 will end down by about 20% compared to 2022. He added a few caveats, like all forecasters should, and invoked Yogi Berra's quote, "the future ain't what it used to be." CCJ

Treat your lube oil like it's an asset, not a consumable

Imagine never having to change your oil again, not in your car, but in your combined cycle's gas turbine (GT). Dr Matthew Hobbs, EPT Clean Oil, Calgary, Alberta, Canada, invites you to "rethink" how you treat your lube oil, first by focusing the treatment system on *soluble* varnish, and second, by adding ion charge bonding (ICB) ion exchange resins to continuously remove that soluble varnish.

In a webinar on March 9, "Eliminating varnish-related failures through lubricant chemistry management," Hobbs asserted that use of ICBs essentially can avoid five to 10 oil changeouts over the life of a typical baseload GT, converting lube oil into an asset.

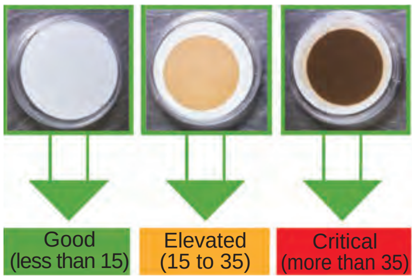
Doing so can save a bank vault's worth of money (estimates available in the presentation), mostly by avoiding up to 24 hours of annual downtime attributed to poor lube-chemistry management. Varnish is responsible for more GT downtime than any other factor, claimed Hobbs.

Use of ICBs can also lower the carbon footprint of the machine. Hobbs stated that lubricant manufacturing is the most energy intensive sub-process in an oil refinery. If you put a value on that avoided carbon, the savings are even greater.

On the cost side, Hobbs, in responding to a separate communication following the webinar, reported that the cost of ownership of ICB would be around $6750/year (capital + consumables) over a 20-year life of a single 7F machine.

Most of Hobbs' comments addressed deficiencies in current/typical lube-oil chemistry practice. "Today's maintenance programs are as outdated as the pay phone," he mused. Most of the deficiencies center on *soluble* varnish, tagged as the root cause of varnish issues, such as the following:

- End users tend to rely on third-party labs for testing, which often don't test for varnish.
- Labs typically do not *correctly* run the all-important "membrane patch colorimetry" test (MPC, ASTM D7843): Samples must be heated for 24 hours and incubated for 72 hours to consistently detect soluble and insoluble varnish and establish an apples-to-apples comparison (Fig 1). Labs should report the hold times, in addition to the color intensity (ΔE) result.
- Cleaners/solubilizers change the form of varnish but don't remove it; filters, while essential to remove other impurities, only remove insoluble varnish.



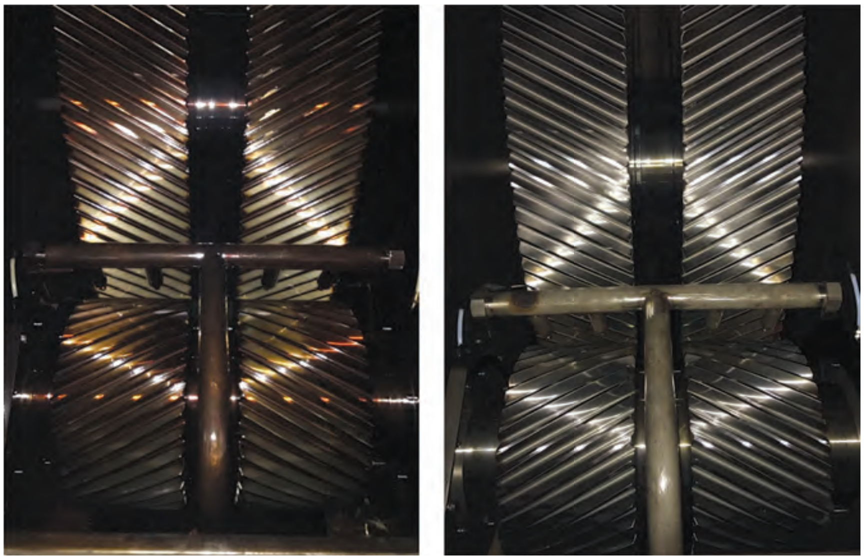
1. Varnish is captured on a 0.45-µm lab patch in the MPC test

Engineered ICB ion exchange resins are thus the best option, according to Hobbs. Because oil-breakdown products are more attracted to the resin than to metallic component surfaces, these systems remove soluble varnish, which in turn reduces insoluble varnish, in a "positive feedback loop." The amount of soluble varnish in the oil is dependent on operating temperature. Constant recirculation through ICB resins keeps the oil below the varnish saturation state.

The presentation, available at https://www.ccj-online.com/ept-webinar/, includes some dramatic video of varnish saturation changes with temperature and photos of MBC tests as well as varnished and unvarnished components (Fig 2).

During the Q&A, Hobbs noted the following:

- He favors the rotating pressure vessel oxidation test (RPVOT, ASTM D2272) as a monitoring tool, but it does not substitute for the MPC test.
- Regeneration of resin is very energy intensive and generally not worth the time or money: Only about five to 13 lb of resin is used over the life of a machine.
- Design of the ICB ion exchange resin system, especially resin selection, must be tailored to the user's needs and type of lubricant.
- One user Hobbs is familiar with had varnish issues in his machine even when the MPC level was as low as 9. Note that below 15 is considered "acceptable," 15-35 elevated, and more than 35 critical. CCJ



Before After

2. SGT-800 turbine is shown before (left) and after (right) removal of soluble varnish with ICB resin; life savings in refill costs for such a machine are on the order of $460,000, with lifetime reliability savings three times that figure

BOOKSHELF • BY JOHN F D PETERSON

How your gas turbine came to be

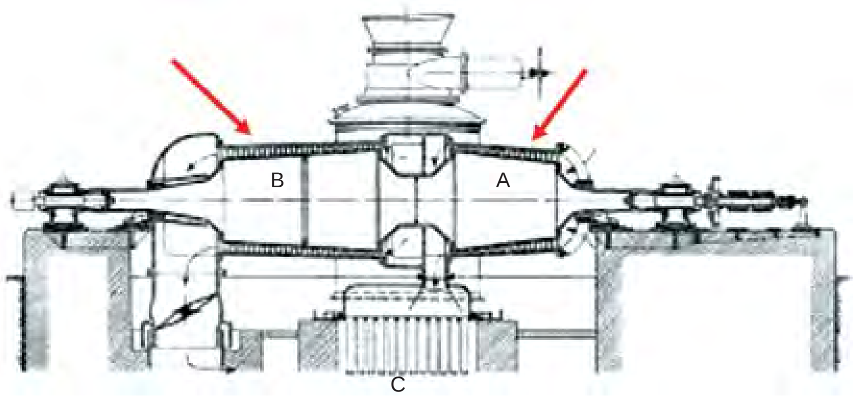
Gas Turbine Powerhouse
Development of the power-generation GT at BBC/ABB/Alstom (2nd edition, 2014)
By Prof Dr-Ing Dietrich Eckardt
De Gruyter, Oldenbourg, 498 pages, $85 hardcover

The fact that you are looking at this page in Combined Cycle Journal gives me high confidence that you are not only familiar with gas turbines but interested in them as well. If, from time to time, you also wonder how in the world these magnificent machines came to be. . . .then you are my target audience.

Gas Turbine Powerhouse is a story of heavy-duty gas turbine development and manufacturing from the point of view of Brown Boveri & Cie a/k/a BBC, a Swiss company that once stood foremost among the industry's giants. Perhaps you have not heard of BBC; but if you are familiar with basic gas turbine history, or remember gas turbine fleets before 1990, then the name Brown Boveri is not new to you.

Some of you may even recall that in Neuchatel, Switzerland, in late 1939, the first gas turbine in power generation service began operation. That engine, designed and built by BBC engineers and technicians, is now an historical landmark, recognized in 1988 by the ASME and the Swiss Engineers and Architects Assn as the first commercially successful gas-turbine-driven power generation installation in the world.

The book follows BBC's history of gas turbine development and manufacture from the early 1900s through the company's official end in 1987 but includes substantial information on further development by its successor



1. In Stolze's engine, the compressor is identified as "A" and the turbine as "B" companies. These (at first a newly formed Asea Brown Boveri–ABB, followed by Alstom) continued to manufacture the engines with substantial technical innovation and improvements along the way. Anyone interested in gas turbine technology will benefit from this account.

For me, however, the greatest value of this story is the historical account of successes and failures, both within the company, and without, between the years 1900 and 1940. This period had been a mystery to me, and especially so because of my previous perception of the "sudden" appearance of an efficient axial compressor on the Neuchatel engine.

This magnificent component of turbomachinery, a high-flow, high-efficiency, axial air compressor, an indispensable part of every heavy-duty gas turbine operating in power generation today, didn't just spring, fully formed, from its inventor's head, did it? Well, no, it didn't.

Around the turn of the century (1900-1906) Sir Charles Parsons struggled to develop an efficient axial blower for the purpose of coal mine ventilation. Both compression ratio and efficiency were very low.

Another engineering pioneer of that same period, Franz Stolze, built an experimental gas turbine with axial compressor and axial turbine, but the combined inefficiencies of the two components prohibited a self-sustained operation of the engine. In the cross-section of Stolze's engine (Fig 1) the compressor component is identified as "A," and the turbine as "B." One can see at a glance that the usual ratio of compressor stages to turbine stages, from, say, 5 to 1, or 6 to 1, is not followed, but is more the inverse. Nevertheless, this early experimental engine is ingenious, and has many familiar features found on successful gas turbines today.

Yet another interesting attempt in the first decade of the 20th century was the Holzwarth Explosion Turbine. This design avoided the need for efficient compression by using a repetitive sequence of confined combustion events. Low-pressure air from a blower was sufficient, along with injected fuel. Valves would open to admit the air and fuel to a chamber, then close to confine the combustion process within the chamber.

After each combustion event, a third valve would open, allowing the chamber of hot, high-pressure combustion gas to vent through a nozzle and bladed turbine wheel. These curious monstrosities actually achieved limited commercial success despite their single-digit thermal efficiency and complex machinery.

This obvious "work-around" used in the Holzwarth Explosion Turbine achieved through pulses of hot gas with a *constant-volume* combustion process what the "dreamed of" steady-state *constant-pressure* combustion process had been considered unable to do.

Whether known or unknown by Holzwarth and his team, a more conventional machine had already succeeded in achieving the steady-state, constant-pressure process several years before. Aegedius Elling, a Norwegian engineer, designed and built what many believe is the first truly functional, self-sustaining gas turbine in history. The year was 1903.

The engine used a six-stage centrifugal compressor, steam injection, and radial turbine to generate 11 hp. The fact that the compressor was of a centrifugal design instead of axial does not take away from the magnificent achievement of this gas turbine pioneer.

Elling continued developing his concept with a recuperated engine producing 75 hp, but for some reason ceased his experimentation a few years later. His farsighted intuition is revealed in these two predictions that he made in those early years of gas turbine technology:

- There was no practical reason why a gas turbine might not make a million horsepower.
- The gas turbine engine could be a made-to-order aircraft powerplant.

I do wish I knew more of Aegedius Elling and his work. For some reason, many histories neglect even a mention of Elling, and *Gas Turbine Powerhouse* commits only a paragraph to his work. Nevertheless, despite the lack of attention to this Norwegian engineer's contributions, I consider Elling's 1903 engine to be properly described as the first functionally successful gas turbine in history.

Three years after Elling's initial success, two Frenchman, Charles Lemale, and Rene Armendgaud, built a much larger engine using a Brown Boveri 25-stage, multi-casing, centrifugal compressor, one of the world's largest at the time. With steam injection, and a water-cooled, two-stage "Curtis wheel" turbine it produced about the same power as Elling's, at an efficiency estimated to be 2% to 3%.

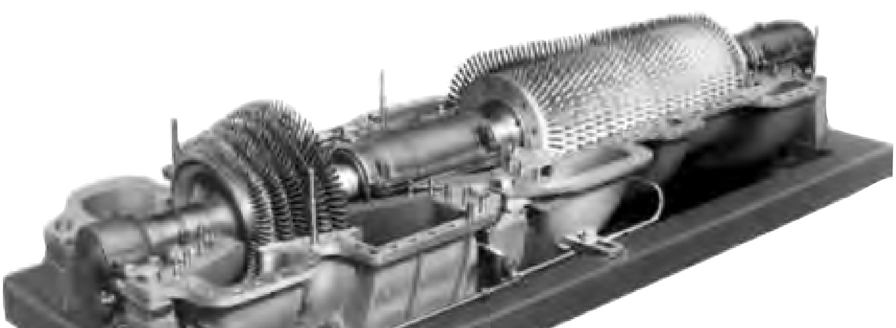
The story continues through the second decade of the 20th century with improved Holzwarth Explosion Turbines, and the introduction of turbochargers for various applications. Rapid development of these two product lines (particularly the turbocharger) led eventually to the Velox boiler after 1930.

These are especially interesting since they bridge the gap between the Holzwarth success and true constant-pressure gas turbines. BBC intended the Velox boilers to be capable of a high steam output for their size (think locomotives and marine applications), with the ability to start and ramp up quickly.

The Velox concept utilized high-pressure combustion in reinforced furnace structures, resulting in very high volumetric heat release. Energy recovery from the high-pressure exhaust gas, via a turbocharger, boosted the combustion air pressure, reducing (or eliminating) input horsepower for the forced-draft fan. Functionally these Velox boilers were gas turbines producing steam.

At this point, if you are still reading, you wonder: "Well, great! But what about axial compressors? Where did the Neuchatel gas turbine's air compressor come from?" This, as you recall, was my own question from the very start, and here *Gas Turbine Powerhouse* began to deliver. It turns out that most Velox boilers, after about 1933, utilized multi-stage, axial-flow compression and expansion in the turbocharger pairing.

Even more astounding, in 1934,



2. Compressor/expander in 1936 catalytic cracker process shows a close resemblance to a modern frame gas turbine another BBC project included a 13-stage axial compressor for supersonic wind tunnel testing at an aeronautical research facility in Zurich. I know I am running out of room to write, but I will also mention BBC's Mondeville 10-stage test compressor rotor, completed one year earlier (1933), the first commercially available axial compressor in the world, with a pressure ratio of 2.6 and an adiabatic compression efficiency of 83%.

These revelations push axial-compression R&D efforts at BBC into the mid to late 1920s, earlier than I would have ever imagined before reading this amazing story. One ingredient in BBC's formula for success regarding axial compression was the introduction of airfoil theory. This factor had been unavailable (and unknown) to the earlier pioneers of turbomachinery leading to their ultimate lack of success, notwithstanding their otherwise ingenious inventiveness.

Leaving wind tunnels and Velox boilers behind for a moment, I must mention one more surprise in the BBC story during the pre-war period of axial-compressor development, and one much closer to home. In 1936 the first commercial operation of a fixed-bed catalytic cracker for petroleum refining began operation at the Sun Oil Refinery in Marcus Hook, Pa. This was the Houdry Process, named for its developer, Jules Houdry, and the heart of its gas circuit was a gas expander, and air compressor. Fig 2 shows the combined unit on the half shell.

Doesn't this look a lot like a modern heavy-duty gas turbine? In fact, it is by anyone's measure a genuine gas turbine, with axial compressor and turbine. The combustor was the catalytic cracker itself. Apparently, also attached to the machinery string was a generator to make electrical power from the excess shaft power.

Move over Neuchatel, here is another heavy-duty gas turbine "first" to command a share of our admiration!

Several names stand out during this period of axial-compressor innovation at BBC: Jean von Freudenreich, Georges Darrieus, and Claude Seipple. This last individual was a 28-year-old just back from an assignment in the US. Herein lies a mystery, and one as-yet untold in the story. The young engineer/inventor, Seipple, returned to Baden in 1928 and became a very important figure in BBC's axial-compressor development as well as in Germany's axial-flow aircraft engine development.

The author of *Gas Turbine Powerhouse* promises the rest of the story in a second book, *Jet Web,* which I just received. It too is available at Amazon. Be looking for another book review sometime soon to learn the rest of the story.

John F D Peterson, who graduated from Georgia Tech in 1970 with a BS in Chemical Engineering, recently began his 53rd year as a process engineer at BASF's Geismar (La) chemical production site. Although retired as a direct employee of BASF, he continues part-time as a contract engineer in the company's Utilities Dept. Plus, he provides troubleshooting, training, and performance assessment/optimization services to gas-turbine owner/operators nationwide.

Peterson has been involved in gas turbine O&M since the mid-1980s for several cogeneration projects. He was a co-founder of what it known today as the Frame 6B Users Group and remains active in that organization.

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Advanced Turbine Support 45
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Allied Power Group 54
Alta Solutions 34
AMETEK Power Instruments 22
AP4 Group 50
Avail Bus Systems, The Calvert Company 68
Baker Hughes 3
BBM-CPG Technology 2
Bearings Plus 33
Cascade MVS 14
Chentronics 30
Crown Electric 7
CTTS 59
CUST-O-FAB 10
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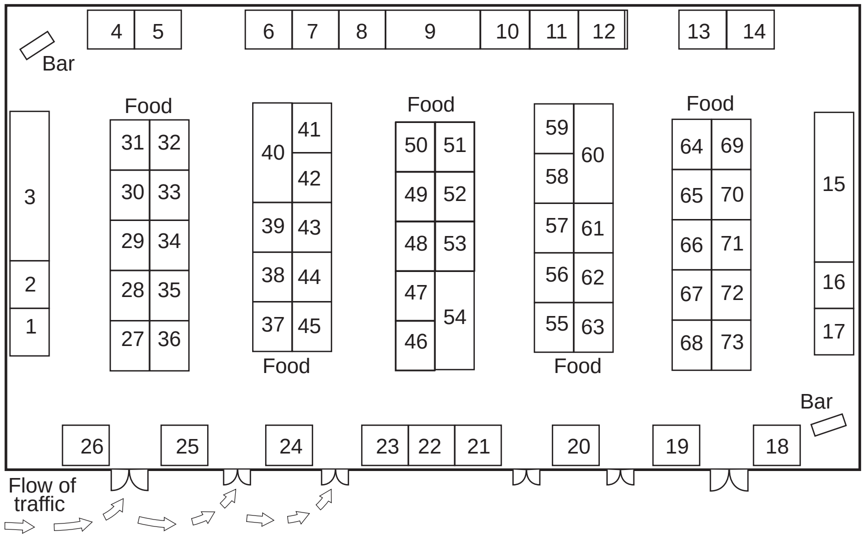
Turbine Services Ltd 47
Universal Plant Services 61
Veracity Technology Solutions LLC 51
Woodward Inc 70
World Wide Gas Turbine Products Inc 56
Young & Franklin 8

Akimel Ballroom



Exhibitors, booth number

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1 .... Hansen Turbine
2 .... BBM-CPG Technology
3 .... Baker Hughes
4 .... TRS Services LLC
5 .... Riverhawk
6 .... ISOPur Fluid Technologies Inc
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8 .... Young & Franklin
9 .... Sulzer Turbo Services Houston Inc
10 .... CUST-O-FAB
11 .... Advanced Filtration Concepts
12 .... TOPS Field Services LLC
13 .... Hy-Pro Filtration
14 .... Cascade MVS
15 .... GE Gas Power
16 .... Oilquip
17 .... Pioneer Motor Bearing Co
18 .... Nord-Lock Group
19 .... Republic Turbines
20 .... Electrical Builders Inc (EBI)
21 .... Schock Manufacturing
22 .... AMETEK Power Instruments
23 .... Turbine Generator Advisers
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25 .... Trinity Turbine Technology LP
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39 .... Nederman Pneumafil
40 .... MD&A
41 .... Power Services Group
42 .... HILCO Filtration
43 .... Freudenberg Filtration Technologies
44 .... Turbine Resources Inc
45 .... Advanced Turbine Support
46 .... EthosEnergy
47 .... Turbine Services Ltd
48 .... Independent Turbine Consulting LLC
49 .... Rochem Technical Services
50 .... AP4 Group
51 .... Veracity Technology Solutions LLC
52 .... Mee Industries Inc
53 .... K Machine
54 .... Allied Power Group
55 .... Emerson
56 .... World Wide Gas Turbine Products Inc
57 .... Philadelphia Gear
58 .... Liburdi Turbine Services Inc
59 .... CTTS
60 .... Doosan Turbomachinery Services Inc
61 .... SVI/BREMCO
62 .... Petrotech Inc
63 .... JASC
64 .... Precision Iceblast Corp
65 .... Integrity Power Solutions
66 .... Powmat Ltd
67 .... Donaldson Company
68 .... Avail Bus Systems, The Calvert Company
69 .... Gas Path Solutions
70 .... Woodward Inc
71 .... PowerFlow Engineering Inc
72 .... Stork
73 .... National Electric Coil

2023 technical program highlights

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

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

Monday, July 17

Morning. Introduction to legacy GE frames, presented by Engine Consultant John F D Petersen, a long-time contributor to the industry's collective knowledge (see article, p 68), originally focused on the Frame 6B and recently was expanded by Petersen to serve 7EA and Frame 5 owner/operators as well. This primer/workshop prepares all conference attendees—newcomers and experienced engineers/technicians alike—for a productive experience during the coming days.

Afternoon features user-only sessions for all three groups.

7EA. Independent Turbine Consulting will make two presentations: Vibration—what's wrong with my turbine and Outage planning best practices. Turbine Generator Advisers follows with Extreme ambient-temperature readiness; JASC closes out the day with a case study, Twenty years of liquid-fuel reliability.

Frame 5. Presentations/discussions will be conducted by Allied Power Group (Life extension—reliable operation beyond OEM design), PSM (Frame 5 combustion technology), Doosan Turbomachinery Services, and Cascade MVS. The last company specializes in field balancing of rotating equipment.

Evening (5:30 to 8:30) is reserved for the Vendor Fair.

Tuesday, July 18

Morning:

7EA. Advanced Turbine Support presents its annual review of What the company's inspectors are finding in the field, followed by user presentations and discussion. Next, Allied Power Group presents on S2 OEM bucket tip shroud material loss (findings and repair). A user presentation follows on Hydrogen fuel experience, with PSM taking the group to lunch with a thought-provoking presentation on Combustion and intelligent data solutions to meet grid demands.

Frame 6B. GE presents on a variety of topics of interest, followed by relevant discussion.

Frame 5. A Sulzer presentation on Thermal block overhauls and rotor lifetime evaluation is followed by case studies from Baker Hughes.

Afternoon:

7EA. MD&A presents first, on Turbine upgrade solutions; EthosEnergy

Group is next, on Rotor life extension—understanding new designs and benefits; CTTS follows on Compressor vane looseness—what to look for and what to do; SVI/Bremco closes the day with Case studies on turbine exhaust gas path and upgrades to improve, safety, reliability, and performance. Note that interactive discussion sessions follow each presentation.

Frame 6B. GE Day concludes with a series of breakout sessions geared to user interests.

Frame 5. Baker Hughes presentations followed by open discussion with attendees.

Wednesday, July 19

Morning:

7EA. GE Day presentations begin with a brief State-of-the-industry review followed by Things you should know regarding new TILs, RCA updates, etc. A discussion-focused case study of a Hydrogen/fuels conversion project in Florida is next, with New things to consider (the OEM's latest items in development and implementation) taking the group to the break. Final presentation of the morning features Reliability ideas—user case trends and recommendations by engineers from GE Product Service. That is followed by Breakout 1 featuring these concurrent sessions: Peaker roundtable, Cogen roundtable, Live outage, LNG roundtable.

Frame 5. Highlights are Baker Hughes case histories and a Vibration troubleshooting workshop conducted by Independent Turbine Consultants.

Afternoon:

7EA. Three breakout sessions, capped by Ask GE anything, complete the technical portion of GE Day. An offsite event hosted by the OEM runs from 6 to 10 p.m.

Components of Breakout 2 are Generator 101, Controls/software repairs, LNG roundtable; Breakout 3 features 7E 101, Combustion (DLN, MNQC), Live outage, and Generator 101; Breakout 4 offers Accessories/BOP reliability, Rotors and casings, Repairs, and 7E 101.

Frame 5. The basics of generator testing and inspection, a workshop conducted by AGT Services, dominates the program.

Thursday, July 20

Morning only; conference concludes at noon

7EA. Electrical Builders fills the first hour with Tips to avoid a failure—system critical bus function and maintenance mitigation techniques. MD&A follows the break with 7A6 generator high-speed balancing. Emerson completes the technical program with Planning a turbine control upgrade.

2022 conference report

7EA Users Group

In 2022, the 7EA Users Group joined the Legacy Turbine Users (LTUG) under the Power Users umbrella and co-located its annual meeting with those of the Frame 6B and Frame 5 Users Groups. The three independent conferences were held at the end of last summer in the San Antonio Marriott Rivercenter.

Themes from the 7EA meeting include outage activities and performance, compressor clashing events and solutions, rotor life assessment, blade pitting, bus duct refurbishments and replacements, exhaust system issues and repairs, combustor fuel nozzles, controls, and hydrogen (H_2) firing. Highlights follow.

As you read through the summaries below, keep in mind that you can dig into subjects of particular interest by reviewing the PowerPoints posted in the 7EA section of the Power Users website at www.powerusers.org. You must be a registered owner/operator to gain access, but that's a simple process if you're not already signed up.

Also, you can use the same gateway to review the presentations made at the Frame 6B and Frame 5 conferences. Abstracts of their content follow the 7EA material.

H_2? Been there, done that. Now that the Biden Administration is offering generous subsidies for H_2 production and firing, gas turbine (GT) owner/operators are undoubtedly getting more serious about that fuel. However, plant personnel want to know more about how hydrogen co-firing affects their equipment day in and day out.

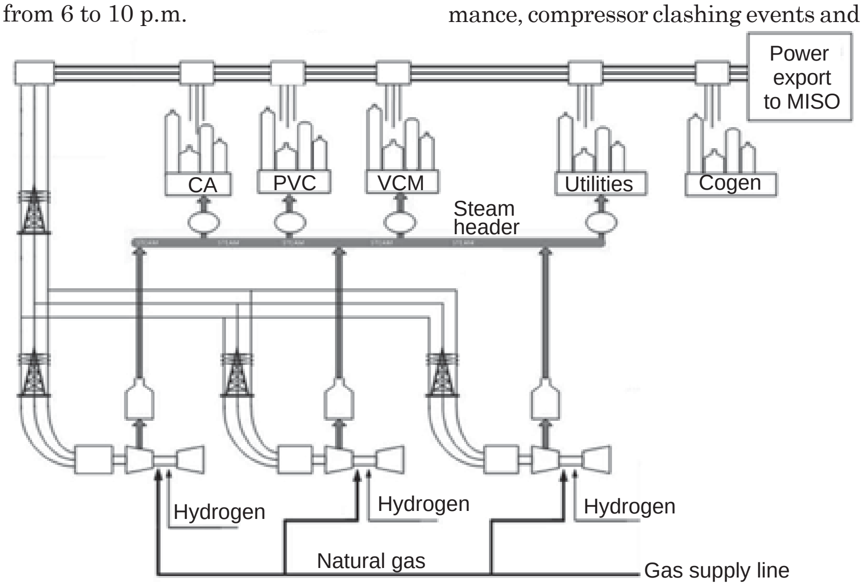
A plastics plant from the Gulf Coast co-firing H_2 for several years offers some valuable clues. One production area of this petrochemical complex makes chlorine from brine with H_2 as a byproduct, which is then compressed and filtered before it is fired in three 7EA GT/HRSG cogen units (Fig 1). With three GTs running, the percentage is around 20% (30% when two machines are operating). The state's Dept of Environmental Quality requires analyzing the H_2 stream for sulfur twice a year.

Even in a "poor performance" year, the plant saved over $4-million displacing natural gas. At full H_2 firing, the plant avoids 234 tons/day of CO_2.

The presenter reviewed the H_2 delivery system, mostly control valve and system mods and safety valves and logic, but noted "no special mixing equipment was required" for the GT combustors. Two O&M issues were detailed. Fuel-nozzle plugging is common during operation, but this is caused by impurities in the H_2 stream, oils and chlorides in particular. Condensate plugging also occurs under some conditions of natural gas and H_2 feed temperatures.

Regarding safety, there was a detonation of H_2 at the compressor when O_2 was captured in a filter and ignition occurred (source still unknown). The compressor was upgraded with O_2 meters and trip valves.

24-year scope outage. Representatives from the same site reviewed a 24-year major-scope outage with extensive list of lessons learned. End Result: 9.9% production improvement in one



1. Three 7EAs anchoring the cogeneration plant serving a major petrochemical facility has been burning 20% to 30% hydrogen, a process byproduct, for several years. Issues mostly focus on fuel nozzles and process impurities in the H_2 steam unit, 11.8% in another. Third unit is scheduled for fall of this year.

"Major" in this case means purchase of three new compressor and turbine rotors and one new generator field, upgraded compressor protection software, replaced/upsized CO_2 fire protection system (from 4 to 6 tons), replacement of one step-up transformer and the EX2000 excitation cabinet and software with a EX2100E model, and chemical cleaning of the high-pressure boiler.

Readers are urged to review slides 27-49 for the lessons learned, too voluminous to review here in the detail that they deserve, other than to generalize:

- Do not assume a new field was assembled properly in the factory.
- Verify conductivity between the field and the exciter.
- Do not trust that a new rotor from the factory is machined properly. Verify all specifications once the rotor arrives on site, not prior to installation.
- Confirm proper thermocouple penetrations pattern in the exhaust duct prior to fabrication and shipment.
- Blow down CO_2 piping and nozzles in the fire protection system, consider larger nozzles in the load compartment, and have a plan in place for extra CO_2 delivery (site almost exhausted its supply testing the system).
- Be aware of chain of custody when completing software logic changes, and make sure involved parties are communicating effectively.
- Verify torque-converter actuators are set specific to the unit.
- Verify inlet-guide-vane (IGV) low-voltage differential transmitter (LVDT) positioning versus the documented standard, and that the IGV angle is properly set while hydraulics are running before starting the unit, and not just assume the displayed value is correct.

The last slide in this deck gives qualitative assessments of the contractors involved in the work.

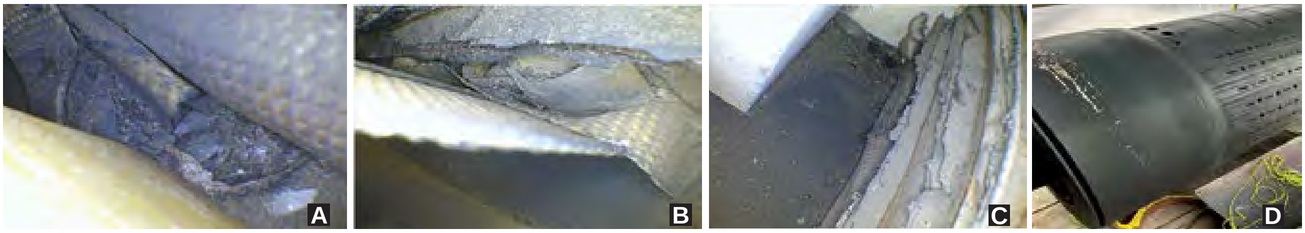
Stator vane replacement. A site with four simple-cycle 7EA units commissioned in 2002 replaced the S1-S4 stator vanes after they experienced clashing damage in all four units in 2015. True peakers, each unit had only between 3000 and 3700 fired hours, but between 460 and 485 starts. The clashing was discovered after a contractor had performed thorough borescope inspections. The recommendation was to continue operating but with borescope inspection every 24 starts; site personnel decided to inspect annually.

The four sets of vanes were purchased in 2019 at the tail end of the LTSA with the OEM. Outages were planned in 2020, and conducted in late 2020 and 2021. The units had not been taken apart since commissioning, so they "broke lots of bolts" but fortunately planned for this. The site took the opportunity to implement a long list of TILs as well. Other work included a CI inspection while the parts were out of the unit, rebuild compressor bleed valves, and readjust No. 2 bearing vibration probes.

One important detail that made the third outage "go like clockwork": The site requested, and got, the same crew from the OEM that had worked on the first two outages.

Generator rotor rewind. One of four generator rotors at this site with 32 trips, 938 fired starts, 959 total starts, and 7779 fired hours went through a rewind that necessitated the rotor being offsite for 53 days. Field windings, retaining-ring insulation, and retaining rings all experienced heat damage (Fig 2) and were deemed "not satisfactory," according to the GT OEM and the generator manufacturer.

You'll have to peruse the slides for details as this is essentially a pictorial story. The presenter did note that two main leads had to be built, as the old ones were destroyed during disas-



2. Heat damage to the 7EA generator field is revealed on the tie next to the retaining-ring insulation in **A**, on the insulation itself (along with copper dust as shown in **B**, on the retaining-ring insulation as shown in the turbine-end view—**C**, and on the retaining ring proper **D**

sembly. The unit has been operational since (Apr 5, 2022) with no issues.

Bus-duct replacement. A mid-South site with 12 gas turbine/generators replaced the rectangular non-segmented bus duct on Units 4-7 with the "industry standard" circular one (including heaters), relying on a temporary solution (use of ceramic internal duct insulators) for water ingress and pooling in the interim. The interim solution was half the cost of the permanent one so it made sense to go full on.

Three months after the purchase order was issued, equipment was onsite, with another two weeks for demo, installation, and commissioning for each duct. Before the approximately 20 photos of the work in the preso is a slide listing the advantages of the circular design: geometry allows easier shedding of water, all flanges are welded not bolted, rubber boot connectors reduce vibration stress points and act as seals, aluminum housing reduces rust and corrosion, and new ducts use existing bus structures with new mounting hardware.

Fleet issues. Insurers are not users but at least you can find the word "user" in the spelling, and their interests are generally aligned with the sites they protect. A representative from a major powerplant insurance firm reviewed 7EA fleet issues, ticking off a list of ailments and associated TILs any careful reader of CCJ is already familiar with—including compressor stage one vane distress, clashing, and compressor failures.

Perhaps less familiar is a relatively new loss-prevention tool, the clashing "ping test," developed by EPRI, which helps assess the risk of blade-tip liberation remotely through early detection of oxidation and debris accumulation. The method involves recording and comparing the sound, or "ping," of a tapped locked-up blade and comparing it to values for loose, or normal, blades. A few more details are provided in the slides but the complete procedure/protocol is covered in EPRI Report No. 3002010469, issued in 2017, "Pinging Protocol To Assess Operational Risks In Gas Turbine Compressors."

A preliminary conclusion from a survey involving 100 machines exhibiting clashing "seems to confirm that" clashing is more prevalent during operation below ambient temperatures of 50F and tends to occur at the bottom of the compressor. Also noted is that units with failures in Texas had a high-angle IGV opening.

LOTO near miss. In the category of, you can never be too vigilant about safety, a user from California briefed the audience on a near-miss during generator substation (GSU) repair. A plant engineer noticed a contractor performing a task that was not discussed in the morning's pre-job briefing meeting. The engineer halted the work.

Contractors were found checking voltages on a GSU cooler fan motor, and the breakers were not in lock out/tag out (LOTO) nor was this task part of the written scope, or the oral review which had just taken place. No accident, no injuries, and a huge win for "see something, say something" when it comes to safety culture.

Rotor blade tip distress. In a vendor presentation well-aligned with user interests, Mike Hoogsteden, Advanced Turbine Support LLC, catches your attention early. After a slide that says "What we are seeing in the 7EA fleet during inspections," he doesn't wait to let you know. Immediately below, in red cap letters is "Stage 1 still not addressed," referring to TIL-1854 addressing rotor-blade tip distress on compressor stages 2 and 3. To reinforce his point, he adds that the TIL does not address stage R1 or recommend in-situ inspections. The TIL also says tip losses are considered low risk—really?

Over 1400 in-situ dye penetrant inspections conducted by Advanced Turbine Support have revealed 75 cracked R1 rotor blades, and 55 blade tip liberations—42 stage R2 and 13 stage R3. "Low risk?" he asks again. The remaining several dozen slides review findings (pictorial and descriptions), associated TILs for different blade materials, and several solutions available, including an advanced in-situ blend technique, and equipment which can inspect from the IGV through stage 12. Also, this teaser at the end: "Generator robot anticipated release date fall 2023."

Minor to major. We're not talking baseball or music, but a generator case study. Jamie Clark, AGT Services

3. Updated circular isophase bus-duct support systems typically have fewer footers/columns and hangars than the traditional rectangular design

Inc, takes you on a pictorial tour of a 7EA generator that went from a major outage with minor findings (2013), to a minor "field in" outage (2019), and then to a major outage involving field and stator rewinds (2020).

Pitting detection tool. In a case of a user asking a vendor to develop a tool all users could benefit from, Kevin McKinley, Veracity Turbine Services, covers a corrosion-pitting inspection tool that can detect cracks in compressor airfoils. Reps at coastal or chloride-rich ambient environments (where pitting corrosion is more prevalent) take note.

In 2017, Veracity developed an advanced inspection protocol for 7EA S-1 airfoils combining phased-array UT (PAUT) and traditional eddy-current techniques to detect cracking in the center of the airfoil. The method has now been advanced and improved to identify and better quantify the degree of pitting and cracking across the entire airfoil surface.

In addition to interim borescope inspection (BSI), Veracity recommends performing PAUT and eddy current array (ECA) inspections of the first-stage compressor stators and rotating airfoils, This satisfies TIL-1884 and "exponentially increases the probability of detection of any cracks." For outage inspections, the company recommends the following protocol: 100% visual inspection to identify all rows with pitting, 100% eddy-current array on all rotating and stationary compressor airfoils, 100% ultrasonic phased array on all airfoils showing signs of pitting, and ultrasonic tomographic data for the worst-case pitting on each row that exhibits visual evidence of pitting.

He concludes with some photos from a field case study of an S-3 stator.

Emissions feedback control. Jeff Hansen, ODEC, shows screen shots and tutorials for Auto Tune and Peak Fire, the former a feedback control loop that takes live, actual continuous emissions monitoring system (CEMS) data in a feedback loop to control NO_x and CO emissions.

Briefly. . .

Exhaust frame mods. David Clarida, Integrity Power Solutions, provides an exhaustive list of exhaust-frame modifications and upgrade options. The slides begin with some basics of Frame 7 exhaust-frame design, components, and assembly options, then list typical problem areas (for example, flex-seal retention assembly, clamping-ring bolt clips) and upgraded design/

components for each. A second section does the same for the exhaust-frame aft diffuser—including inner-barrel circumferential cracking, aft flex-seal ring separation, and turning-vane cracking.

Bus duct H_2O. High-temperature unit cycling aggravates condensation in enclosed bus ducts. Mohsen Tarassoly, EBI (Electrical builders Inc), delineates a host of anti-condensation solutions— including drain plugs, isophase bus (IPB) insulator heaters, strip heaters, and dry air (air pressure) systems. If any of your equipment looks like what Mohsen illustrates with photos under "impacts of ground current and moisture combined" and "when to be concerned," you'll want to keep reading.

Exhaust gas path. Scott Schreeg, SVI/Bremco, lists common problems with the non-pressure parts of GT exhaust-gas-path systems, then explains the available inspection methods (mostly visual but also drone and thermography), and repair, replace, and upgrade considerations. Because design methods and materials have changed substantially over the last 30 years or so, there may be hidden opportunities to improve performance.

Circular non-seg bus. The high-amperage, circular non-segregated bus (Fig 3), an updated version of the non-segregated design pioneered by Westinghouse in the 1970s, is built like isophase and competitive with non-segregated design. So says Bruce Hack, Crown Electric/National Breaker Services, who also reminded the audience that Crown Electric built the newest IPB factory in North American in 2006.

The original design is prone to bolt/torquing issues, water ingress, and air/contaminant ingress because of the large number of joints (8-12-ft bolted sections). If you are experiencing these issues, and would consider a replacement with a modern circular design, Hack's presentation includes several dozen photos from a field install, along with factory photos identifying advantages and design nuances.

Controls. Abel Rochwarger, GTC Control Solutions, a division of ap4 Group, reviews the upgrade of controls for two gas turbines from Mark VI EX2100 and LS2100 to Mark VIe EX2100e and LS2100e.

Fuel nozzles. Joe Palmer, MD&A, tackles what he considers the most neglected aspect of a combustion system overhaul: the fuel nozzles. Improperly maintained nozzles affect most everything when it comes to performance—temperature spreads, flashbacks and lean blowouts, tuning, unwanted trips, etc. MD&A offers technically advanced flow nozzles that Palmer says improves on the OEM's tolerances by 50%. In-situ flow testing, developed in 2017, can identify nozzle issues or eliminate the nozzles as a culprit when investigating performance problems.

Rotor life assessment is a huge area of interest today and Mark Passino, MD&A, takes you on a tour of the capabilities of MD&A and MHI (parent company) in this area, based on more than 270 comprehensive GT rotor inspections, to identify and deal with: dovetail cracking; compressor and turbine-disc rabbet cracking; stage 1 and 2 disc dovetail wear, creep, and surface pitting; general lifecycle fatigue, especially arising from high-ambient-temperature operation; and other ailments. To serve the industry, MD&A/MHI has reverse-engineered, built, and validated all the components from a fully bladed, new-condition, 7EA compressor and GT rotor.

OEM versus non-OEM controls upgrade. Turbine Controls & Excitation Group, a division of ap4 Group, outlines some considerations for deciding whether to go with the OEM or non-OEM when needing what's commonly called the "digital front end" (DFE) of a GT control system—that is, removing or upgrading components of outdated controllers, CPUs, and other digital components. The presenter notes that firms are "practically giving the hardware away" in some cases to lure customers.

H_2-based decarbonization. If the Biden Administration's Inflation Reduction Act's (IRA) subsidies have your higher-ups scrambling to learn more about hydrogen co-firing, you can get smart in a hurry by studying PSM's comprehensive H_2 development program described in breathtaking detail by Jeff Benoit and Katie Koch. PSM's goal is to offer GTs up to 300 MW that can burn anywhere from 0 to 100% H_2 with one scalable combustion platform. The so-named "Hyflex" platform is part of a broad vision for PSM, Thomassen Energy, and their parent, Hanwha, to become "the most innovative GT partner with a global presence."

Fuel nozzle seals. Fuel-nozzle tip leakage impairs performance in a number of ways—ranging from nuisances to premature outages. Sulzer's Jim Neurohr explains the primary impacts of inadequate nozzle tip seals, how to test and check for leaks, sources of tip leaks, and then compares Sulzer's "zero-leak" solution to the OEM's.

Frame 6B Users Group

Annual meetings of the Frame 6B Users Group have four major components: User presentations, vendor presentations, roundtable discussion sessions chaired by members of the steering committee (sidebar), and GE Day. User and vendor presentations and outlines of the discussion sessions can be found in the Frame 6B section of www.powerusers.org, the GE presentations on the OEM's myDashboard website.

What follows is a summary of the user group's 2022 conference agenda to help identify those presentations that might benefit you.

User presentations:

Calculating compressor efficiency is a valuable teaching aid developed by J C Rawls, recently retired from BASF-Geismar.

GE 6B S1V clash, a case history based on ExxonMobil's experience, shows the damage that can occur if stator-vane rock is not addressed in your maintenance program.

Vendor presentations:

Gas-turbine train alignment, Troy Broussard of Cascade MVS, covers hot versus cold alignment, OEM targets, importance of measuring thermal growth, laser alignment, tolerances (spacer versus close-coupled), and a case history of Frame 5 alignment.

Mobil solvancer: Improving turbine reliability and reducing the cost of operation with advanced technologies, Jim Hannon of ExxonMobil.

Everything rotors, Katie Koch of PSM.

Hydrogen: Current and future capabilities of the 6B gas turbine, Jeff Benoit of PSM.

Combustion-system optimization, Jim Neurohr and Michael Andrepont of Sulzer.

Turndown or shutdown? Combating the effects of increased cycling, Jeff Schleis and Chris Chandler, EthosEnergy.

Rewinding HV generator stators, Gary Slovisky, National Electric Coil.

Discussion sessions:

- Safety roundtable, chaired by Mike Wenschlag.
- Auxiliaries roundtable, chaired by Zahi Youwakim.
- Inlet air roundtable, chaired by Mike Wenschlag.
- Compressor roundtable, chaired by Doug Leonard.
- Combustion roundtable, chaired by Robert Chapman.
- Turbine roundtable, chaired by Jonathan LaGrone.
- I&C roundtable, chaired by Kevin Campbell.
- Generator/exciter roundtable, chaired by Mike Adix.

OEM presentations:

- Driving reliability with monitoring and diagnostics.
- Interval extensions.
- Combustion technology refresh and deep dive.
- 6B: Global hydrogen leader and next steps.
- Extending the life of a 6B rotor.

OEM breakout sessions (all discussion):

- Combustion technology.
- Rotor end of life.
- Generator and excitation maintenance.
- Maintenance interval extension.
- Controls upgrades and instrumentation.
- Repair technology updates.

LTUG steering committees, 2023

7EA

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

Past members:
Joshua Coots, *Duke Energy*
Guy LeBlanc, *IHI Power Services Corp*

Frame 6B

Michael Adix, *Motiva Enterprises*
Kevin Campbell, *Chevron*
Robert Chapman, *Chevron*
Jonathan LaGrone, *Formosa Plastics Corp USA*
Doug Leonard, *ExxonMobil Technology and Engineering*
Mike Wenschlag, *Chevron, El Segundo Refinery*
Zahi Youwakim, *Indorama Ventures, Port Neches Operations*

Steering committee advisers:
Jeff Gillis, *ExxonMobil retired*
John F D Peterson, *BASF retired*

Past members:
J C Rawls, *BASF-Geismar*
Kevin Bovia, *BASF-Geismar*

Frame 5

Josh Edlinger, *Eastern Generation*
Shannon Lau, *Suncor Energy*
Logan Quave, *Indorama Ventures*

Frame 5 Users Group

The following is a summary of the user group's 2022 conference agenda to help identify those presentations that might benefit you.

Vendor presentations:

Frame 5's future as a critical peaking asset, Allied Power Group.

Wet low emissions technology to meet New York State's NO_x abatement program for Frame 5 turbines, Roy Milum, Petrotech.

Gas turbine train alignment, Troy Broussard, Cascade MVS. Joint presentation with the Frame 6B Users Group.

Decarbonization: Hydrogen and the current GT install base, Katie Koch and Jeff Benoit, PSM.

Methods to improve operational performance of GTs, LQ Lawson and Jeff Cozbey, Shock Manufacturing.

Vendor training workshops:

Generators, Jamie Clark, AGT Services.

Controls, Abel Rochwarger, GTC Control Solutions, ap4 Group.

Rotors, Paul Tucker, Don Norsworthy, and George Weilbacher, FIRST

Baker Hughes presentations

- Service engineering.
- Houston Service Center and BH repair network.
- Turbine upgrades.
- Certified renewed equipment.
- LT-16 brownfield replacement of older Frame 5s.
- Hydrogen fuel capabilities.
- Additive manufacturing.

BASF Geismar

BASF Geismar

Owned and operated by BASF Chemical Co

85 MW, gas fired, two 1 × 1 Frame 6-powered cogeneration units (one with an unfired HRSG, one fired) plus four conventional boilers and one small steam turbine/generator, located in Geismar, La

Plant manager: Graham White

Increase equipment protection using duct-burner firing overrides

Challenge. Plant's HRSG duct-burner firing rate (fuel control valve) was controlled solely by the Boiler Master controller based entirely on steam demand. If it called for more steam, the gas valve opened to send more fuel to the duct burners which, in turn, produced more steam. This control scheme ignored all other operating parameters, with the exception of high duct temperature, to control the steam production rate.

But other parameters also are important to control to protect the equipment. What if the steam temperature is too high, or the drum level too low, or the burner pressure too high, etc? While there are specific controls designed to regulate these important parameters, malfunctions can occur that allow them to drift out of control with the consequence of failure being greater at higher firing rates.

The duct-burner firing controls (Boiler Master) did not monitor these important process parameters when deciding the firing rate; therefore, the unit was at risk of equipment damage or of tripping if the firing rate pushed the process parameters too far out of range.

Solution was to create some controllers that monitored these other important equipment protection parameters and allow them "to have some say" in the firing rate. As a process-control improvement initiative, "firing overrides" were programmed based off of critical process parameters. Besides the existing duct-temperature limit, overrides for the following parameters were installed:

- High steam temperature.
- High steam flow.
- High burner pressure.
- Low steam-drum level.
- High steam-drum level.

Most of the time, these critical process parameters would remain within the desired range and thus the overrides would not be triggered or have any effect upon the process (that is, the output value from each override would be zero).

But suppose, for example, an issue developed with the HRSG desuperheater system which resulted in insufficient steam cooling. Instead of continuing to fire at high rates that could produce excessively high steam temperatures (high enough to damage the superheater tubes or downstream piping), the high-steam-temperature override controller output value would increase, and this would lower the firing rate by automatically reducing the Boiler Master signal value.

A warning alert would activate to notify the operator that an override was active, requiring investigation. It was considered abnormal/unacceptable to continuously operate with an active override.

This "override" philosophy could include other process parameters that could be affected by burner firing rates. High drum pressure, high stack emissions, high tube temperature, or poor steam quality (possibly resulting from carryover), for example, also could be used to override firing rates.

When using these types of override controllers, consider the consequences of a failed instrument providing information to the override. In BASF Geismar's case, the output range of each override controller was limited to the minimum amount believed necessary to correct the process abnormality.

Results. On several occasions since their implementation, the overrides have kicked in to limit the duct-burner firing rate, thereby protecting equipment. The most frequent override to activate was high steam temperature. Some of these incidents were caused by desuperheater valves failing closed, a manual valve inadvertently left closed during startup, and failure of a temperature transmitter used to calculate the appropriate desuperheater water flow rate.

On one occasion, a freak incident occurred when a piece of steel inside the steam drum detached, partially plugging the drum outlet pipe. The obstruction reduced steam flow through the superheater. This led to very high steam temperatures, activating the override to cut back the firing rate and prevent the drum from over-pressurizing until the failure could be identified and the unit shut down. Staff believes the high-steam-temperature override controller has averted major equipment damage more than once.

Project participants:
J C Rawls, technology engineer (utilities department)
Troy Braud, DCS programmer

Upcoming conferences for users

June 5 - 8, Siemens Energy, Large Gas Turbine Conference, Orlando

Siemens Energy's LGT Conference is for owner/operators of the following gas turbines: 8000H, 501G, 501F/5000F, 501D5-D5A, and 251B10-12. Registration is by invitation only. If you qualify for participation and have not received an invitation, please contact dawn.mccarter@siemens-energy.com. Venue for this year's meeting is Renaissance Orlando at SeaWorld®.

What follows is an overview of the meeting's technical content. Note that the two sessions allocated for each of the engines identified above total at least six hours of presentation/discussion time, allowing the experts to dig deep into topics of importance. Special sessions also have been set aside for user-only discussions.

Tuesday, June 6, highlights include the only steam turbine and generator sessions on the program. The generator session covers these topics, among others: rotor lockup update, SGen-1000A end blocking recommendations, overview of the SGen-1000A cooling control system, and generator monitoring with GenAdvisor.

The steam-turbine session includes updates on titanium blading and valves, plus coverage of the KN MAD 11 bearing and experience with very-low-load operation.

The first of two 251B10-12 sessions also is on the Tuesday program. Content includes technical updates on IGVs, vibration, exhaust tunnel, bleed valves/actuators, and R1 turbine blades. Plus, a review of recent events, product improvements, and rotor and casing inspection and evaluation (RCIE).

Siemens Energy's Technology and Innovation Showcase is open from 4 p.m. to 7. This robust exhibition includes booths/displays by Siemens Energy and the company's key suppliers. The two-dozen or so participants in the latter group include Arnold Group, Bearings Plus, Caldwell Energy, Frenzelit, Groome, Kingsbury, Nord-Lock Group, Parker Hannifin, Pioneer Motor Bearing, REXA, and Shock Manufacturing.

Wednesday, June 7, and Thursday, June 8, feature sessions on all of the engines addressed at the conference; agenda highlights for each frame are below, except for the 251 covered Tuesday. Receptions both evenings promise relaxing conclusions to both days.

8000H. Updates on the turbine, VGV, rotor, and casing. Plus, mods and upgrades, plant solutions, starting reliability, igniters, low-load turndown system, gas-assisted fuel-oil start, combustion, and field-service innovation.

501G. Updates on fleet technology, fleet support, NextGen system, R1 vanes, R4 blades, kettle boiler, rotor program, TMS, and supply chain. Plus, R3 blade-ring assembly findings, compressor maintenance, debris review, parts life extensions, fleet pool planning, etc.

W501F/5000F. Compressor: VGV, HSB diagrams, lock bolt. Combustion: ULN overview, liquid fuel. Turbine: Blade-tip rubbing, vane carrier deflection, ISSH overview. Rotor: Air separator, torque tube, vibration, belly bands. Casings and exhaust: RCIE, trunnions.

W501D5-D5A. Technical update, product improvements, and recent events.

June 6 – 7, 501D5-D5A Users, 24th Annual Meeting, Chattanooga

Venue is the Westin Chattanooga.

Day One highlights: Keynote address by Larry Sparks, TVA general manager for outages and projects; closed user session; closed user session with premium vendors; vendor fair.

Day Two features closed user sessions that include presentations by owner/operators on the following topics: Gray's Ferry mods and upgrades; issues shared by Borger Blackhawk; 2022 catastrophic failure at Olin Corp; TVA parts experience.

Premium-vendor participation: Allied Power Group, Camfil Power Systems, Doosan Turbomachinery Services, National Electric Coil, Sulzer Turbo Services Houston, and Trinity Turbine Technology.

Other vendors participating: Parker Hannifin, Petrotech, Pioneer Motor Bearing, ROMCO Manufacturing, Schock Manufacturing, and TOPS Field Services.

Questions? Contact Gabriel A Fleck, PE, at chairman@501D5-D5AUsers.org.

June 20 – 22, Air-Cooled Condenser Users Group, Annual Meeting, Richmond

Venue is Dominion Energy's Innsbrook Technical Center in Glen Allen, Va.

Chairman Andy Howell, EPRI's technical executive for Boiler and Turbine Steam and Cycle Chemistry (ahowell@epri.com), reports that the user group's 2023 conference will be organized similarly to those in past years: two days of classroom-style presentations/discussions followed by a field trip.

The former cover subject matter on corrosion and chemistry (moderated by Barry Dooley of Structural Integrity), design and performance (moderated by Riad Dandan of Dominion Energy), and O&M (moderated by Rishi Velkar of NV Energy). Status reports on guidance documents published by the user group and IAPWS (International Assn for the Properties of Water and Steam) are included in the classroom program.

This year's field trip is to Dominion Energy's Greensville County Power Station, a 1588-MW, 3 × 1 combined cycle with an 80-cell ACC, one of the world's largest.

The classroom agenda, which has not been finalized as CCJ goes to press, is likely to include the following:

- Case study: Persistent air in-leakage problems and resolution.
- Structural design improvements for fan durability.
- Steam-side chemistry and corrosion in ACCs.
- Thermocouple installation and subsequent benefit for wintertime and periods of low generation.
- Update on ACC installation at a large waste-to-energy plant.
- Air in-leakage case report.
- Case study: Fan upgrades.
- Air in-leakage ACCUG guidance document.
- Wind mitigation ACCUG guidance document.
- ACC steam-side finned-tube corrosion downstream of tube entries.
- Update on hybrid cooling retrofit installation.
- Drone inspection of ACC heat distribution with infrared camera.
- CFD study of ACC airflow and performance-improvement potential.
- Gearbox oil and other improvements at the Greensville County Power Station.
- Stellenbosch University ACC research update.

July 23 – 27, Ovation Users' Group, Annual Meeting, Pittsburgh

Venue is the Westin Convention Center Hotel.

The Ovation™ Users' Group annual conference, now in its 36th year, offers an opportunity for automation professionals in the power industry to engage with their peers, broaden their knowledge base, and gain valuable insights from industry experts on the latest tips and tricks, implementation successes, and proven project solutions.

Subject-matter experts will share their expertise during the conference technical breakout sessions, with a spotlight on new Ovation 3.8 features and an introduction of Ovation Green, a dedicated portfolio of software and automation solutions for renewable energy.

Additional discussion topics include the following: advanced applications, alarm strategies, analytics, connectivity and networks, controllers and I/O, cybersecurity, enterprise data solutions, remote operations, simulation, and turbine solutions and excitation.

An expanded exhibit hall offers the opportunity to speak with Emerson experts and participate in demonstrations of the most innovative software, automation technologies, and services available to the industry today. Plus, the company's industry partners will be showcasing their products and services, highlighting how they partner with Emerson to make attendee plants and processes more productive.

Agenda highlights:

Monday, July 24.

8 a.m. to 5 p.m. General session, industry sessions, and open forum.
5 to 7. Exhibits and product demonstrations.
7 to 9. Networking dinner.

Tuesday, July 25.

8 a.m. to 4:30 p.m. General session and technical breakout sessions.
4:30 to 6. Exhibits and product demonstrations.
6 to 10. Networking reception and dinner.

Wednesday, July 26.

8 a.m. to 4:30 p.m. Technical breakout sessions and technical panel.
4:30 to 6. Exhibits and product demonstrations.
6 to 10. Networking reception and dinner.

Thursday, July 27.

8 a.m. to noon. General session and technical breakout sessions.
1 to 4. Optional training seminar: A deep dive into the Ethernet Link Controller. Recall that your ELC can help with faster, more efficient integration of robust data from third-party devices. What you will learn by participating in the seminar:

- Configuring the ELC for connectivity to the I/O level.
- Easily add new communications protocols.
- Options for full communication redundancy.
- Benefits of the SCANblock function.
- Time-stamping for sequence-of-events, alarms, and historical storage.
- Helpful troubleshooting tips.

INDUSTRY BRIEFS

Electric power industry loses two giants: Joe Liburdi and Jane Hutt

Liburdi Engineering Ltd's founder, Joe Liburdi, well respected by gas-turbine owners and operators worldwide, died in mid-March. He started the company in a modest rental unit near Westinghouse Canada in Hamilton, Ont, Canada, in 1979, and over the next 43 years expanded the firm into a reputable global organization.


Joe Liburdi

Liburdi was known for his unwavering commitment to quality, workmanship, and safety. He was a trailblazer in the gas-turbine repair and welding automation industries, having introduced numerous pioneering technologies that form the basis of more than 30 patents in the materials and joining fields.

Liburdi was a philanthropist and community leader and a generous supporter of higher education and various charities. His kindness, humility, and wisdom touched the lives of all who had the privilege of knowing him.

Jane Hutt is best known by the industry at large for her leadership in the creation and development of the International Generator Technical Community online forum that today serves 5300 members in 124 countries. Her day job was marketing manager for National Electric Coil, which she joined in 1996. The first post on the IGTC was in December 2009. Although Jane retired from NEC in 2018, she continued as the IGTC Webmaster until her passing in early February.

Hutt's relentless work on behalf of the industry earned her the chairperson positions of several groups within the American Society of Mechanical Engineers—including Turbine Generator and Auxiliaries, Public Affairs, Prime Movers Awards, plus

Jane Hutt

secretary of the Puget Sound Section. Most recently she served the Generator Users Group, which operates under the Power Users umbrella, as an advisor.

Hutt was recognized by the ASME with the society's Dedicated Service Award, and by the GUG with its 2018 Maughan Award. Inscription on the latter reads, in part, "For her outstanding leadership in the pursuit of open communication between generator users and the design/maintenance community."

The Air-Cooled Condenser Users Group (ACCUG) held its 13th Annual Conference, in person, at the Hilton Stamford Hotel and Executive Meeting Center in Stamford, Ct, Sept 13-15, 2022.

A few weeks earlier, ACCUG conducted its first no-cost virtual training session on some items covered at the conference (Sidebar 1).

ACCUG is the electric power industry's only user group dedicated to discussing and resolving operation and maintenance (O&M) issues with air-cooled condensers. Annual conference topics include corrosion and chemistry, design and performance, O&M, and publishing of ACCUG Guidance Documents.

More than 50 attendees discussed these topics at the 2022 meeting, followed by a tour of the induced-draft ACC now in operation at nearby Competitive Power Ventures' (CPV) 805-MW Towantic Energy Center, commissioned in 2018 (Sidebar 2). Andy Howell, EPRI's technical executive for Boiler and Turbine Steam and Cycle Chemistry, chaired the event.

Below are conference highlights as a guide for the 2022 presentation materials now available at https://acc-usersgroup.org/presentations/accug-2022/.

Reliability

Rishi Velkar, a plant supervisor at NV Energy, gives specific examples for various reliability programs in *ACC reliability improvement*. Most who have visited an ACC will appreciate the elevator installed in 2016. The only follow-up costs have been annual certification and testing, and one overspeed governor replacement.

Elevators help with inspections, maintenance, carrying of supplies, walkdowns, and in one major case, a contractor life-threatening health rescue, and now are installed on all NV Energy ACCs.

Velkar discusses a master control console for fan motors, and repairs to a fan cubicle, all listed as low-cost derate avoidance. He also outlines a $1 million estimate for specific vibration, and oil pressure and temperature, monitoring equipment and upgrades. Velkar shows new cranes and concrete landing structures for gearbox replacements and drawings for a rupture-disc exchange.

He ends with a list of upcoming projects (fan motors and blades, motorized vacuum pumps, and an auxiliary boiler to hold vacuum and improve startup).

ACC 2023 June 20-22

The Air-Cooled Condenser Users Group's 2023 meeting will be held at Dominion Energy's Innsbrook Technical Center in Glen Allen, Va, June 20-21. Thursday, June 22, is reserved for an optional tour of the utility's Greensville County Power Station's ACC.

Visit https://acc-usersgroup.org for meeting details, hotel suggestions, registration, etc. Questions? Contact sheila.vashi@sv-events.net.

Warsaw waste-to-energy

In Poland and most of Europe, greenfield powerplants with ACCs have strict design targets being met by a new waste-to-energy unit presented by MVM EGI (Hungary). Details are provided in the PowerPoint, *ACC of largest waste-to-energy plant under construction in Poland.*

MVM EGI is a global cooling system provider based in Budapest; MVM Group is the largest power utility in Central and Eastern Europe.

Because waste-to-energy plants usually are located in or near cities, common benefits of this new unit include:

- Low-noise operation.
- Small visual impact.
- Small footprint.
- Zero water discharge.
- No plume.

The new unit in Warsaw (Fig 1) meets these objectives for cost-effective dry cooling and features ease of operation and maintenance. At 25 MW, the project will be the largest of its type in Poland.

The forced-draft ACC is located on the roof of the steam-turbine building (Fig 2), and wind characteristics and air flow are altered by the boiler building and high elevation. György Budik, commercial director, reviews the CFD analysis and wind-load calculations, as well as foundation and structural steel requirements.

He also explains the design challenges for expansion joints and other critical components, as well as special measures taken to avoid freezing. Limited space for the exhaust steam duct called for unique solutions for expansion joints and load-bearing parts of the duct (Fig 3).

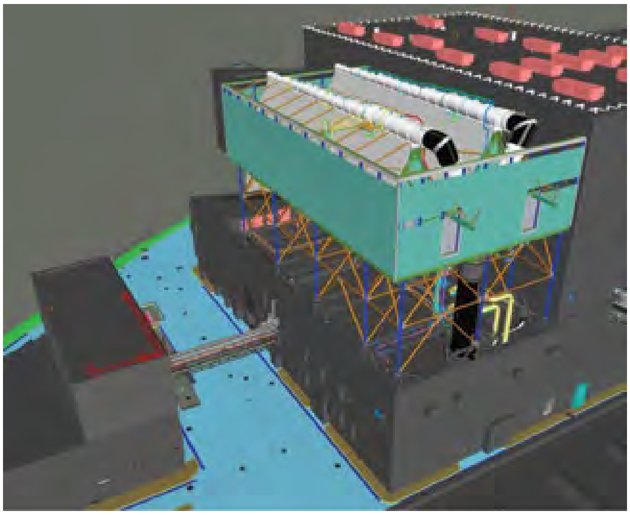
Because the plant is used for district heating in winter, evaluation of anti-freezing measures is discussed in detail.

Corrosion and chemistry

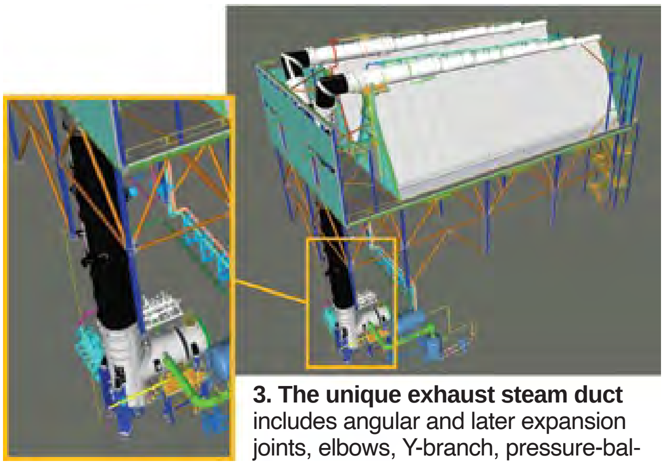
In *ACC corrosion and cycle chemistry,* Howell presents information provided by Barry Dooley of Structural Integrity. He launches into flow-accelerated corrosion (FAC) and its consequences, then moves to inspections using the Dooley-Howell Corrosion Index method (DHACI), followed by an update on film-forming substances.

He stresses that corrosion and

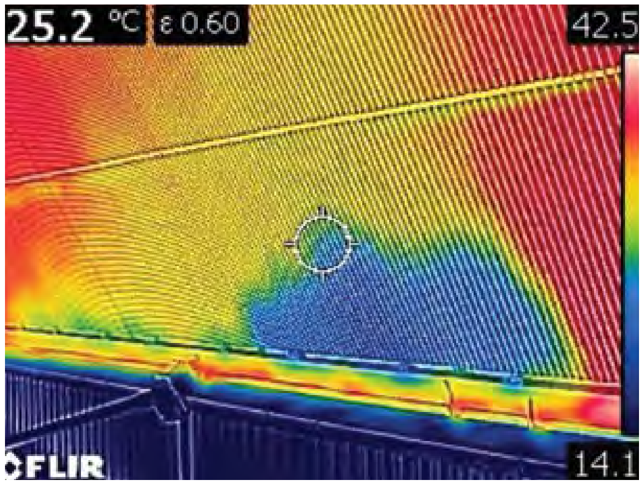
1. Poland's largest waste-to-energy plant in Warsaw features minimal visual impact and low-noise operation



2. ACC wind load characteristics are atypical due to location beside the boiler building



3. The unique exhaust steam duct includes angular and later expansion joints, elbows, Y-branch, pressure-balanced expansion joint, and integrated drain pot



4. Air pockets are visible in cold sections of the A-frame bundles

chemistry issues are common worldwide, regardless of unit size or location.

DHACI has become an accepted global method for accurately measuring and monitoring corrosion in critical parts of the ACC (tube entries, cross-member supports, lower ducts, etc). The index is discussed in detail in *ACC.01: Guidelines for internal inspection of air-cooled condensers*, available at https://acc-usersgroup.org/reports/. It reliably indicates high iron concentrations within the cycle. Consequences can include the following:

- HRSG deposits requiring expensive chemical cleaning.
- HRSG tube failures caused by overheating, under-deposit corrosion, and hydrogen damage.
- Steam turbine deposits.

Corrosion/FAC in the ACC therefore reveals the need for iron removal processes, condensate polishing, and/or filters—also discussed in the conference.

Howell clearly states two important points:

1. As explained in earlier conferences, the relationship between total iron and pH is consistent worldwide, and corrosion leads to elevated iron levels throughout the system. With the accuracy of the Dooley/Howell index, monitoring the ACC can essentially help control unit cycle chemistry.

2. Evidence is global and consistent, drawn from specific operating experience in the US, Australia, Canada, Chile, China, Cote d'Ivoire, Dubai, India, Ireland, Mexico, Qatar, Abu Dhabi, South Africa, Trinidad, and the UK.

Howell moves to a brief discussion on how ACC two-phase FAC appears arrested with film-forming substances (FFS). For a review on this expanding topic, see https://www.ccj-online.com/protection-of-metal-surfaces-a-wakeup-call-on-film-forming-substances/.

He ends with a quick review of selected Technical Guidance Documents published by the International Association for the Properties of Water and Steam (www.iapws.org) with particular relevance to plants with ACCs.

Flow-accelerated condensate corrosion (FACC)

Howell then turns to his own presentation and expands with *Steam cycle chemistry items in ACCs,* highlighting idiosyncrasies of steam-side corrosion based on microscopic investigations that reveal some variations from typical two-phase corrosion.

Those who want the details should look here and dive into the intergranular faceted surfaces and cross-section microstructures that show what Howell calls "flow-accelerated condensate corrosion (FACC)." Microscopic observations indicate the differences.

He explains further distinguishing conditions such as operating temperatures below those optimal for single- or two-phase FAC, and an observation that under consistent conditions, metal loss may actually stop if relative stability is reached in the corrosion process.

This leads to a focused discussion on film-forming chemicals and equilibrium.

Condensate polishing

A discussion on *Condensate polishing in ACCs* reminds that "if properly designed, installed, maintained, and operated, polishing ensures that condensate directed towards the boiler/HRSG will be high quality and have minimal contamination."

Although required for once-through boilers and nuclear steam generators, polishers are an option for most combined-cycle HRSGs and that decision is based on many factors. Both deep-bed and powdered-resin types are reviewed.

For air-cooled plants, the most common sources of steam-cycle contamination are air in-leakage (AIL, the primary source), makeup-water system failures, contamination of chemical treatments, poor practices in regeneration of deep-bed polisher resin, and decomposition of resins at elevated temperatures.

This presentation also discusses polishing for once-through steam gen-

1. ACCUG's first virtual training session addresses air in-leakage, corrosion, and more

The Air-Cooled Condenser Users Group held its inaugural no-cost virtual training session last July (2022)—a two-hour online event focused on air in-leakage, corrosion, and ACC performance enhancements.

Moderators/presenters were Riad Dandan (Dominion Energy), Rishi Velkar (NV Energy), Barry Dooley (Structural Integrity), and Andy Howell (EPRI).

Co-host Howell began by explaining that content was based on input, questions, concerns, and ideas raised recently through discussion forums at https://acc-usersgroup.org.

The international assembly numbered 150 participants.

CCJ participated, finding value in the technical content, Q&A, and ideas to share with its readers. The takeaways, outlined below, offer insights, verifications, new approaches to old problems, and troubleshooting experiences that can apply to nearly all powerplants.

Air in-leakage. Most air-cooled condensers operating today are large units made of thousands of finned-tube bundles acting as the heat-transfer surface to condense turbine exhaust steam (forced convection). Condensing creates a required internal vacuum, but also raises the threats of air in-leakage and dissolved oxygen in the condensate.

All ACCs, whether forced- or induced-draft, are elevated structures to allow required air flow up and over the tubes.

Large units can contain more than 20,000 tubes—that's 40,000 tube welds with in-leakage potential. In-leakage opportunities also exist throughout ACC system components and connections.

Checking for leaks is complex, painstaking, and should be comprehensive. As one presenter clearly encouraged: "Don't forget ground level."

Here are a few examples of leakage potential, beyond the tubes themselves:

- Welds.
- Valves.
- Expansion joints.
- Bolts.
- Any corrosion areas.
- Rupture discs.
- Piping under insulation.
- Previously repaired leak areas.

Testing complications are many, and include factors such as:

- Size and volume of the structure.
- Height and testing access.
- Weather and winds.
- ACC fan operation during testing.
- Cost of tracer gas and restrictions on alternatives such as SF_6.

Traditional detection methods and their normal frequencies and challenges were covered. Other alternatives, such as infrared (IR) scanners/cameras and acoustic leak detection, received mention.

Discussions quickly turned to the effect of in-leakage on dissolved oxygen within the system, and O_2 levels considered acceptable for normal powerplant operation. Barry Dooley offered that less than 10 ppb at the condensate pump is considered normal when deaeration is part of the system, but this depends upon unit design, location, and ambient conditions.

"I have seen up to 600 ppb, which is very unusual," he explained. "Normally, levels of 20 to 40 ppb are considered high." Dooley added, "High oxygen levels can occur during cold start, but should soon settle unless there is leakage."

Howell then offered a rule of thumb: "I would not advise doing a helium test unless there is a reason, such as high oxygen/carbon dioxide or abnormally high air ejection. If there is little indication of a leak, any present will be small and difficult to locate."

Other system chemistry discussions followed, although online time was limited.

Participants were then encouraged to use the forum at https://acc-usersgroup.org for further questions and to share thoughts with other users.

Chemistry and corrosion. Dooley presented 10 slides on common chemistry concerns, most raised by participants during their registrations. Topics included common damage conditions, and the relatively new topic of film-forming substances for metal protection.

Flow-accelerated corrosion and detection methods dominated the discussions.

Performance. "Performance enhancements are always important, but become even more so in warmer weather," explained Howell. "No ACC is big enough at 100F ambient to achieve ideal backpressure for the power cycle."

Ideal operation is difficult to achieve, but many basic search strategies for improvement include these:

- Open doors.
- Gaps in the tubes.
- Bent fins.
- Recirculation of warmer air from perimeter cells.
- Need for tube fin cleaning.

Other improvement strategies could include:

- Spray misting.
- Adding a small condenser and wet cooling tower.
- Deluge cooling (flooding a tube row).
- Fan uprates.
- Wind screens.

Questions and concerns. The final section, led by NV Energy's Velkar, reviewed other questions submitted by attendees. Principal topics were:

- The effects of ambient wind speed and direction.
- Wind-induced blade cracking concerns.
- Variable-speed fan experience.
- General ACC cleaning methods.
- Common gearbox issues.

CCJ's Scott Schwieger, who coordinated and managed this two-hour event, offered a list of selected fundamental resources for the ACC community:

- https://acc-usersgroup.org
- https://filmformingsubstances.com
- https://iapws.org

Ongoing forum, future events. Online discussion forums are available at https://acc-usersgroup.org/forums/ and include announcements from the group's steering committee for upcoming events.

Technical discussions are available under these categories:

- Design.
- Fans and gearboxes.
- Inspection.
- Operation and maintenance.
- Performance issues.
- Steam cycle, chemistry, and corrosion.

Future online virtual discussion sessions will be announced in CCJ and at https://acc-usersgroup.org.

erators with ACCs and hybrid-cooled (wet/dry) systems.

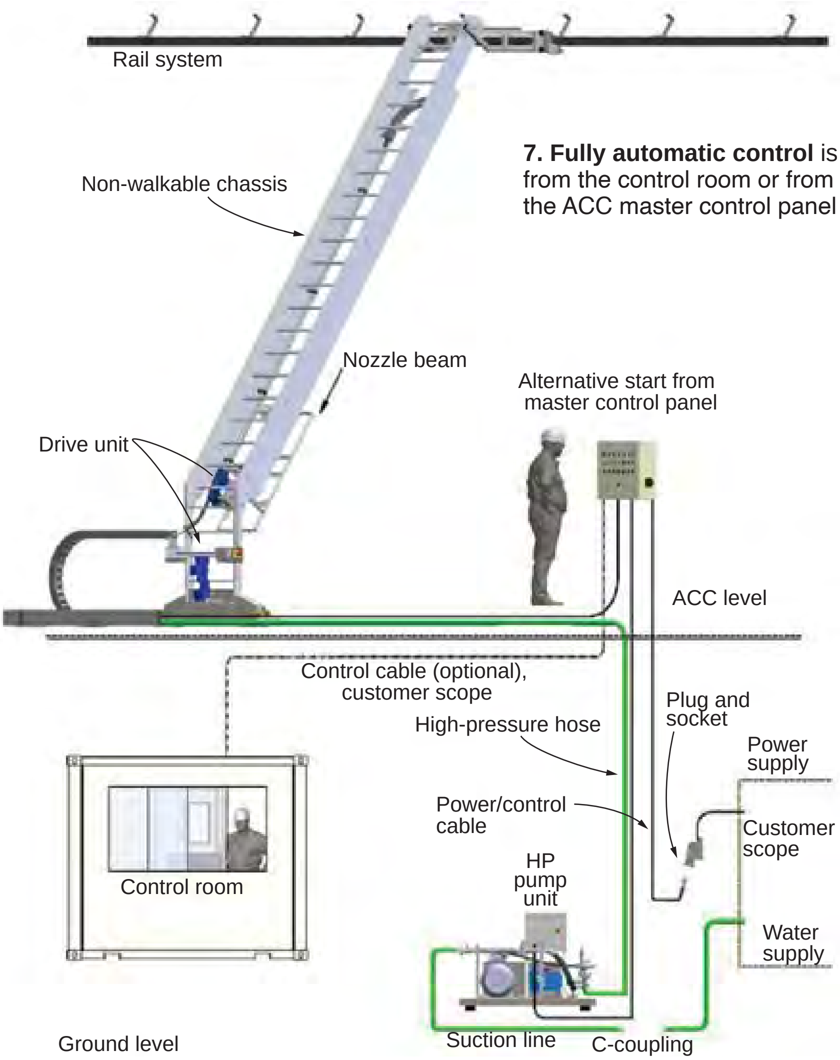
The conclusion: "Condensate polishing is problematic in use with ACCs and multiple factors should be evaluated to determine whether polishers are useful for a specific plant and, if installed, how to select, design, and operate polishers for optimum performance under ACC conditions."

Air pockets

Evapco Dry Cooling discusses the causes, effects, and prevention of *Air pockets in ACC tubes*. Primary causes are backflow, vacuum system perfor-

5. The Distran Ultra Pro (left) makes image-based results available for air in-leakage detection (right)

6. ERDCO's Armor-Flo device links to the plant DCS



7. Fully automatic control is from the control room or from the ACC master control panel

mance, excessive saturated oxygen, and excessive air ingress. Common results are reduced ACC performance and freezing risk.

In A-frame units, air pockets are visible in cold sections of the bundles (Fig 4). The presentation walks through the process where, during backflow, steam condenses but air can be left behind in pockets.

Capacity differences in the tubes are generally from air velocity or temperature differences at the face of the tube bundle. Air pockets can form in the higher capacity tubes with lower relative air temperature or higher relative air velocity.

Vacuum system performance is also an issue because vacuum is necessary and "no ACC is 100% leak tight."

In addressing excessive saturated oxygen, the presentation covers the various deaerator types and expected O_2 levels.

Air-ingress discussions include examples of leaks seen near valves and turbine shaft seals. Detailed case studies on prevention and proper ACC design close out the presentation.

Helium and options

In *Alternatives to helium for AIL detection in ACCs*, Howell first presents the benefits of helium tracer gas for leak detection:

- Almost always used for AIL into the vacuum created by powerplant condensers.
- Can be challenging for ACCs because of structure size, additional potential leak locations, and the effects of air currents (tracer must be applied close to point of in-leakage).

Therefore, time requirements can be extensive. Primary alternatives are infrared cameras and acoustic measurement. Coverage of the pros and cons of these alternatives is excellent.

Basics for infrared are:

- Availability and convenience.
- Easy temperature adjustments.
- Relatively rapid process.
- Good screening tool for follow-up helium testing of specific areas.
- ACC remains in operation.

Howell then reviews equipment and processes and offers some interesting tips for infrared surveys, such as recording only on the outside of fan modules and easier detection in cold weather.

For acoustics (Fig 5):

- Both audio and imaging-based results now available.
- Improvements made in background noise cancellation.
- Good screening tool for follow-up testing.
- Best when unit is offline supporting vacuum.

He again presents typical equipment and experiences.

Howell ends with an ERDCO Armor-Flo® device for continuous

2. CPV shares experience with Towantic's induced-draft ACC

Competitive Power Ventures' Towantic's air-cooled condenser is a V-frame/W-style Enexio induced-draft system composed of six streets, each with five fans (Fig A). There are 18 condenser (C) sections and 12 dephlegmator (D) sections, with steam isolation on streets 1, 5, and 6.

Recognized basic advantages of induced-draft systems are reduced total ACC height (less visual impact), smaller footprint of columns, and lower initial cost over traditional forced-draft units.

CPV's Nick Levandoski takes this further, both pros and cons:

Operationally, there is less vibration stress due to elimination of the fan bridge for possible longer life of gearboxes and fans.

He lists more operational advantages:

- Reduced auxiliary power is possible because of a lower pressure drop on the air side.
- Less hot air recirculation.
- Less sensitive to wind effects.
- Higher flexibility of sectionalizing (part-load operation) if required.
- Uniformity of air flow is improved over the face of the ACC heat exchanger tubing.

A few negatives discussed during his presentation include access from the walkway to the elevated motors and gearbox, and cleaning space limitations.

The main steam duct at Towantic is of all-welded construction for leak avoidance (Figs B and C). Length is more than 300 ft and the largest section diameter is 23 ft. Seven steam ducts then run across the top.

The steam header conveys steam to the condensing cells. Condenser tube bundles are installed below the fans. Condensing cells 1, 3, and 5 are parallel-flow tube bundles. The second and fourth cells in each row are combination modules which contain parallel condensing and counterflow D bundles. The D bundles are connected to the condenser air extraction system for removal of air and non-condensable gasses.

Expansion joints are varied:

- Single hinged.
- Tied universal.
- Dogbone.
- Single (2).

The Alex-system tube bundles are single-row, single-pass heat exchangers composed of relatively flat cross-section tubes (8 × 0.75 in.) with aluminum fins. All condensing bundles are welded together to the steam header. At the lower ends, all bundles are connected together via integrated condensate collection/steam crossover headers.

Each motor, fan brake, and Siemens/Flender right-angle gearbox is located 30 ft above the walkway (Fig D), and for that reason extra precautions are taken in preventive maintenance.

The 30, seven-blade Cofinco fans are 36 ft. across.

The as-built finned-tube cleaning system is automatic vertical and manual horizontal, with a cleaning width of 4.7 ft through 22 nozzles at 1450 psig. Flow rate is 32 gpm. It is of the no-access rolling ladder design by AX Systems.

Some issues encountered. One of biggest issues to date: A main steam-duct leak in the last expansion joint before it goes into the riser for the streets. This duct location is 23 ft diam. The expansion joint was replaced in spring 2021.

Another ongoing issue is air pockets in the D cells. Although not yet resolved, it is believed to originate upstream of the ACC. Investigation continues.

A few best practices. Gearbox seals have been an ongoing issue. Therefore, the plant began, on a semi-annual basis, to supply a filter press (water and particulate, 6 micron) to all gearboxes and run for 1.5 to 2 hours each. This, combined with oil samples prior to filter pressing, provides a good indication of oil condition for each gearbox. It also keeps the gearbox seals from failing prematurely and allows the plant to see if anything is breaking down inside.

Also, the plant installed three vibration probes on each ACC motor and three on each gearbox, running cables to a remote location. These allow the site to take vibration readings monthly on running ACC equipment, providing useful vibration data on a regular basis. The site can better understand condition of the equipment and look for alignment, coupling, and motor or gearbox bearing issues.

At CPV's Valley Energy Center (also induced-draft), knowing the challenges and time associated with disassembly and reassembly of the fan blades and hub assembly to change out a seal, the Maintenance Dept worked to understand the failure mechanism and brought in Corrosion Products & Equipment (CPE) to collaborate on a solution. A flange-mount split seal was chosen. After a year of operation, the Inpro seal solution remains leak-free and reliable. This program will be implemented at Towantic.

For other best-practice achievements at Towantic, see https://www.ccj-online.com/?s=Towantic.

Noteworthy operating points. Condenser vacuum is pulled initially by operating both liquid-ring and maintained by collapsing of steam within the finned-tube bundles. The

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monitoring of air exhaust flow rate, recorded on the plant DCS (Fig 6).

Gearbox

In *Gearbox durability*, Sumitomo Drive Technologies walks users through gearbox startup torques, sealing, and lubrication.

Kris Herijgers (Hansen Industrial Gearboxes, Belgium) presents data for both forced- and induced-draft units. He focuses on the market-driven challenge of frequent stops and starts.

Startup can lead to three times nominal torque (or higher), with an additional sinusoidal transient torque. Gear contact stresses must be kept below the endurance limit for both conditions.

With today's cycling challenges, "Traditional American Gear Manufacturers Assn (AGMA) calculations are not sufficient," the gear expert says. Sophisticated calculation tools are thus required that consider starting method and peak torque including the transient torque, as well as the sum of all start cycles.

He then provides details of sealing and lubrication to reduce maintenance costs.

Windscreens

In *Wind effects on air-cooled condensers*, Galebreaker Industrial reviews wind-screen applications to counteract wind-induced loss of thermal performance, mechanical stresses, and tube fouling.

The fundamental placement of windscreens includes:

- Perimeter screens to reduce blade stress.
- Cruciform screens for improved thermal performance.

Galebreaker covers crosswinds and performance impacts, and the dynamic impacts on blade loading and vibration. CFD analysis and example solutions follow.

Application to an innovative sloped-structure ACC is also discussed.

A. Induced-draft ACC at CPV Towantic Energy Center (left}

B. Main steam duct is all-welded construction for leak avoidance (below)

C. Largest main duct diameter is 23 ft (left)

D. Each motor/gearbox assembly is 30 feet above the walkway (below)

liquid-ring pumps remove the air and non-condensable gases from the ACC during normal operation. An air valve is provided to protect against pump cavitation.

Freeze protection is required at the site. During sub-freezing operation, ice can accumulate in the upper part of the D bundles. To remove the ice, the D fans are stopped periodically to warm the tubes.

This warming function becomes active when ambient temperature is below 35.6F after a time delay of two hours. Typical D warming cycle duration is five minutes. Active warming cycle from street to street is separated by 30 minutes.

Fully automatic cleaning

To view a fully automatic ACC cleaning and cooling system with low water use, see *Fully-automated cleaning robots* by JNW Cleaning Solutions GmbH, Germany.

Managing Director Arndt Krebs discusses how his company has been cleaning ACCs in Europe and South Africa since 1995, and in the US with partner Conco since 2001. Fully automatic systems have been in place since 2012.

Most semi-automatic systems operating today require two hands-on operators. The fully automatic system is centrally controlled, often from the control room.

8. Narrow walkways are inherent in induced-draft units

Designed for and when in continuous operation, the fully automated system also becomes an ACC cooling device with these benefits:

- The cooling performance of the ACC remains high.
- Increases in backpressure are reduced significantly.
- Turbine efficiency remains high.
- Turbine throttling can be avoided.

Krebs offers plant evidence, and discusses the benefits of cooled equipment versus higher cleaning-water consumption, along with JMW's HP-pump innovations to save water. He concludes with conversion of semi-automatic to fully-automatic systems.

Cleaning induced-draft ACCs

AX Systems presents specifics of *Cleaning induced-draft ACCs* noting that these V-frame/W-style designs present some unique cleaning obstacles and all cleaning equipment must avoid collisions with obstacles in narrow walkways (Fig 8).

Stellenbosch research

The South African utility Eskom operates massive air-cooled condensers, and Stellenbosch University is heavily involved in both operational issues and research for improved efficiency.

In *Axial-fan performance and noise modeling*, members of the Dept of Mechanical and Mechatronic Engineering present detailed accounts of predicting both performance and noise in large-diameter axial-flow fans.

Those looking for a refresher on fan aerodynamic noise mechanisms can find it here with details on rotational and non-rotational noise and the dominant noise mechanisms. This includes fan numerical modeling and comparisons with experimental results.

Stellenbosch has developed the M-fan as a large-diameter (24 ft) axial-flow fan with rectangular blades, and cambers of 3.5% at the blade root and 0.8% at the tip. The design was tested in the ISO 5801 Type A fan test facility equipped to measure flow rate, pressure rise, shaft power and running speed.

Also defined are visualized numerical model results at the design flow rate.

Numerical fan noise predictions follow, breaking down the noise spectrum into components to achieve better understanding of individual noise mechanisms and how they can potentially be reduced.

Details emerge on:

- Turbulence ingestion noise.
- Tip vortex formation noise.
- Trailing edge noise.
- Total fan noise.
- Fan noise scaling and measurement.

Deep-dive details are provided. Some conclusions:

- Fan performance can be modeled accurately in a 3-D CFD virtual testing rig.
- By combining trailing-edge noise strip theory and turbulence ingestion noise models, the total fan noise spectrum can be predicted numerically with good accuracy compared to experimental measurements.
- The standard fan test facility can be used to perform comparative measurements to determine the noise characteristics of scaled fans.

The facility is now being refined to reduce self-noise during testing.

In another presentation, *R&D at U of Stellenbosch*, Prof Hanno Reuter defines the university's involvement in South African ACCs, activities that have spanned five decades. Detlev Kroger initiated ACC research at Stellenbosch in the 1970s and South Africa's large ACC designs and features are greatly influenced by this research.

Stellenbosch facilities outlined include a variety of experimental facilities with typically 50 to 70 postgraduate students per year.

Reuter includes selected current research and results from various university professors and PhD candidates, along with direct-contact details.

Published documents

Two guideline documents are currently available at https://acc-usersgroup.org/reports/:

- *ACC.01: Guidelines for internal inspection of air-cooled condensers (2018 update).*
- *ACC.02: Guidelines for finned tube cleaning in air-cooled condensers (2021 update).*

Also available are the following:

1. *Flow-accelerated corrosion in seam generating plants* by Barry Dooley and Derek Lester, PowerPlant Chemistry 2018, 20(4).
2. *Corrosion in air-cooled condensers: Understanding and mitigating the mechanisms* by Setsweke Phala et al, Eskom, Johannesburg, South Africa.

In-progress ACC Guidelines were discussed at the conference:

- *ACC.03: Guidelines for air in-leakage in air-cooled condensers.*
- *ACC.04: Guidelines for wind mitigation in air-cooled condensers.*

Outlines for upcoming ACC.03 and ACC.04 are available at *ACC guideline documents*, 2022 Annual Conference.

Question period

A 45-min discussion period at the end of the meeting focused on submitted questions dealing with wind impact on efficiency and blades, variable fan speed control, finned-tube cleaning and water collection, gearbox replacement frequency, known structural resonance issues, use of electric motors, safety protocols for blade liberation, and rupture-disc replacement strategies. CCJ

7F 2022 Best Practices

The 7F Users Group and CCJ are working together to expand the sharing of best practices and lessons learned among owner/operators of large frame engines. One of the user organization's objectives is to help members better operate and maintain their plants, and a proactive best practices program supports this goal.

Details for the two entries from 7F-powered plants judged Best of the Best in 2022—St. Charles Energy Center and Empire Generating LLC—appeared in CCJ No. 72, published late last fall. Other entries in the 2022 Best Practices program recognized with awards are listed in the sidebar here. The nearly two-dozen best practices shared by your colleagues at 7F facilities are likely to offer an idea or two for improving safety and performance at your facility.

The Best Practices Awards program for owners and operators of generating facilities powered by gas turbines celebrated its 18th anniversary in 2022. Over the years, more than 800 best practices entries have been received from more than 200 individual plants and fleets.

Best Practices Awards presented to plants powered by 7F gas turbines in 2022

St. Charles Energy Center ...... **No. 72, p 16**
Active, wireless monitoring of high-energy piping improves safety, reliability

Empire Generating LLC ...... **No. 72, p 20**
Plant upgrades zero-in on solutions for fall prevention

Central Eléctrica Pesquería (CEP) **105**
'Improved' brush holder offers safety benefits
Copper braids outperform carbon brushes for shaft grounding
Replacement valve actuators provide ergonomic benefits, speed maintenance

Essential Power Newington **102**
Electronic safety orientation program for contractors
Upgrade to boiler-water sample panel helps ensure proper chemistry
Automating chemical injection key to tighter control of cooling-tower operation

Griffith Energy **101**
3D printing of control-valve trim promises big saving

Liberty Electric **112**
Increasing the speed of access to SDS forms

Magnolia Power Project **112**
Staying agile in a changing generation landscape

River Road Generating Plant **98**
'Hazard hunts' promote safer working conditions
Spare set of inlet filters improves plant availability, performance
Remote electronics for hotwell level transmitters eliminate erroneous readings

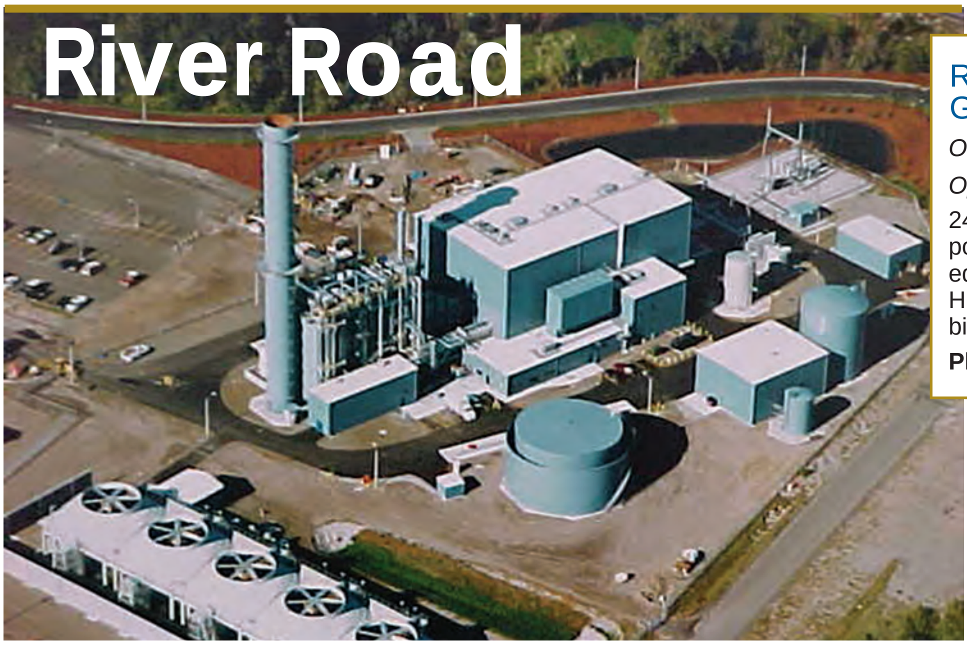
Rumford Power LLC **108**
Reduce O&M cost by cutting energy use when offline
Faster hot starts benefit the bottom line

Salem Harbor Station **107**
Winter-readiness testing upgrades reduce startup issues

Saudi Aramco **110**
Benchmarking a large gas-turbine fleet

Washington County Power LLC **109**
Meter protects personnel during fire-pump electrical testing

River Road



River Road Generating Plant

Owned by Clark Public Utilities

Operated by General Electric

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

Plant manager: Robert Mash

Some findings from River Road hazard hunts

Electrical wiring, trip hazard. Some clamps for cooling-tower electrical conduit were no longer providing the support needed (left). Staff reinstalled or replaced disconnected and missing clamps (right)

Trip and clearance hazards were mitigated by increasing awareness using appropriate signage

Piping-support failures and the possibility of falling objects. Broken pipe-support components were identified and fixed or replaced; hangers no longer providing the level support required were adjusted

Hazards identified by observing the collection of grab samples were ergonomic in nature, plus loss of balance was experienced in some cases while reaching between pipes (no photos available). Issue was corrected by redesigning sample ports to eliminate kneeling, reaching, and/or bending

'Hazard hunts' promote safer working conditions

Challenge. River Road personnel are encouraged to identify hazards that exist in their plant. An operator performing rounds, a mechanic working with a contractor, and typical housekeeping inspections are among the ways to identify hazards that may exist. Motivating the team to continuously and proactively look for hazards to mitigate risk is ongoing.

Solution. Staff developed a "hazard hunt" program that encourages employees to deep dive into specified safety topics or concerns observed. Employees define their own "hunt" criteria and close their findings with either immediate-action or work-order submittal. Findings and lessons learned are shared plant-wide.

Results. Empowering employees to "hunt" for issues they are either concerned or passionate about, typically yields more meaningful results than if you were to just hand a worker an inspection form. Empowerment helps employees excel in their jobs. It also provides ownership of project development.

Project participants:

Justin Hartsoch, operations manager
Margie Brice, EHS
Steve Ellsworth, operations

Spare set of gas-turbine inlet filters improves plant availability, performance

Challenge. The prevalence of wildfires in the Pacific Northwest has dramatically increased in the past several years, a trend predicted to continue. The local air quality during times of forest-fire smoke has caused many concerns, including the performance of the GT inlet filter system.

The increase in differential pressure (Δp) caused by particulates that comprise forest-fire smoke can rapidly reduce plant performance and may lead to equipment degradation. In extreme cases, engine shutdown may be necessary.

Forest-fire events typically occur during extended periods of hot weather, which correspond to an increase in electrical demand and higher power prices.

During a late-summer extreme smoke event in 2020, ambient air quality at River Road was so poor, visibility was reduced to 500 ft. Inlet-filter DP quickly increased to a high level. With many West Coast powerplants experiencing the same issue, and there was a high demand for inlet filters.

As fall approached and the smoke cleared, the plant was subjected to several days of dense fog. Moisture from the fog mixed with the already heavily loaded filters and increased Δp to alarm levels. Ultimately, the plant was shut down to avoid filter-house damage.

HEPA filters had been ordered for the following spring outage and were not available for a short turnaround in the fall. Lack of availability and long lead time to acquire replacement filters was exacerbated by the collective demand for filters on the West Coast.

Clark Public Utilities' energy resources manager worked closely with GE O&M to determine the best course of action. The outcome: River Road was able to quickly procure and install a set of non-HEPA filters to get the plant back online in a timely manner.

Solution. Non-HEPA filters remained in service until the spring outage in May 2021 when they were replaced with the HEPA filters on order that had arrived in time for the outage.

Following this experience, and given the rate of increase in the number and intensity of seasonal forest fires, a full set of spare HEPA filters was purchased and stored onsite. A spare set of inlet filter wraps also was procured and stored onsite to respond to future smoke events.

Results were an improvement in availability and performance. The spare set of filters will dramatically reduce downtime during periods when power prices are highest and power is needed most. Plus, the risk of plant efficiency loss has been reduced.

Project participants:
Justin Hartsoch, operations manager
Doug Burson, warehouse and parts procurement
Jared Yeager, operations
Terry Toland, CPU energy resources manager

Remote electronics for hotwell level transmitters eliminate erroneous readings

Background. Two level transmitters are used for calculating the hotwell level at River Road to determine if control valves should open or close to maintain the level setpoint (typically 18 in.). The calculated hotwell level also is used as a starting permissive and to trip the condensate pump on low level.

Challenge. The plant's two original condenser-hotwell level transmitters were integrally mounted on stilling-well taps connected to the hotwell. This position exposed the transmitter electronics to high vibrations that ultimately caused them to vibrate apart and send erroneous level readings to the DCS.

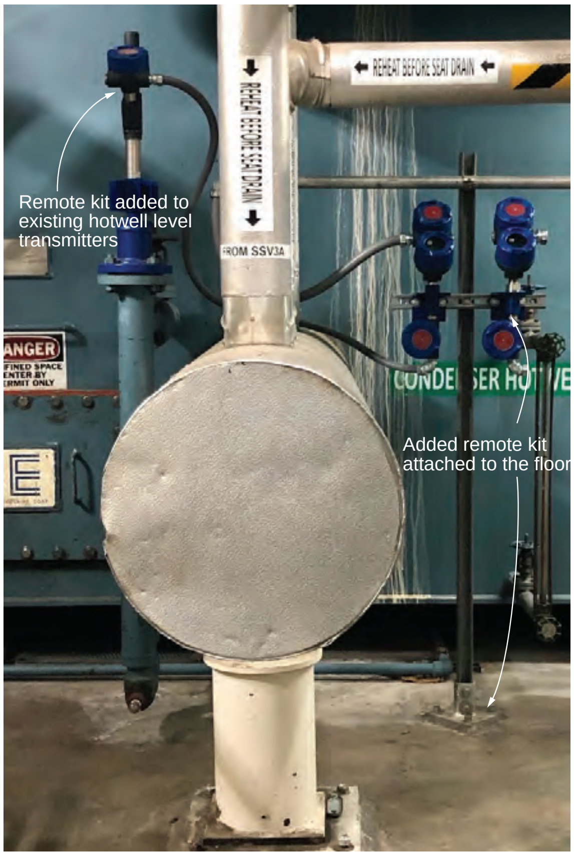
When the difference between the readings from the two transmitters is greater than 3.2 in., a manual reject alarm changes the level control loop to manual until the deviation alarm is corrected. This caused control-room operators to devote more attention than advisable to that control loop while running the plant.

At times, the difference between the levels from the two transmitters—type Magnetrol E3 Modulevel—was greater than 4 in.

Solution. Install remote electronics kits on the E3 level transmitters and move the electronics away from the vibration prone area (Fig 1).

Results. Following installation of the two remote electronic transmitter kits, the level transmitters have been consistently reading within 0.25 in. of each other. With remote transmitters attached to the floor, the erroneous signals caused by condenser vibration have been eliminated. Plus, the risk of a false condensate-pump low-level trip is reduced.

Project participants:
Steve Dahl, IC&E technician
Jack Blair, IC&E technician



1. Remote electronics kits for the level transmitters eliminated the impact of condenser vibration on hotwell level measurement

Ammonia-piping upgrade a safety improvement

Challenge. When River Road is operating baseload, it receives a bulk delivery of 29.4% aqueous ammonia two or three times a month. After accepting a load of dirty ammonia that contaminated the ammonia tank and system, a sock filter was installed next to the tank fill connection. Operators used a flexible, chemical-resistant hose with camlock fittings between the ammonia filter housing and the ammonia-tank fill line (Fig 2 left).

The flexible hose and its camlock fittings are a potential source for an ammonia leak during the bulk delivery. In addition, the delivery hose presents a potential trip hazard for both plant operators and delivery drivers when in use during the offloading process. Note that the hose was replaced annually as a preventive measure to reduce the risk of leaks from its degradation.

Solution. Staff developed a plan to mitigate the safety risk to operators and delivery drivers by removing the flexible hose and connections, and installing permanent 2-in-diam, Type-304 stainless steel piping (photo right).

The filter assembly was placed downstream of the ammonia tank fill-line connection within the piping containment area. MOC (management of change) was used to update drawings, procedures, new-piping testing process, and project cost, and project implementation.

2. Permanent piping replaced flexible hose and original connections

Results. Risk was reduced for site and delivery personnel, contractors, and the environment. The hazard reduction was developed and executed by plant O&M personnel. The flexible hoses and connections were eliminated, and the piping modification did not create any additional hazards.

Finally, there was a minimal cost saving by eliminating the need to replace the flexible hose and camlock fittings annually.

Project participants:
Ken Roach, maintenance manager
Mike Buhman, maintenance
Mark Todd, operations

Ergonomic improvement: Motor operators installed on large steam valves

Challenge. Manual steam isolation valves (HRSG high pressure, hot reheat, and cold reheat) were retrofitted in 2002 to allow River Road to "bottle-up" steam pressure during short layups and to permit injection of nitrogen during extended layups. At that time, there was insufficient electrical breaker capacity at local power panels to support three motor-operated valves (MOV).

Absent local panel capacity, power would have to come from the main motor control center (MCC) 600 ft away. Control power also would be needed for a future tie-in to the DCS for operation and valve-position indication.

Note that it took about 10 to 15 minutes to fully open or close each of the valves, requiring considerable physical energy. An ergonomic analysis identified possible injuries that could be incurred while manually operating these valves; the safety committee recommended installing MOVs to mitigate this risk.

Solution. Plant personnel worked with Clark Public Utilities to develop a plan for adding a new 480-V power panel locally from a breaker in the main MCC. The new panel provided spare 480-V breakers to support temporary auxiliary equipment used near the HRSG during outages. Control power then was added to a remote DCS cabinet.

Note that work was required on the existing steam-valve bonnets to accommodate the MOVs.

3. Valve operators were upgraded from manual (left) to motor-operated

Result. The three MOVs were installed and tested during the plant's annual outage. A 480-V, 100-amp service panel was installed locally at the HRSG.

Now operators can open and close the MOVs locally without physical strain and move to the next startup/shutdown task, mitigating ergonomic risk. At the time this Best Practice was submitted to CCJ, the MOV controllers had not yet been connected to the plant DCS to permit remote open/close operation from the control room.

Project participants:
Ken Roach, maintenance manager
Jack Blair, IC&E technician
Steve Dahl, IC&E technician

3D printing of control-valve trim promises big savings

Griffith Energy

Owned by Griffith Energy LLC

Operated by Consolidated Asset Management Services (CAMS)

570 MW, gas-fired 2 × 1 7FA.03-powered combined cycle equipped with NEM HRSGs and a Toshiba steam turbine, located in Golden Valley, Ariz

Plant manager: Scott Henry

Challenge. Griffith Energy typically spent well over $100,000 annually to rebuild its boiler feedwater control valves to accommodate the wear and tear of operation and the need to ensure high availability and reliability.

The plant had been approached several times over the years to replace the original control valves with IMI CCI Drag® valves. Not so simple. In addition to the valve and actuator, such an upgrade would require board approval of a CapEx project, welding, cleaning of the piping, NDE of the welds, new spare-parts inventory, and drawing and manual updates (MOC).

Griffith management hadn't pursued the installation of new valves primarily because of project scope and cost. At least 16 of the plant's control valves could have been involved. Note that the plant has had excellent experience with IMI CCI Drag valves—including HP and hot-reheat steam bypass, spray attemperator, and desuperheater valves.

Griffith was aware that IMI CCI had done custom retrofit projects 20 years ago, but not recently—mostly because of a corporate decision to focus on valve sales. Staff requested that the company re-evaluate the possibility of retrofit trim for the Griffith valves. However, flow requirements would have made the disk stack too tall to fit in the existing valve body.

Solution. Over the last few years, advances in additive manufacturing (3D printing) processes became cost-effective and IMI CCI engineers were able to design Drag valve trim to fit the valve body. This was a game-changer. Rather than the need for a large CapEx project, the site would be able to simply install new trim, change the part number in the CMMS system, and be done. IMI CCI provided new valve tags with names, trim characteristics, part numbers, etc.

Griffith entered a pilot program with the valve manufacturer to install the first Retrofit3D trim sets into four of the most critical and difficult applications (Figs 1 and 2). Staff supplied IMI CCI with the OEM's valve data sheets and historical operating data for engineering to accurately calculate flow/pressure needs across a wide range of plant operations.

1. Original control-valve trim is at left, IMI CMI's retrofit trim is at right

2. New trim is inserted into the existing valve body

Results. The first trim sets were installed in fall 2019 and performed well, as expected. These valves were inspected the following spring after about five months of operation. The trim parts looked like they had just been installed. The valves were reassembled with new soft goods and returned to operation.

The decision was made to upgrade all the remaining valves on HRSG 1 and reinspect after two years. Reinspect/rebuild intervals might be extended based on the as-found condition of the parts. HRSG 2 is consuming the remaining OEM and refurbished-parts inventory. As those parts are scrapped, IMI CCI trim sets will replace them.

The Retrofit3D trim is comparable in cost to the refurbished OEM trim and is expected to last at least three years longer—likely more. This could equate to a $500,000 to $900,000 saving on parts, not including the annual labor cost to rebuild. In sum, this project has resulted in a high-reliability, long-life, low-cost operation that simply requires a change to the inventory record and library.

Newington

Essential Power Newington

Owned by Essential Power Investments

Operated by Cogentrix Energy Power Management

565-MW, dual-fuel 2 × 1 combined cycle located in Newington, NH. Plant operated baseload from COD in 2002 until it began cycling in 2008

Plant manager: Tom Fallon

Electronic safety orientation program for contractors

Challenge. Essential Power Newington annually processes hundreds of contractors through its site-specific safety orientation program, consisting of an instructional safety-related video and certificate of completion. The rate of certifications increases significantly during outage periods.

The challenge of completing site safety and compliance training efficiently and effectively without impact to outage work schedules can be demanding. Beginning in early 2020, and continuing through 2021, Covid-19 concerns limited personal interaction and congregation in an effort to minimize risk of transmission. With contractors arriving from all areas of the country, the site explored digital and remote avenues which had not been invested in previously.

Solution. Staff explored various electronic resources to deliver its safety orientation video, facility EH&S rules (Fig 1), and NERC CIP compliance protocols to personnel arriving onsite. Critical quality features included the following: (1) ease of use for the end user and administrator, (2) ability to edit content as needed going forward, (3) compatibility with mobile phone use, and (4) ability to electronically verify completion.

Microsoft Office 365's Forms program was the solution selected. It has the ability to e-mail contractors/vendors a message with an optional QR code and/or forms.office.com hyperlink.

Use of a mobile device and QR code allows quick navigation and orientation, and completion of required tasks. A hyperlink also is provided for PC use. Once the user receives the e-mail and accesses the form using either the QR code or link, he or she is able to review a customizable and site-specific embedded SharePoint link to the site's 7-min orientation video (Fig 2).

There also are several easily navigable electronic forms to review and verify completion.

Once the video has been watched and the form completed, the user initials the electronic form and submits it to the site's EH&S manager. From there, data are compiled in a user-friendly electronic database for staff to review and to track the completion status of contractors. Electronic timing of form completion identifies potential attempts at subversion of the orientation process.

Results. The Office 365 Forms program has been tested by several employees and found effective and easy to use. Having the ability to watch the video and review and submit the electronic form from a mobile device provides contractors a user-friendly

* Required

HS5, Appendix F Contractor and Visitor Environment, Health & Safety Rules

COGENTRIX ENERGY

Each Contractor Worker and/or Visitor must read, understand, and comply with the following rules:

2

General Requirements

- All Contractor Supervisors must complete a Contractor Work Permit at the beginning of the day and close the permit at the end of the day.
- Contractor Workers shall not work at any time when their ability is or may be impaired as a result of the use of legal prescription drugs.
- Contractor Workers must be seated in moving vehicles and seat belts worn while the vehicle is in motion.
- Fighting, horseplay, gambling, possession of firearms or other weapons, possession or use of alcohol or illegal or unauthorized drugs is prohibited.
- Except in "Designated Smoking Areas," smoking is not permitted on the Facility property.
- Eating and Drinking is only permitted in designated areas.
- All tools and equipment shall be inspected prior to use. Unsafe tools and equipment shall not be used.
- Contractor Workers will perform work in such a manner as to assure at all times maximum safety to self, fellow workers, and the public and in accordance with all Federal, State, and Local requirements.
- Contractor Workers who do not either feel qualified or physically able to perform will not attempt to work.
- Contractor Workers will perform work according to proper EHS practices and procedures as posted, instructed, and prescribed.

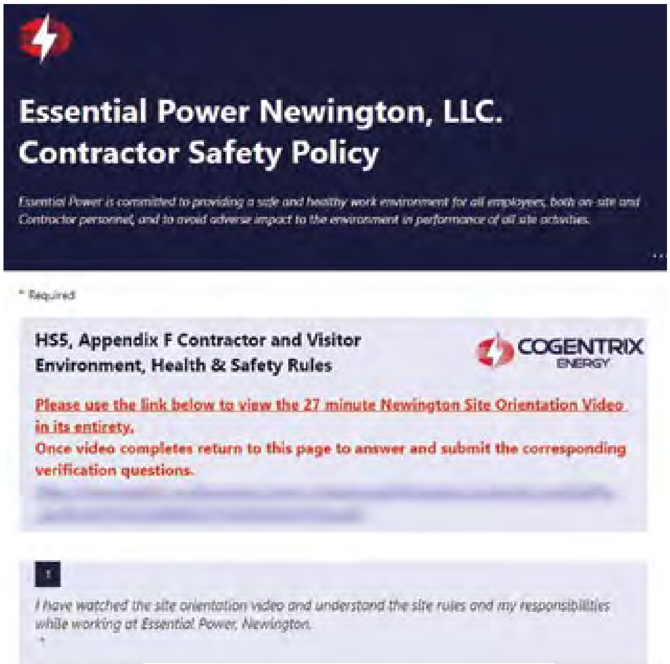
1. Site-specific safety orientation program introduces contractors and visitors to the plant's health, safety, and environmental rules. Certificates are issued to all who complete the program successfully method for completing site orientation from outside the plant prior to arriving for the Newington outage.

Plus, electronic submission frees up significant paper resources and filing requirements.

Also, headcounts onsite in contractor orientation workspaces are reduced to those infrequent occurrences where electronic submission was not feasible ahead of time. When prequalified contractor personnel arrive onsite, they immediately report to the specified Point of Contact (POC) and receive their orientation-completion hardhat stickers.

The POC is able to quickly review orientation completion status in the electronic repository and directly answer any questions relevant to the training in the context of the contractor's work scope.

In sum, investment in electronically facilitated site orientation saves resources and time and the efficiency of contractor safety- and compliance-training certification.



2. Primary component of Newington's safety orientation program is a 27-min video

Project participant:
John Pierce

Upgrade to boiler-water sample panel helps ensure proper chemistry

Challenge. EPC engineers integrated a firetube boiler into the design Essential Power Newington for use during cold-plant startups to provide steam for turbine seals and HRSG sparging. The auxiliary steam system includes a deaerator supplied with cold demineralized-water makeup. Aux boiler use for HRSG sparging has increased as the plant moved from its original baseload operating profile to more of a seasonal peaking operation.

Sparging can be necessary for days at a time, or longer, depending on market dynamics and ambient temperature. Treatment chemicals are added via small electronic metering pumps. Chemical-pump stroke rates are adjusted manually based on grab-sample analysis in the water lab by an auxiliary plant operator. The original construction did not include any continuous analyzers to ensure proper control of boiler-water chemistry.

Solution. Site personnel reviewed water-chemistry key parameters for the low-pressure firetube boiler, selecting these three characteristics for continuous measurement: blowdown pH and conductivity, and feedwater dissolved oxygen. Staff then worked with a vendor to design a sample panel to measure the three variables using sampling equipment currently used onsite in the HRSG sampling system (Fig 3).

The final challenge for design of the sample panel was to find a location in the aux-boiler building where the panel would be close to the sample sources while also allowing O&M personnel proper access to other equipment. This involved minimizing the wall panel's depth to maximize aisle space.

Results. Personnel completed installation of the sample panel during a recent plant outage. Analyzer outputs were wired to the DCS, where screen graphics were added and alarm triggers set. The analyzer outputs also were added to the PI historian for long-term trending and alerts.

3. Wall-mounted sample panel measures continuously auxiliary-boiler blowdown pH and conductivity, and feedwater dissolved oxygen

While several additional continuous analyzers would be necessary to automatically control boiler chemistry, these three continuously measured characteristics help ensure proper chemistry maintenance between grab-sample analyses.

Project participants:
Kyle Malenfant, I&E technician
Michael Dill, I&E technician
Eric Pigman

Automating chemical injection key to tighter control of cooling-tower operation

Challenge. Because Newington was designed to operate baseload, it did not have an automatic scale-inhibitor injection system for the 1.5-million-gal saltwater cooling tower, which operates at 2.0 cycles of concentration and has a 150,000-gpm recirculation rate. A single salinity meter was installed on the circulating-water-pump discharge but there was no means for measuring makeup-water salinity continuously to accurately monitor for tower cycles.

The chemical treatment program for scale and dispersant control is an HEDP/polymer combination, which is injected into the tower basin. River-water makeup quality, 2.0 cycles of concentration, high surface temperatures in the condenser, and desired operating pH range were used to arrive at the optimal concentrations of treatment chemicals. A buffer is included to allow for routine fluctuations in makeup-water quality or upsets.

Given water-sample testing interferences with tower salinity, injection feed rates were based on blowdown flow rates, adjusted manually. This led to many occurrences of over- and under-injection because blowdown rates can fluctuate daily and seasonally.

Solution. Two new chemical-injection metering pumps were installed with microprocessor controls. The scale-inhibitor pump injection controls now run in automatic via a 4-20-amp control signal based on tower blowdown flow rate. In addition, a salinity meter was installed at the river makeup source to accurately monitor for tower cycles for tighter control.

These changes are conducive to a better tower chemistry program, one with both consistent scale protection and chemical control ranges. The makeup-water salinity instrument ensures consistent as-designed tower cycles, which, in effect, increases the concentration in the tower, and by automating the scale-inhibitor pumps, reduces chemical consumption. In sum, these changes reduce chemical costs and maintain a tighter tower-chemistry control program.

Results. With additional training on blowdown control rates and chemical injection operations, the control for combatting scale in the surface condenser is much tighter. Having accurate tower cycles, because of the added makeup salinity meter, allows staff to better regulate tower blowdown and injection feed rates to accurately manage the system during all operational profiles—while still offering opportunities for reductions in chemical consumption.

The scale-inhibitor automation improvement allows for less manual intervention when tower blowdown rates are fluctuating frequently based on plant operating profiles.

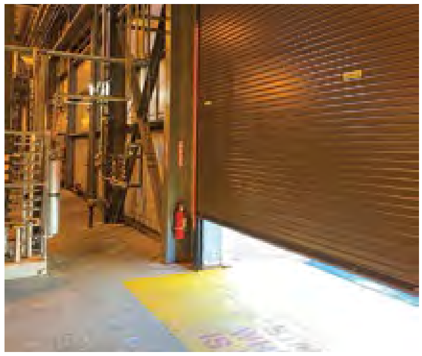
Project participants:
Joshua Leighton, Eric Pigman, and Scott Courtois

Warning lights for overhead doors make plant safer for staff, visitors

Challenge. Large overhead roll-up doors are a concern in industrial workplaces—a recognized hazard that could cause serious physical injury or equipment damage if not acknowledged and controlled. Reasons include these: They are heavy, may fall closed while traveling if the head works fails, and may not be equipped to auto-reverse when they come in contact with an object or person.

Solution. Staff analyzed options for improving the safety and communications protocols for traversing through the plant's large 20 × 20-ft turbine-hall overhead doors (Fig 4), commonly used by a large number of people. Visual indicators were deployed to provide additional warning and to remind personnel and visitors about overhead-door safety and site expectations.

Industrial LED light strips were a practical solution. The power and controls for them are incorporated easily into the operation of the door opener while providing warning lights by flashing RED when the door is in motion. Once the door reaches its *fully open* limit switch, the light strips turn solid GREEN (Fig 5). When the door moves closed, the LED strips again flash RED until the door fully closes against the pressure limit switch; the lights shut off after 30 seconds. The warning-light system is installed on both sides of the door frame, and both inside and outside.



4. Red LED light strips signal when the overhead door is in motion

5. Green LED light strips report "all clear" for vehicles and personnel to walk through the door

6. Conspicuous floor markings remind plant personnel and visitors to stay clear while the door is in motion

In addition, large floor markings were developed to remind walking personnel to use the adjacent walk-through door for exiting and entering the turbine hall rather than an overhead door.

In conjunction with installation of the light strips on the door frame and conspicuous floor markings (Fig 6), the site instituted a standing directive that the doors not be driven or walked through while in motion. They can be traversed only when in the *fully open* position and the lights are solid GREEN.

Results. Use of visual stimuli to let staff and contractor personnel know a door is in motion, and communicating that you must not drive/walk through an overhead door in motion, has helped to prevent equipment damage and other safety events.

Project participants:
Mike Dill, I&E technician
Kyle Malenfant, I&E technician

Central Eléctrica Pesquería (CEP)

Owned and operated by Techgen

900-MW, 7FA.05-powered 3 × 1 combined cycle located in Pesquería, Nuevo León, México

Plant manager: Mario Alberto Ontiveros de la Torre

‘Improved’ brush holder offers safety benefits

Background. CEP’s four generators are equipped with the OEM’s EX2100e excitation system to control ac voltage at the generator terminals and/or reactive volt-amperes (VAr). Plant’s excitation system has a collector on the free side of the generator, where carbon brushes transfer the excitation current to the rotating slip rings and produce an electromagnetic field in the generator.

Incident. During normal monthly preventive maintenance, the following occurred when changing a brush on the negative pole: Technician inserted the brush holder, using its insulated handle (Fig 1), unaware that the carbon brush had slid out and been pushed to the middle space between the collector rings. The resulting electric arc damaged the rings and generator rotor.

Solution. After the event, the maintenance and technical control team conducted a root cause analysis (RCA) and investigated collector-brush-system replacement options. GE’s “improved” brush holder (Fig 2) was selected for the following reasons: (1) Reduced the possibility of contact with live brushes, a significant safety benefit; (2) Provided higher reliability by eliminating incomplete insertions; and (3) Assured higher availability by reducing the risk of collector discharges.

Plus, brush wear can be seen easily through the inspection window, or by inspecting the wear indicator on the brush pigtail.

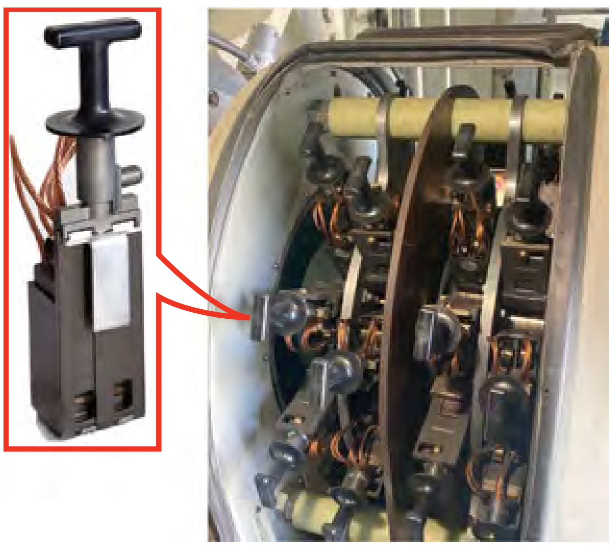
Results:

- Separation from energized components makes for a safer system, especially when changing out brushes with the turbine/generator in operation.
- Reduced risk of brush hang-ups.
- Tool-less maintenance given the permanently attached handle, which also reduces the time required for brush change-out.
- Reduced risk of collector flashovers.
- Increased brush size/life.
- Lightweight aluminum construction with a durable and anodized surface coating.
- Less susceptibility to brush-current selectivity (uneven current distribution between brushes).
- Direct replacement of single-wide holders without modification to the brush rigging.

Project participants:

Arturo González, technical control chief
Odon Acosta, maintenance chief
Arturo Macías, electrical coordinator

1. Technician inserts brush equipped with an insulated handle



2. “Improved” brush holder for generator collector

Copper braids outperform carbon brushes for shaft grounding

Challenge. Eliminate an unsafe condition present in the grounding-brush systems for CEP’s gas turbine/generators and implement an operating practice to enhance personnel safety and reduce the risk of equipment damage during routine maintenance.

The original grounding-brush system has a spring-type lock (Fig 3 left) that must be pulled and removed to release the brush for replacement or to perform maintenance, which sometimes must be done with the generator in operation

(Fig 3 right).

These factors are conducive to an unsafe condition because of the close distance between the operator and the working generator—a noisy environment with strong air currents.

Solution. After an exhaustive analysis by technical staff, an alternative grounding system was identified—one similar to that used in the steam turbine/generator. It uses copper braids that are extracted easily by pulling the fixing lever (Fig 4 left) and removing the braid to the side (Fig 4 right).

The new grounding system reduces the time required for maintenance: It is of simpler design than its predecessor and maintenance consists only of cleaning with dielectric solvent and verifying that the braid is not too worn (or replacing it if it is).

For insertion, the braid is placed on one side and pressed with the locking lever and it is ready for operation.

Results. The increased accessibility afforded by the new grounding system allows handling the components at a safer distance than previously—further away from the rotating machinery. Plus, the maintenance interval has been extended from one month to two, making the grounding system safer and easier to maintain.

Project participants:
Odon Acosta, maintenance chief
Arturo Macías, electrical coordinator
Plus, Isaí Real, Jorge González, and Jorge Rosalio

3. Brush-holder lock is of the spring type (left); strong air currents are caused by the moving rotor (right)

4. Braid fixing lever is at the left; grounding-system arrangement at right illustrates how simple it is to access the braid for maintenance and removal

Replacement valve actuators provide ergonomic benefits, speed maintenance

Background. CEP has a ZLD (zero liquid discharge) gray-water treatment plant incorporating softening, ultrafiltration, reverse osmosis, and electrodeionization. Throughput extends to nearly 6200 gpm.

Challenge 1. Reduce or eliminate failures of actuators for valves serving CEP's five ultrafiltration modules. The original actuators were of a very robust design, each weighing about 200 lb. Thus, their removal for maintenance required cranes and the intervention of specialist personnel from different areas of the plant's O&M team (Fig 5).

Regular actuator maintenance, typically required every six months because of wear and tear experienced by positioners, instruments, and other components primarily attributed to high vibrations, took about 16 hours. Actuator location complicated maintenance because of ergonomic concerns.

Solution 1 involved replacement of the original actuators with smaller, lighter ones (about 50 lb), thereby improving maintenance access to mitigate ergonomic concerns. Remote positioners were another improvement. Maintenance on the new actuators can be performed in-situ, eliminating the need for cranes and specialist personnel.

Results 1:
- Improved system availability.
- Time required for maintenance cut

5. Original actuators for valves serving the ultrafiltration modules were replaced with smaller, lighter alternatives to improve maintenance access and mitigate ergonomic concerns in half.

- Increased efficiency of maintenance personnel.
- Reduced costs of maintenance and spare parts.
- Less noise.
- Fewer module ruptures attributed to vibration.
- Ergonomic benefits included fewer accidents and fewer injuries to maintenance personnel.

Challenge 2. Increase the availability of the ZLD, which requires a heat exchanger to increase water temperature before it enters the crystallizer. This heat exchanger must be cleaned of scale deposits every two weeks using EDTA and nitric acid to maintain the level of performance required. Heat-exchanger cleaning takes from 18 to 24 hours.

Solution 2. A second heat exchanger, independent of the original with all instrumentation required, was installed for use during cleaning turns and as a backup for the original.

Results 2. ZLD system availability and efficiency are assured.

Challenge 3. Eliminate or reduce recurring problems in the sludge-dewatering portion of the gray-water treatment plant. The two dewatered-product transfer pumps in the line to the cold-lime softening system suffered continual impeller damage and mechanical-seal wear, which caused pipes to plug and contributed to excessive maintenance.

Solution 3. The original multistage centrifugal pumps were replaced by single-stage units equipped with mechanical seals lubricated by service water to flush the seal cavity continuously, mitigating wear.

Results 3:

- Improved system reliability and availability.
- Eliminated corrective maintenance; only preventive maintenance is required today.
- Reduced the cost of maintenance and spare parts.
- No lubrication problems were associated with the seal flush system.
- Reduced the cost of cleaning the sludge dewatering system.

Project participants:
Odon Acosta, maintenance chief
Plus, Moises Arroyo, Daniel Mendoza, Rolando Goytortua, Alma Rivera, Jonathan Herrera, Marco Lopez, Alejandro Domínguez, Juan Carlos Facio, and Luis Melgarejo

Winter-readiness testing upgrades reduce startup issues

Challenge. Salem Harbor Station is located on the seacoast in the Northeast, where wintertime single-digit temperatures and below-zero wind chills are relatively common. Despite annual surveys and repairs to both heat tracing and insulation, the plant has experienced multiple freeze-related forced outages.

Because many critical valves cannot be stroked without forcing multiple DCS points, plant operators had little visibility on whether critical pumps and valves were available during extended periods of plant shutdown. For example, if an attemperator bypass valve was frozen, it would not be noticed until the plant attempted to start up and the valve failed to open.

Salem Harbor Station

Owned by Footprint Power Salem Harbor Development LP

Operated by NAES Corp

674 MW, two gas-fired 1 × 1 7FA.05-powered combined cycles equipped with Doosan HRSGs and GE A14 steam turbines, located in Salem, Mass

Plant manager: Max Greig

Solution. Staff, led by Plant Manager Max Greig, investigated the possibility of creating custom logic to test critical pumps and valves while offline during freezing conditions. DCS Specialist Dave Norcross worked with the plant operations team to identify assets most likely to freeze during extended offline periods. Using his experience on the Mark VIe DCS, Norcross created custom test logic for each asset that would bypass the need for placing forces within the DCS.

Plant operators can now check all assets as part of an automated global test, or individual assets based on plant conditions. Isolation valves are stroked open, then closed. Control valves are stroked to 50%, then 100%, and closed. Critical pumps are started, discharge pressure, and in some cases flow, checked, and shut down. Any discrepancies with the test generate a global alarm and flag the problem asset on the corresponding DCS screen. Operators then can take corrective actions before the issue causes an outage or failed start.

Results. Since the improved testing program was put into service midway through winter 2021-2022, the operations team has used the tests once or more per shift during freezing conditions. Test frequency is determined by ambient temperature: At 32F, the test might be conducted twice daily, at 0F, hourly. Site staff has been able to identify several potential freeze-ups and take immediate mitigating actions. Outcome: The plant has not experienced outage or startup issues related to assets included in the new testing program since its implementation.

Rumford Power LLC

Owned and operated by Cogentrix Energy Power Management

270 MW, gas-fired 1 × 1 7FA.03-powered combined cycle equipped with a Nooter Eriksen HRSG and a GE A10 steam turbine, located in Rumford, Me

Plant manager: Justin Castagna

Reduce O&M cost by cutting energy consumption when offline

Challenge. The operational profile for Rumford Power has changed significantly over the past 20 years, as it has for many powerplants. Rumford now spends more time offline than online and consumes a large amount of station service energy to keep the plant available to the ISO.

Personnel collaborated to find ways to reduce station service load when offline. Two promising ideas emerged: Use a smaller air compressor and smaller closed cooling water (CCW) pump to satisfy offline needs. The original CCW pump, designed for baseload operation, has a 4160-V motor; the proposed offline CCW pump, a 480-V motor.

Solution. Reduce the power bill by identifying efficiencies that could be gained plantwide and execute promising projects. Two systems targeted were the plant compressed-air and CCW systems. Both were oversized for the service required when the plant was not operating.

Looking first at plant air, calculations based on metered readings were made to determine the cost of running the existing compressors when the plant was not producing electricity. Seeing an opportunity for savings, staff investigated lower-capacity, more-efficient compressors to fulfill plant needs while it was offline.

Staff also saw the large power draw from the 4160-V CCW motor could be reduced by installing a smaller pump for offline use.

Results. Both projects were successful. The new, quieter, more-efficient, and lower-capacity 480-V air compressor for offline use reduced power consumption for compression by 20%. Payback on this portion of the project was originally calculated at just under five years.

The CCW mod proved even more beneficial. Use of the 480-V drive assembly while the plant is offline reduced power consumption by over 70%, resulting in an estimated payback of less than two years (photo).

Given today's astronomical power prices in New England, both projects are expected to pay for themselves in less time than originally predicted.

CCW pump with a 480-V driver in place of a 4160-V motor reduced power consumption by 70% when Rumford is offline

Project participants:
Bill Calden, Jon Hambrick, and Justin Henry

Faster hot starts benefit the bottom line

Challenge. Rumford Power had had a two-hour starting window with ISO-NE (New England) since beginning commercial operation 20 years ago. Previous guidance recommended holding the loading of equipment when stress curves hit 60%, as calculated by data monitoring software. Goal was to decrease the time required to release Rumford for dispatch during hot starts. Investments in gas-valve upgrades to obtain purge credits were not economically feasible.

Management decided to spend 2021 optimizing the performance of the dedicated operations team to reduce the time it took to go from first breaker close to the low economic operational limit of the plant.

Challenges to achieving the stated goal included the addition of four new operators to staff, and changing the accepted method of starting the plant. Operators historically had used the two-hour starting window to thoroughly check plant equipment and confirm its operation, performance, and setpoints. The push to consistently load the units to release the plant for dispatch faster and not spend as much time checking BOP equipment was an added stress to staff.

Baselines were established from the first four hot starts of the year: It took an average of 87 minutes to dispatch Rumford's single unit, burning an average of just over 1500 dekatherms of natural gas.

Solution was to collaborate, share best practices, and optimize performance. The plant has a solid starting procedure, one modified over time to increase availability. Lessons learned have contributed to procedural adjustments to add checks and balances that ensure safe, reliable operation. By paying attention to detail, and communicating best practices from shift to shift regarding ways of reducing start time, the plant ultimately was able to eliminate hold points in the procedure and drive down startup costs.

Results. Over a period of 64 hot starts since the drive to increase starting efficiency began, the plant average for a start was less than one hour from first breaker close to release of the unit for dispatch with ISO-NE—a reduction of almost half an hour from previous averages. The plant also saw an average reduction in gas consumption of 485 Dth per start.

Given the volatile gas pricing in the New England market, this strategic operation performed by plant staff over the course of the year provided savings well into six figures for natural gas burned while bringing the plant online. The best result: There were no missed unit starts or trips attributed to this initiative.

Project participants:
Dean Baker, Trevor Boutaugh, Jesse Hilton, Bob Richardson, Nick Gray, Bill Calden, and B J Dunlap

Washington County Power LLC

Owned by Gulf Pacific Power LLC

Operated by Cogentrix Energy Power Management

600 MW, four gas-fired, simple-cycle 7FA gas turbines, located in Sandersville, Ga

Plant manager: Mike Spranger

Meter protects plant personnel during fire-pump electrical testing

Challenge. Annual testing of the electric fire pump requires a technician to break the plane on a size 3 wye-delta starter and check volt and amp readings at multiple flow rates. This program requires multiple technicians to assist the fire-system contractor during testing. One technician has to suit up in the appropriate arc-flash suit to read the meter while another monitors for safety purposes.

Solution. Plant staff installed a digital meter to monitor volts and amps on each phase of the starter.

Results. The digital meter allows the contractor to safely perform annual fire-pump testing without exposing plant technicians to an arc-flash hazard.

Project participants:
Derek Boatright, O&M manager
Ralph Chandler, compliance supervisor

Digital meter monitors volts and amps on each phase of the starter for the electric fire pump to protect staff when conducting tests

Saudi Aramco

Riyadh 10, a/k/a PP10 began life in 2010 as a 36-unit simple-cycle greenfield project and then expanded to ten 4 × 1 combined cycles. All gas turbines burn crude

Saudi Aramco

Multiple power generation sites and owners

Operated by Saudi Aramco

Many gas turbines rated 150 MW and higher, manufactured by multiple OEMs, and configured into heat-recovery systems at several sites within the Kingdom

Plant managers: Multiple

Benchmarking a large gas-turbine fleet

Challenge. Saudi Aramco operates more than 200 gas turbines in mechanical-drive and power-generation service. These units are located at several sites around the Kingdom of Saudi Arabia, with many power-gen turbines producing 150 MW or more. One of the difficulties in managing such a large number of engines is the inability to determine fleet operational and reliability performance—specifically from a centralized perspective.

Solution was the development of a real-time performance-analysis system for use in the company's engineering solutions center to compare the various Saudi Aramco sites. Objective of this benchmarking system was to (1) track asset performance, (2) identify areas of weakness, and (3) find enhancement opportunities to optimize utilization, reliability, and operational performance.

The solution was developed by using well-defined algorithms provided with data from the company's corporate server—specifically PI data points. An average of 6-million data points are extracted from the servers and processed by the benchmarking system. Raw data are processed to calculate the following key performance and asset indicators, among others:

- Unit running hours.
- Number of starts attempted.
- Number of unit trips.
- Unit utilization.
- Loading and capacity factor.
- Annual and monthly average load profiles.
- Annual and monthly average fuel consumption.

The model is capable of making complex calculations to cover the following parameters for power-generation units:

- Gas-turbine site-available power at different ambient conditions, using a correction curve and degradation factor.
- Gas-turbine heat rate and overall thermal efficiency.

The staff-developed algorithms allow validation (isolation) of any out-of-range plant data points—including sudden data spikes, disappearance of data, and time out of service. The results from each site and gas-turbine model were validated using these three methods:

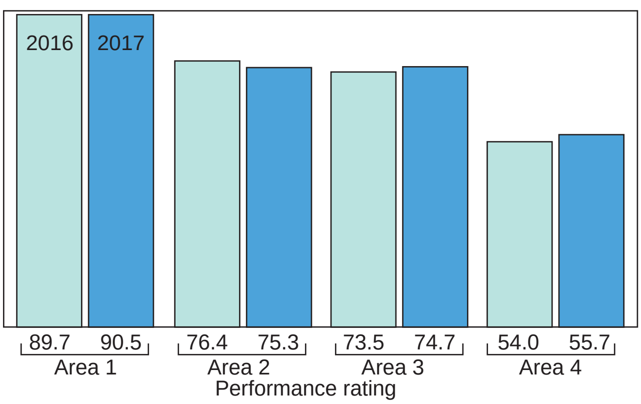
- A year's trip data for the units, manually collected from operating sites.
- Previous performance test reports.
- Equipment data sheets.

The benchmarking system can be accessed remotely for real-time monitoring. An annual benchmark report is published for management.

Results. The benchmarking system has been in service since 2016, providing the company current and historical performance data to support identification of operational limitations, poor operating practices, and overhaul extension possibilities. Fig 1 is an example of performance monitoring per site over a two-year period.

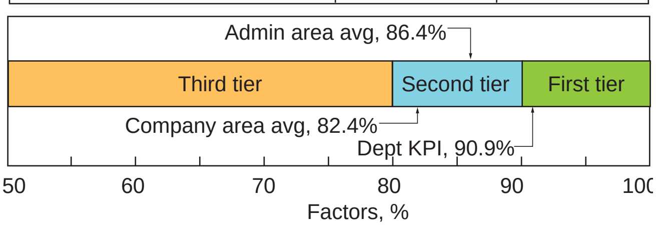
Unit trips versus age. One of the performance relationships studied is the impact of age on unit reliability (specifically, number of trips). Investigators found the number of trips independent of unit age. Rather, it and the number of repetitive starts is related to a non-standardized approach to startup, inadequate instrumentation checks, and the absence of a management checklist prior to shutdown inspection activities.

A startup best practice was implemented for the fleet to ensure reliability improvement.



1. Performance of power-generation assets improved over a two-year period in three of the four operating areas

Gas-turbine duty	Avg utilization factor, %	Avg capacity factor, %
Mechanical-drive sites	60	82
Grid-connected cogen sites	84	94.5
Off-grid power-gen sites	65.5	53



2. Average utilization and capacity factors are compared for plants on and off the grid

Saudi Aramco in brief

Saudi Aramco, a/k/a Aramco, which industry old timers may remember as the Arabian-American Oil Co, is one of the world's largest integrated energy and chemicals companies, with both upstream and downstream operations. The former are based in Saudi Arabia, while the downstream business is global.

The upstream segment consists of exploring for, developing, and producing crude oil, condensate, natural gas, and natural-gas liquids. Downstream activities consist of refining and petrochemicals, base oils and lubricants, retail operations, distribution, supply and trading, and *power generation.*

Important to the best practice described in the text portion of this article is that Aramco is the exclusive supplier of natural gas in the Kingdom of Saudi Arabia and that its gas portfolio is rich in liquids. Further, the company owns and operates the so-called Master Gas System—an extensive network of pipelines that connects its key production and processing sites throughout the country.

According to the government's Electricity and Cogeneration Regulatory Authority (ECRA), Saudi Arabia had 83 licensed powerplants with a total capacity of 85.2 GW at the end of 2019. Of this, Saudi Electricity Co (SEC) owned 39 facilities with a combined capability of 55.3 GW—65% of the country's total capacity.

Consultant Chris Bergesen, an expert in global electric generation and delivery, told the editors that just prior to the pandemic, 38 GW of Saudi Arabia's licensed generating capacity was in conventional steam/electric plants, 30 GW in simple-cycle gas turbines, and 17 GW in combined-cycle plants. Most of these facilities are less than 20 years old today.

All Saudi thermal generation is by oil and natural gas. Aramco, a partial owner of SEC, is both the utility's main fuel supplier and an important customer. Natural gas use has been increasing steadily given one of SEC's main initiatives has been the conversion of existing oil-fired plants to gas. Aramco's fuel mix at the end of 2019 was 37 GW natural gas, 23 GW heavy fuel oil, 18 GW crude oil, and 7 GW diesel oil. Note that most gas-capable SEC units can burn HFO or distillate for load.

Saline Water Conversion Corp is the second largest power producer in the country, with about 6.5 GW coming from gas and steam turbine/generators at its six desalination plants. The third-largest power producer is IPP Hajr for Electricity Production Co, which has a 4-GW combined cycle.

The physical appearance of Saudi powerplants differs dramatically from those installed in the US today given the large number of units required to interface effectively with process facilities.

Riyadh 9, a/k/a PP9, is a 1680-MW station with eight gas/diesel-fueled engines installed in 2004 and 20 crude/gas-fired units installed in 2007. All units are rated 60 MW

Qurayyah, started as an open-cycle powerplant and converted to fifteen 3 × 1 combined cycles

Faras is a 1610-MW facility with 17 gas turbines rated from 75 to 140 MW

Use factor. Power-generation sites connected to the national grid have both a relatively high average annual utilization factor (84%) and capacity factor (94.5% of site-rated output) as shown in Fig 2. The main factor in having a higher utilization and capacity is the "grid factor," where additional power produced by the plant is put on the grid with a price.

The most common reason for not achieving full utilization and average capacity is a steam shortfall. Keep in mind that steam is used for the site process and capped by the plant requirement. Recommendation to increase utilization and capacity factor was to conduct a steam demand and reserve study to optimize use of HRSGs and the fired boilers, and to evaluate the possibility of mothballing certain boilers.

Another viable solution—one that would assist in power reclamation—could be the integration of an additional steam turbine/generator. However, this would require further evaluation of the house-load requirement for the site or financial benefit of exporting power. A further opportunity to increase capacity factor is focusing on the unit's energy efficiency by applying best practices, such as compressor washing, along with performing condition-based replacement of inlet air filters.

Off-grid power-generation sites have relatively low utilization and capacity, 65.5% and 53%, respectfully. Reason for under-utilization is lower-than-expected power demand: Much of the fleet operates as spinning reserve—standby or offline. An opportunity exists to study the feasibility of connecting the previously mentioned locations to the grid for energy export.

O&M. One unexpected outcome of the benchmark system is the identification of poor O&M practices of some facilities. Two such practices were identified among the facilities utilized the least. They were: (1) Frequent switchovers among plant units in a single year, and (2) use of the sister units for spare parts.

Reliability speaking, both of these are considered poor practices: The first will cascade the overhaul cycle in one year, causing spikes in maintenance cost; the second negatively impacts the availability of the cannibalized units and increases the maintenance cost of the main unit because users will pay more to ensure its high reliability.

The recommendation was to proceed with a best standby practice for the switchover frequency for the machine, which will support in preventing the cascading of unit overhauls in one year while having more units available for operation—rather than relying on a number of units and cannibalizing the others.

Since the system has been used since 2016, the data retained have been used beyond measuring the performance factor and recommendation, with each year further possibilities are evaluated and, in some cases, implemented or planned for implementation. Staff has been able to use the benchmarking system to do the following successfully:

- Retain historical data.
- Provide a forecasting tool for maintenance planning.
- Provide a planning tool for decision making for plant expansion.
- Leveraging the system for operational excellence.
- Work as a data-driven tool for risk-based decisions.

Finally, efforts are underway to enable the benchmarking system to assist (1) in the evaluation of maintenance intervals beyond those recommended by the OEM and (2) in extending the lives of capital parts.

Project participants from Saudi Aramco's Consulting Services Dept:
Muath Alahmadi, gas turbine engineer
Abdulrahman Alsultan, gas turbine engineer
Osama Zidan, gas-turbine group leader

Magnolia Power Project (MPP)

Owned by Southern California Public Power Authority (SCPPA)

Operated by Burbank Water and Power

310 MW, gas-fired 1 × 1 7FA.03-powered combined cycle equipped with an Alstom HRSG and a GE A14 steam turbine, located in Burbank, Calif

Plant manager: Frank Messineo

Staying agile in a changing generation landscape

Challenge. The electric system has changed significantly since Magnolia, designed as a baseload unit, entered commercial service in 2005. The proliferation of renewable energy has altered both the daily and seasonal energy output needs for the plant and to remain competitive MPP had to improve its operational flexibility.

Solution was to give MPP the ability to operate at lower outputs to take advantage of shifts in demand because of renewable power fluctuations. SCPPA partnered with GE to allow Magnolia to safely operate at a lower minimum load and increase its ramp rate using Axial Fuel Staging (AFS) in conjunction with an Over Board Bleed (OBB) system.

Results. Implementation of AFS and OBB effectively reduced the minimum output of MPP from 165 to about 87 MW and doubled the ramp rate to 10 MW/min. Other benefits included reduced emissions and lower variable costs—the latter by reducing fuel use when the plant is operated at lower outputs. MPP is believed the first application of AFS/MPP technology on a 7F gas turbine.

Project participants:
Sean Kigerl, power production engr
Jeff Fan, sr electrical engr
Mario Bautista and Nick Hammett, asst power production supts
Claudia Reyes, sr environmental engr
Wendy Hsiao, environmental engr

Increasing the speed of access to SDS forms

Liberty Electric

Owned and operated by Vistra Corp

541 MW, gas-fired 2 × 1 7FA-powered combined cycle equipped with Aalborg HRSGs and a Toshiba steam turbine, located in Eddystone, Pa

Plant manager: John Kolarick

Challenge. Liberty Electric's Safety Committee members were concerned about speed of access to Safety Data Sheets (SDS). Especially concerning was access during outages when large numbers of contract personnel were onsite—often outnumbering staff by 10:1. The SDS sheets were maintained in the control room, and online through a third-party database. Constrained access could result in a significant time delay before beginning first-aid treatment or spill response in an emergency.

Solution proposed by Mechanical Technician Joel Nagle was to create a QR code that could be scanned with a smartphone. Doing so would direct the phone's browser to the SDS online database. The QR code was created and signs were printed with the code and instructions for use. These signs then were posted at doorways plant-wide.

Results. There had been no emergencies at the plant to quantify the value of the QR idea before this best practice was prepared. But the idea has received widespread support of staff and contractors. Plus, an editable file was shared with the Vistra corporate safety team, which distributed it fleetwide.

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Pitfalls to avoid when buying a powerplant

Consolidated Asset Management Services (CAMS), one of the electric-power industry's leading integrated services firms offering comprehensive asset management, O&M, financial services, and compliance and consulting solutions, shares its considerable experience with those considering a unit purchase in "8-pitfalls to Avoid When Buying a Power Generation Asset," available online at no cost (www.camstex.com).

Evidence of CAMS' accomplishments includes the company's success in CCJ's annual Best Practices Awards program. Over the last decade, the nominal hundred generating units in its portfolio (totaling about 40 GW of capacity) have earned 75 awards—including Best of the Best citations including the Best of the Best citation in 2022 to St. Charles Energy Center, which it operates for Competitive Power Ventures. Details of St. Charles' achievements are presented in a separate article elsewhere in this issue.

The authors of "8-pitfalls" note in their introduction that "evaluating a power asset becomes increasingly difficult without a sound understanding of power operations and fundamental asset-management optimization capabilities." Highlights of the guidance document include those summarized below.

Engage an independent engineer to conduct an unbiased assessment of the asset, as required by lenders for their underwriting of the potential acquisition. But because this report may be generic in nature, focusing on the general commercial viability of the project (for example, compliance with permits), the prospective buyer is encouraged to dig deeper into plant specifics—including O&M history.

The authors suggest having an O&M partner throughout all phases of the acquisition process. "Working with an O&M provider to assess a facility's O&M needs will create a realistic, actionable game plan for the future. With this approach there are fewer surprises and the buyer has a solid foundation to optimize."

Account for existing corporate support and its replacement cost. If the generating unit of interest is included in a portfolio of assets, beware the possibility that costly corporate support services may not be included in the seller's model. Example: The cost of regulatory support to assure compliance with NERC and other requirements. The seller may make generic assumptions as to the cost of providing these services in its model, but such simplifications can leave the potential buyer with unbudgeted costs after the generating unit is acquired.

Woodbridge Energy Center, a 2022 recipient of CCJ's Best of the Best Practices Award, is operated by CAMS

Develop a custom O&M budget for the facility of interest. Avoid the temptation of "adjusting" the plant's existing budget: Build a realistic operating budget from the ground up by having experienced personnel review each line item.

Additional revenue opportunities. While the custom O&M budget will help control the expense side of the operating statement, the buyer should consider investigating the potential for additional revenue opportunities to further increase profitability. A few areas to consider:

- Is the plant capturing its full value in the marketplace? Look into electrical interconnections and corresponding agreements to be sure they are consistent with the actual capability of the facility.
- Is the area on which the plant is built fully utilized? If not, can the excess be sold?
- Is there unused inventory that can be liquidated?

Evaluate plant personnel. During site visits, discussions with plant staff can be informative and provide insights into operational and plant issues that might not be identified otherwise. While sellers typically do not want to give prospective buyers access to plant staff, they should insist on it. One outcome of personnel due diligence is an optimal staffing plan to ensure safe, reliable operation based on current and future requirements.

Property tax evaluation. A powerplant typically is a significant revenue resource for the local taxing authority. Given the many special tax abatements and other grants that could apply to the taxable value, it is in your best interest to validate the assessment and explore ways to improve asset value.

IT requirements. Powerplants require extensive IT connections and equipment. Plus, cybersecurity requirements, telemetry, systems control, emissions, fuel monitoring, RTO/ISO communications, and software licenses all must be accounted for. A comprehensive audit of inherited systems and devices is important. One reason is that it's typical for a seller to not upgrade aging equipment when a facility is for sale. An IT audit can identify unforeseen security and reliability issues while contributing to the development of a good IT process for the facility.

Support after the sale. Acquiring a power-generation asset is a team effort that takes many months of hard work. But keep in mind that realizing the full potential of your investment takes another team of experts with the capability to optimize all aspects of the resource and the marketplace. CCJ